Thirty-sixth Annual

Gaseous Electronics Conference

October 11-14, 1983

PROGRAM AND ABSTRACTS

SPONSORED BY:
Atmospheric Sciences Research Center of The State University of New York at Albany
and The General Electric Research & Development Center

ASSISTED BY:
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ACKNOWLEDGEMENTS

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Finally, we wish to thank the General Electric Research and Development Center and particularly the Mechanical Systems and Technology Laboratory for providing direct financial support and the services of a variety of people essential to the organization of this conference.

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36TH GASEOUS ELECTRONICS CONFERENCE PROGRAM

REGISTRATION AND MIXER (CASH BAR)

THRUWAY HOUSE

OCTOBER 10, 1983

MONDAY EVENING 7:30 - 10:00

OCTOBER 11, 1983

9:00 - 9:10 OPENING REMARKS LECTURE HALL 23

TUESDAY MORNING

AA: RECOMBINATION AND ATTACHMENT Chairperson: A. P. Hickman - SRI International	9:10 a.m. ASSEMBLY HALL	AB: GLOWS I Chairperson: O. Biblarz - Naval Postgraduate School	9:10 a.m. Lecture Hall 23
AA-1 PLASMA SCREENING EFFECTS ON ELECTRON-ION RECOMBINATION IN A MOLECULAR GAS W. L. Morgan, Lawrence Livermore Nat'l Lab.		AB-1 ONSET CRITERIA FOR CONSTRICTION AND FILAMENT FORMATION IN DIFFUSE GLOW DISCHARGE PLASMAS Gerald L. Rogoff, GTE Labs	(20 min.)
AA-2 ELECTRON-ION RECOMBINATION IN THE PRESENCE OF WATER VAPOR W. L. Morgan, Lawrence Livermore Nat'l Lab.		AB-2 THE ELECTRON TEMPERATURE IN A MEDIUM PRESSURE RECTANGULAR TUBE POSITIVE COLUMN PLASMA T. Kaneda, N. Imamato & T. Kubota, Tokyo Denki Univ., Japan, J.S. Chang McMaster Univ., Canada	
AA-3 NEGATIVE ION FORMATION IN SF_6 SPARK BY-PRODUCTS I. Sauers, L.G. Christophorou, & S.M. Spyrou, ORNL and U. of Tennessee		AB-3 CHARACTERISTICS OF HF AND DC. LOW-PRESSURE ARGON DISCHARGES C. M. Ferreira & J. Loureiro, CEL, Lisbon Tech. U.	
AA-4 ISOMERIC DEPENDENCE OF THE ELECTRON ATTACHMENT TO PERFLUOROALKANES S. M. Spyrou, S. R. Hunter, and L. G. Christophorou, ORNL & U. of Tennessee			

COFFEE 10:00 - 10:30

BA: ELECTRONS AND PHOTONS

Chairperson: R. S. Freund - Bell Labs.

10:30 a.m.
Assembly Hall

BA-1 ELASTIC SCATTERING OF ELECTRONS BY HCN MOLECULES IN A TWO-POTENTIAL APPROACH AT INTERMEDIATES AND HIGH ENERGIES
A. Jain and S.S. Tayal, Dept. Applied Math., The Queen's Univ., Belfast N. Ireland

BA-2 VIBRATIONAL EXCITATION OF D_2 BY LOW-ENERGY ELECTRONS
S. J. Buckman and A.V. Phelps, Jila Univ. of Colorado & NBS

B-3 LOW-ENERGY ELECTRON SCATTERING BY NONLINEAR CLOSED-SHELL POLYATOMIC MOLECULES
A. Jain and D.G. Thompson, Dept. of Applied Mathematics, The Queen's Univ., Belfast N. Ireland

BA-4 ELECTRON IMPACT CROSS SECTIONS FOR IONIZATION AND DISSOCIATIVE IONIZATION OF CD_4 AND THE CD_3 RADICAL
F. A. Baiocchi, R. C. Wetzel, & R. S. Freund, Bell Laboratories

BA-5 THE EFFECTS OF ELECTRON CORRELATION UPON MULTIPLE IONIZATION IN STRONG LASER FIELDS
J. N. Bardsley, M. Comella & B. Sundaram, U. of Pittsburgh & W. L. Morgan, Lawrence Livermore Laboratory

BA-6 ABSORPTION OF ULTRAVIOLET RADIATION IN MICROWAVE DISCHARGES
A. Petelin and C. Wood, Fusion Systems Corp.

BA-7 DYE LASER INTRACAVITY ABSORPTION FOR PLASMA DIAGNOSIS
G. O. Brink and S. M. Heider, State Univ. of New York at Buffalo

BA-8 ZERO CORE-CONTRIBUTION CALCULATION OF PHOTODETACHMENT OF TRANSITION METAL ANIONS
R. M. Stehman, S. Grot, and S. B. Woo, Univ. of Delaware & E. M. Helmy, Delaware State College

BA-9 PHOTOEMISSION FROM ORGANIC CRYSTAL PARTICULATES INTO GASES
Wm. Y. Fowlkes, M. Pope, L. Altwegg, Eastman Kodak Co., Rochester, N.Y.

BB: GLOW DISCHARGES II

Chairperson: J. S. Chang - McMaster University

10:30 a.m.
Lecture Hall 23

BB-1 ENERGY BALANCE IN A HIGH PRESSURE COLLISIONAL-RADIATIVE PLASMA
P. A. Vicharelli & A. V. Phelps, JILA, Un. of Colorado &NBS

BB-2 SEGREGATION PHENOMENA IN AC LOW-PRESSURE MERCURY-ARGON DISCHARGES
R. A. J. Keijser, J. Mezger and R. L. A. v.d. Heijden, Nederlandse Philips Bedrijven B. V., Eindhoven, The Netherlands

BB-3 FLOWING POSITIVE COLUMN THEORY FOR THE AMBIPOLAR DIFFUSION CONTROLLED GLOW DISCHARGE AT MODERATE REYNOLDS NUMBERS
J. D. Miller and J. S. Chang, McMaster University

BB-4 MEASUREMENT OF NEGATIVE ION DENSITIES IN NF_3 DISCHARGES
K. Greenberg and J. T. Verdeyen, University of Illinois at Urbana-Champaign

BB-5 CHARACTERISTICS OF RADIO FREQUENCY GLOW DISCHARGES IN HELIUM AND HELIUM/SILANE MIXTURES
C. B. Fledderman and J. T. Verdeyen, University of Illinois at Urbana-Champaign

BB-6 ELECTRON-BEAM CONTROLLED DISCHARGES, THEORY AND EXPERIMENT
L. E. Kline, J. F. Lowry, and J. V. R. Heberlein, Westinghouse R&D Center

BB-7 THE EFFECT OF NEGATIVE ION PROCESSES ON THE ELECTRON TEMPERATURE IN MOLECULAR GAS DISCHARGES
S. Ono and S. Teii, Musashi Inst. of Technol., J. S. Chang, McMaster University

BB-8 PRODUCTION OF ELECTRONS THROUGH ATOMIC HYDROGEN IONIZATION IN PARTIALLY IONIZED MOLECULAR HYDROGEN
J. A. Kunc and M. A. Gundersen, University of Southern California

LUNCH 12:00 - 1:00

C POSTER SESSION I — 1:00 p.m. Ballroom

C-1 EFFECTS OF NA AND K ON THE RECOMBIANTION OF CUCL AND CUBR IN A PULSED DISCHARGE
W. Winiarczyk and L. Krause, Dept. of Physics, U. of Windsor, Canada

C-2 THE EFFECT OF VIBRATIONAL EXCITATIONS ON THE ELECTRON DISTRIBUTION FUNCTION
R. Brakel, G. Ecker and K. U. Riemann, Ruhr Universitat, Bochum FRG

C-3 He* (2^3S), Ne*($^3P_{2,0}$)-HCl COLLISIONAL ENERGY-TRANSFER PROCESSES
A. J. Yencha, A. K. Khan and S. Brown, Dept. of Chemistry, SUNY at Albany, N.Y.

C-4 EVOLUTION OF THE PHASE-SPACE DISTRIBUTION OF AN ASSEMBLY OF ELECTRONS AT MODERATE AND HIGH E/N,*
Y. Tzeng and E. E. Kunhardt, Texas Tech. University

C-5 THE ATOMIC FLUORINE LASER: A CANDIDATE FOR NUCLEAR PUMPING?
M. J. Kushner, Lawrence Livermore Nat'l Laboratory

C-6 CROSSED BEAM MEASUREMENTS OF ABSOLUTE RATE COEFFICIENTS IN ASSOCIATIVE IONIZATION COLLISIONS BETWEEN NA*(np) and NA(3s) for $5 \leq n \leq 15$, J. Boulmer, R. Bonanno and J. Weiner, Dept. of Chemistry, U. of Maryland

C-7 PROMPT AND DELAYED PHOTOLYSIS OF Cs_2,
F. Davanloo, A. S. Inamdar & C. B. Collins, Univ. of Texas at Dallas; A. S. Naqvi, King Saud Univ. of Riyadh

C-8 PHOTODISSOCIATION OF N_2O by VACUUM ULTRAVIOLET RADIATION
L. C. Lee and Masako Suto, San Diego State University

C-9 PRODUCTION OF EMISSION AT 2,000-12,000 A by ELECTRON IMPACT ON O_2
M. B. Schulman, F. A. Sharpton, L. W. Anderson, and Chun C. Lin, Univ. of Wisconsin-Madison

C-10 A PARAMETER-FREE CORRELATION-POLARIZATION POTENTIAL FOR ELECTRON MOLECULE COLLISIONS: APPLICATION FOR e-H_2 and N_2 Scattering
N. T. Padial and D. W. Norcross, Jila, U. of Colorado and NBS

C-11 RO-VIBRATIONAL EXCITATION OF HCl BY ELECTRONS: THE IMPORTANCE OF POLARIZATION AND OF AN EXACT TREATMENT OF EXCHANGE
N. T. Padial and D.W. Norcross, Jila, U. of Colorado and NBS

C-12 DISSOCIATIVE RECOMBINATION OF HCO^+ IONS AND ELECTRONS
B. Ganguli, M. A. Biondi and R. Johnsen, U. of Pittsburgh

C-13 ION-ION NEUTRALIZATION IN A RADIATION-INDUCED OXYGEN DISCHARGE
H. E. Elsayed-Ali and G. H. Miley, Fusion Studies Lab., U. of Illinois

C-14 HIGHLY ACCURATE DIFFUSION TREATMENT FOR RECOMBINATION OF GENERAL SYSTEMS
M. R. Flannery, Georgia Institute of Technology

C-15 POTASSIUM-SEEDED ARC SOURCE FOR STARK BROADENING STUDIES
J. P. Hohimer, Sandia National Laboratories

C-16 TIME-DEPENDENT BOLTZMANN CALCULATIONS FOR MODEL CASES
L. C. Pitchford and T. A. Green, Sandia National Laboratories

C-17 EXPERIMENTAL AND THEORETICAL INVESTIGATION OF THE PLASMA PARAMETERS AND PARTICLE COMPONENTS IN THE OXYGEN GLOW DISCHARGE POSITIVE COLUMN
R.L.C. Wu, T.O. Tiernan, and Y. Ichikawa, Wright State University

OCTOBER 11, 1983 TUESDAY AFTERNOON

D: WORKSHOP ON
GASEOUS ELECTRONICS PHENOMENA IN PLASMA PROCESSING
3:00 p.m.
Assembly Hall

Chairperson: J. T. VERDEYEN - Univ. of Illinois

OVERVIEW

Professor H. Oskam
Department of Electrical Engineering
University of Minnesota
Minneapolis, MN 55455

I. Plasma Deposition

IA "Ion-Surface Interactions During Semiconductor Growth by Sputtering"
Professor Joseph Greene
Coordinated Science Laboratory
University of Illinois at Urbana-Champaign
Urbana, IL 61801

IB "Plasma-Assisted CVD - Gas-Phase Diagnostics and Film Formation"
Dr. John C. Knights
Xerox Corporation
Palo Alto, CA 94304

II. Plasma Etching

IIA "Plasma Etching - The Role of Ions"
Dr. John Coburn
IBM Research Laboratory
San Jose, CA 95114

IIB "Gaseous Electronics and Plasma Etching Research"
Dr. Daniel Flamm
Bell Laboratories
Murray Hill, NJ 07078

III. Plasma Kinetics

IIIA "Discharges and Plasma-Chemistry Models for Silane Discharges"
Professor Alan Gallagher
JILA
Boulder, CO 80309

IIIB "Status Report of Relevant Cross-Sections and Transport Properties of Silane Discharges"
Dr. Alan Garscadden
Air Force Wright Aeronautical Laboratories
Wright-Patterson AFB, OH 45433

OCTOBER 12, 1983 WEDNESDAY MORNING

E ARCS I 9:00 a.m.
Chairperson: I.M. Cohen - Univ. Of Pennsylvania Lecture Hall 23

E-1 MEASUREMENT OF ZERO-FIELD ELECTRON THERMAL EMISSION INTO A LOW-PRESSURE ARC,
John M. Anderson, General Electric R&D Center, Schenectady, N.Y.

E-2 EFFECTS OF LOW AMBIENT GAS PRESSURES ON CATHODE SPOT OPERATION
L. P. Harris, General Electric Corp. R&D

E-3 EXPERIMENTAL STUDY OF ARC SPOT MOTION ON A CONICAL CATHODE
H.P. Mercure, R. J. Rajotte, M.G. Drouet IREQ, Varennes, Canada

E-4 ARC-GENERATED HOLLOW CATHODES IN A NITROGEN PLASMA TORCH
Harald L. Witting, General Electric Company R&D Center

E-5 CHANNEL MODEL OF ROTATING ARC ROOTS
R. J. Zollweg, Westinghouse R&D Center

E-6 CONDUCTIVITY STUDIES OF MAGNETICALLY CONTROLLED METALLIC PLASMA ARCS
J. L. Lee, M. Nikolich, D. R. Dettman & R. Dollinger, St. Univ. of N.Y. at Buffalo

COFFEE 10:00 - 10:30

OCTOBER 12, 1983 WEDNESDAY MORNING

F: PLASMA BOUNDARIES 10:30 a.m.
Chairperson: J. J. Ewing - Math. Science NW Lecture hall 23

F-1 ATTACHMENT INDUCED CONTRACTION IN THE CATHODE FALL - A MYTH? (20 min.)
G. L. Duke, AFWAL/POOC-3, WPAFB, OH

F-2 CONSISTENT THEORY OF THE CORE AND SHEATH OF A PLASMA COLUMN
K. U. Riemann, Ruhr Univ. Bochum, FRG

F-3 RELAXATION OF FAST ELECTRONS IN FRONT OF A WALL
A. Schumacher, Ruhr-Universitat Bochum, FRG

F-4 THE CATHODE FALL IN ELECTRON BEAM IONIZED DISCHARGES
P. Bletzinger, AF Wright Aeronautical Laboratories

F-5 SPECTROSCOPIC INVESTIGATIONS OF THE SHEATH REGIONS IN AN RF-PLASMA REACTOR
C. Dejoseph, Jr. and P. Bletzinger, AF Wright Aeronautical Laboratories

F-6 COMPUTER SIMULATION OF SF_6 PLASMA ETCHING OF SILICON
L. E. Kline, Westinghouse R&D Center

F-7 LASER-INDUCED DEPOSITION OF SILICON USING ABNORMAL DISCHARGES IN SILANE
P.J. Hargis, Jr. and J.M. Gee and J.D. Verdeyen, Sandia National Laboratories

F-8 DIFFERENCES IN OPTICAL SPECTRA FOR A SPATIALLY VARYING CD-NEON LOW PRESSURE DISCHARGE.
R.Y. Pai, GTE Lighting Products, Danvers, Mass.

LUNCH 12:05 - 1:15

WEDNESDAY AFTERNOON

GA: LASERS — 1:15 p.m., Lecture Hall 23
Chairperson: M.J. Kushner - Lawrence Livermore Lab.

GA-1 KINETIC PROCESSES IN E-BEAM EXCITED XEF(C→A) LASERS (20 min.)
W. L. Nighan - United Technologies Research Center and
Y. Nachshon, F. K. Tittel and W. L. Wilson, Jr.,Rice Univ.

GA-2 PREIONIZATION STUDIES OF RARE GAS HALIDE LASERS,
R. S. Taylor and K.E. Leopold, National Research Council of Canada
Ottawa, Ontario

GA-3 VIBRATIONAL RELAXATION OF THE $B^2\Sigma$ UPPER STATE OF THE HGBR/$HGBR_2$ DISSOCIATION LASER
A. C. Erlandson and T. A. Cool, Cornell Univ.

GA-4 METAL HYDRIDE DISSOCIATION LASERS WITH VISIBLE WAVELENGTHS
A. C. Erlandson and T. A. Cool, Cornell Univ.

GA-5 ELECTRON-ION RECOMBINATION IN CO_2 LASER GAS MIXTURES-
I.M. Littlewood, and M.C. Cornell, Univ. of Missouri-Rolla

GA-6 ORIGINS OF PHOTOIONISATION IN CO_2 TEA LASERS
S. J. Scott and A.L. S. Smith, Strathclyde U. Scotland, UK

GA-7 PERFORMANCE OF WALL BALLASTED DIELECTRIC ELECTRODES FOR LARGE VOLUME CW CO_2 EDL's
M. J. Yoder, D. G. Youmans and J.P. Reilly, W. J. Schafer Associates, Wakefield, Ma. B. H. Burzlaff, J. S. Chivian and A. B. Welch, Vought Corp. Dallas, Texas

GA-8 SCALING EXPERIMENTS WITH A 60 LITER SELF-SUSTAINED CO_2 LASER DISCHARGE
M. J. Pechersky, J. F. Roach, R. J. Spreadbury and R. V. Babcock, Westinghouse R&D Center

GA-9 TRAVELLING WAVE EXCITATION OF HELICAL TE N_2 LASER
S. H. Chang, S. Matsumura & S. Teil, Musashi Institute of Technology, Tamazutsumi, Setagaya-Ku, Tokyo, Japan

GB: ARCS II — 1:15 p.m., Assembly Hall
Chairperson: G. Frind - G. E. R&D Center

GB-1 ARC IN CONVECTION -- FORMULATION
B. K. Choudhury, G. E. , & I. M. Cohen, U. of Penna

GB-2 ARC IN CONVECTION -- RESULTS
B. K. Choudhury, G. E. & I. M. Cohen, U. of Penna

GB-3 EXPERIMENTAL AND THEORETICAL RESULTS FOR LOW CURRENT D. C. ARC IN VARIOUS NOZZLE GEOMETRIES
H. T. Nagamatsu & H. Whang, Rensselaer Polytechnic Institute

GB-4 THERMAL BOUNDARY LAYER AND ARC COLUMN IN PULSED PLASMAS
N. Brates, J. Ravi, and D. M. Benenson, State Univ. of New York at Buffalo

GB-5 TEMPERATURE AT LOWER CURRENTS IN A PULSED AIR ARC
S. Aggarwal, J. Ravi, & D. M. Benenson, State Univ. of New York at Buffalo

HB: ARCS III — 2:05 p.m., Assembly Hall
Chairperson: E. Barreto - ASRC, State Univ. of New York

HB-1 ANOMALOUS HIGH CURRENT BEHAVIOR IN AN E-BEAM CONTROLLED SWITCH
A. J. Palmer, R. J. Harvey, H. E. Gallagher, Hughes Research Laboratory

HB-2 EXPERIMENTAL STUDY OF PARAMETERS DETERMINING THE CHARACTERISTICS OF AN ELECTRON-BEAM CONTROLLED SWITCH.
H. E. Gallagher, R. J. Harvey, A. J. Palmer, Hughes Research Laboratories

HB-3 THE EFFECT OF AN ATTACHER WITH A RATE, INCREASING WITH E/N ON THE PERFORMANCE OF AN ELECTRON BEAM SUSTAINED DISCHARGE SWITCH-THEORETICAL CONSIDERATIONS
G. Schaefer, K. H. Schoenbach , H. Krompholz, M. Kristiansen, Texas Tech. Univ., Lubbock, Texas & A. H. Guenther, AFWL, Kirtland AFB, New Mexico

HB-4 QUASI STABLE OPERATION OF HG/HE E-BEAM PREIONIZED DISCHARGE
A. Mandl & M. W. McGeoch, Avco Everett Research Laboratory

HB-5 CONDUCTIVITY MEASUREMENTS IN HIGH PRESSURE AIR AFTERGLOWS
D. J. Eckstrom and J. S. Dickinson, SRI International

VISITS 3:00 - 5:30

SOCIAL HOUR THRUWAY HOUSE 7:00 - 8:00

BANQUET THRUWAY HOUSE 8:00

OCTOBER 13, 1983 THURSDAY MORNING

I: CORONA
Chairperson: RA. Dougal - University of South Carolina

9:00 a.m.
Lecture Hall 23

I-1 TWO-DIMENSIONAL NUMERICAL SIMULATION OF SPACE-CHARGE-CONTROLLED TRANSPORT AT HIGH CHARGE DENSITIES (20 min.)
S. K. Dhali & P. F. Williams, Texas Tech.

I-2 PRODUCTION OF SOF_2 AND SO_2F_2 IN SF_6/H_2O MIXTURES BY CORONA DISCHARGES
R. J. VanBrunt, T. C. Lazo, & W. E. Anderson, National Bureau of Standards

I-3 SELF-CONSISTENT MATHEMATICAL MODEL FOR STEADY POINT-PLANE CORONA DISCHARGES,
B. L. Henson, Dept. of Physics, U. Missouri, St. Louis

I-4 CORONA DISCHARGE UNDER A PACKED SOLID PARTICLE CONDITION
J. S. Chang & H. Yoshida, Dept. Eng. Physics, McMaster Univ., Canada

I-5 DISCHARGE DEVELOPMENT IN HIGH PRESSURE SF_6 IN A THREE-ELECTRODE SYSTEM
F. Pinnekamp, BBC- Brown Boveri Research Center, Baden, Switzerland

COFFEE 10:05 - 10:30

OCTOBER 13, 1983 THURSDAY MORNING

J: BREAKDOWN
Chairperson: T. M. Proud - GTE Labs

10:30 a.m.
Lecture Hall 23

J-1 FORMATION AND DECAY OF NANOSECOND DISCHARGES IN ELECTRON ATTACHING GASES
W. W. Byszewski, M. J. Enright, J.M. Proud, GTE Labs, Inc Waltham, Ma.

J-2 STOCHASTIC MODELS FOR AVALANCHE BREAKDOWN IN GASES
D. M. Cap, General Electric Co. LBG

J-3 COMPUTER SIMULATION OF THE GROWTH OF TRANSIENT GAS DISCHARGES
K. C. Chung, W. W. Byszewski, GTE Labs, Inc.

J-4 LABORATORY STUDIES OF BEAM PLASMA DISCHARGES
B. D. Green, L. G. Piper, E. R. Pugh, Physical Science Inc.

J-5 FUNDAMENTAL PROCESSES IN LASER-TRIGGERED ELECTRICAL BREAKDOWN
R. A. Dougal and P. F. Williams, Texas Tech.

J-6 TIME CONSTANTS ASSOCIATED WITH GASEOUS RECOVERY
R. N. Dewitt, Naval Surface Weapons Ctr.

J-7 MASS SPECTROMETRY OF GASEOUS BREAKDOWN
D. L. Swingler, CSIRO Division of Chemical Physics, Australia

BUSINESS MEETING 11:45 - 12:15

LUNCH 12:15 - 1:30

KA: EXCITED STATES, LIFETIMES AND QUENCHING

Chairperson: J. Stevefelt - Univ. of D'Orleans

1:30 p.m.
Lecture Hall 23

KA-1 DETERMINATION OF NUMBER DENSITIES OF METASTABLE ATOMS PRODUCED BY ELECTRON-BEAM EXCITATION
J. E. Gastineau, M. H. Phillips, L. W. Anderson, C. C. Lin, U. of Wisconsin

KA-2 RADIATIVE LIFETIMES OF ELECTRONICALLY EXCITED RARE GAS DIMERS BY NEUTRALIZED ION-BEAM SPECTROSCOPY
G. I. Gellene, N. Kleinrock Schneider, R. F. Porter, Cornell Univ.

KA-3 DETERMINATION OF THE QUENCHING RATES OF $N_2^+ (B^2\Sigma_u^+ V=0,1)$ BY N_2
J. Jolly, A. Plain and A. Ricard, Lab. Physique Plasmas, Un. Paris-Sud Orsay, France

KA-4 VUV-EMISSIONS FROM CONDENSED RARE GASES BOMBARDED WITH METASTABLES
G. Nowak and J. Fricke, Phys. Inst. Univ. Wurzburg, W. Germany

KA-5 ELECTRONIC ENERGY TRANSFER BETWEEN STATE SELECTED RARE GAS METASTABLE ATOMS AND SOME ATOMS AND SIMPLE MOLECULES
N. Sadaghi, T. D. Nguyen, T. D. Dreiling and H. Ben Kraiem, Laboratoire de Spectrometrie Physique, Universite Scientifique et Medicale de Grenoble, France

KA-6 INFRARED SPECTRA (2-16 um) OF AR I RYDBERG EMISSION FROM A MICROWAVE-DISCHARGE PLASMA
W. T. Rawlins, A. Gelb, & L. G. Piper, Physical Sciences Inc., & R. A. Armstrong, Air Force Geophysics Laboratories

KA-7 PRODUCTS FROM MICROWAVE DISCHARGES IN N_2O/AR
L. G. Piper & W. T. Rawlins, Physical Sciences Inc.

KA-8 QUENCHING OF $N_2^+ (A\ ^2\Pi_u)$ v' = 2, 3, and 4 by AIR and v' = 2 by NITROGEN AND OXYGEN
L. G. Piper and B. D. Green, Physical Sciences Inc., and W. A. M. Blumberg and S. J. Wolnik, Air Force Geophysics Laboratory

KB: ARCS IV

Chairperson: H. P. Stormberg

1:30 p.m.
Assembly Hall

KB-1 MODELING OF PLASMA BORE-FILLING IN XENON FLASH-LAMPS
M. J. Kushner, Lawrence Livermore National Laboratory

KB-2 RADIATION DECAY TIMES FROM PULSED XENON ARCS
M. J. Kushner, A. E. Orel and H. T. Powell, Lawrence Livermore National Laboratory

KB-3 CHARACTERISTICS OF LARGE BORE XENON FLASHLAMPS
L. P. Bradley and H. T. Powell, Lawrence Livermore National Laboratory

KB-4 TEMPERATURE MEASUREMENTS IN THE ANODE REGION OF A HIGH-INTENSITY ARGON ARC
K. Etemadi and E. Pfender, University of Minnesota

KB-5 FREQUENCY DEPENDENCE OF THE PULSED HIGH-PRESSURE SODIUM ARC SPECTRUM
J. T. Dakin, T. H. Rautenberg General Electric Corporate Research and Development

KB-6 OPTOGALVANIC DETECTION OF ACOUSTIC RESONANCES IN HIGH-PRESSURE SODIUM DISCHARGES
M.J. Jongerius and A. J. M. Ras, Philips Research Labs, Eindhoven

KB-7 OPTICAL DETERMINATION OF THE MERCURY PRESSURE IN HIGH PRESSSURE LAMPS,
H. P. Stormberg and R. Schafer, Philips GmbH Forschungs laboratorium Aachen/Germany

KB-8 HG & NA PRESSURES FROM THE MAXIMA OF THE "D-LINE" IN A NA ARC
P. A. Reiser and E. F. Wyner, GTE Sylvania Lighting Center, Danvers, Mass 01923

L: POSTER SESSION II — 2:50 p.m., Ballroom

L-1 TRIPLE-BEAM APPARATUS FOR ELECTRON IMPACT EXPERIMENTS
W. B. Westerveld, P. Zetner, G. C. King and J. W. McConkey, Physics Department, University of Windsor

L-2 TWO-AND THREE-BODY REACTIONS OF ATOMIC AND MOLECULAR IONS WITH METHANE AND ETHANE AT NEAR-THERMAL ENERGIES
S. Dheandhanoo, R. Johnson, and M. A. Biondi, Univ of Pittsburgh

L-3 EXPERIMENTAL STUDY OF ION MOLECULE REACTIONS AT ELEVATED TEMPERATURES AND ATMOSPHERIC PRESSURES
J. M. Pouvesle, A. Bouchoule and J. Stevefelt, Univ. of Orleans, France

L-4 MODELING OF ION MOLECULE REACTIONS AT HIGH PRESSURES
C. B. Collins and C. D. Eberhard, Univ. of Texas at Dallas and J. Stevefelt, GREMI, Univ. of Orleans, France

L-5 A GENERALISED METHOD FOR ARC MODELLING, ZHONG-JIE, LI, Dept. Of Electrical Eng. and Electronics Univ. of Liverpool

L-6 SIMULATION OF CIRCUIT BREAKER ARC-CIRCUIT INTERACTIONS BY DEFINED TEST CIRCUIT PARAMETERS, Zhong-Jie LI, Dept. of Electrical Eng. and Electronics, Univ. of Liverpool, U.K.

L-7 NEAR THRESHOLD EXCITATION OF KR AND XE BY ELECTRON IMPACT
K. L. Stricklett, A. R. Johnston & P. D. Burrow, Univ. of Nebraska

L-8 SENSITIVE, NON-INTRUSIVE, IN-SITU MEASUREMENT OF PLASMA ELECTRIC FIELDS, Richard A. Gottscho, Glenn P. Davis and Cameron A. Moore Bell Laboratores, Murray Hill, N.J.

L-9 SPECTROSCOPIC DIAGNOSTICS OF A SILANE GLOW DISCHARGE
P.J. Hargis, Jr., and J.M. Gee, Sandia National Laboratories

L-10 COMPLEX POTENTIAL MODEL FOR DIELECTRONIC COMBINATION
A. P. Hickman, SRI International

L-11 A PRELIMINARY STUDY OF ION DIFFUSION IN SF_6 AT HIGH E/N
J. De Urquijo, I. Alvarez, C. Cisneros and A. Morales, Instituto de Fisica, UNAM, Mexico

L-12 SPECTROSCOPY AND PHOTODISSOCIATION OF BR_2^*
C. H. Kuo, I Milkman, and J. T. Moseley, Physics Dept. and Chemical Physics Institute, University of Oregon

L-13 MULTIPHOTON IONIZATION MASS SPECTROMETRY OF METHYLAMINES
J. D. Ganiere, Y. Ono and J. T. Moseley, Chemical Physics Institute, Univ. of Oregon

L-14 ELECTRON EXCITATION CROSS SECTIONS OF XENON
Keith G. Walker, Bethany Nazerene College

L-15 LASER-INDUCED FLUORESCENCE STUDIES OF XEF,
H. Helm, L. E. Jusinski, M. J. Dyer, D. C. Lorents, and D. L. Huestis, SRI Interantional

L-16 VIBRATIONAL RELAXATION AND B/C MIXING IN XEF,
D. C. Lorents, D. L. Huestis, SRI International,
M. Durrett, L. Hosuton, and G. Walters, Rice University

L-17 SYMMETRIC CHARGE TRANSFER BETWEEN SINGLY AND DOUBLY CHARGED IONS.
P. Gangopadhyay and J. N. Bardsley, Univ. of Pittsburgh

DINNER 5:00 - 8:00

OCTOBER 13, 1983 THURSDAY EVENING

M: WORKSHOP ON FAST GAP BREAKDOWN 8:00 p.m.
Assembly Hall

Chairperson - A. V. Phelps - Univ. of Colorado

OVERVIEWS

H. A. Blevin - The Flinders University of South Australia

Professor Blevin will summarize what we know experimentally about non-equilibrium effects and the limits of validity of equilibrium concepts such as ionization coefficient and drift velocity. (20 min.)

E. E. Kunhardt - Texas Tech. University

Professor Kunhardt will talk about non-equilibrium effects in avalanche development with space charge consideration. (15-20 min.)

L. C. Pitchford - Sandia National Labs.

Dr. Pitchford will talk about modeling non-equilibrium effects and attempts to introduce transients into circuit equations. (15-20 min.)

CURRENT RESEARCH

Chatham Cooke - Massachusetts Institute of Technology

Dr. Cooke is studying avalanching in gases on short time scales. He is also looking into the problem of a macroscopic description of circuit equations with transient effects included. (12-15 min.)

W. W. Byszewski - GTE Labs.

Dr. Byszewski has done experiments on discharge formation in highly overvolted gaps. He has also seen evidence of runaway electrons in the same apparatus.

R. A. Alvarez - Lawrence Livermore National Laboratory

Dr. Alvarez is now doing experiments designed to measure microwave power transmitted through a partially evacuated waveguide for very high power, short pulses input.

OCTOBER 14, 1983 FRIDAY MORNING

N: TRANSPORT PHENOMENA
Chairperson: W. H. Long, Northrup Res. & Tech. Ctr.

9:00 a.m.
Lecture Hall 23

N-1 ELECTRON LONGITUDINAL DIFFUSION COEFFICIENTS IN ARGON
F. Li and L. C. Lee, San Diego State University

N-2 ELECTRON DRIFT VELOCITIES IN SILANE-HELIUM AND SILANE-ARGON MIXTURES
A. Garscadden, A. F. Wright, Aeronautical Lab. and K. A. Kirkendall and M. L. Andrews, Wright State University

N-3 NON EQUILIBRIUM BEHAVIOUR OF AN ELECTRON SWARM IN SF_6
J. P. Boeuf, E. Marode, Laboratoire de Physique des Decharges, ESE, GIF/Yvette, France

N-4 TRANSPORT COEFFICIENTS AND COLLISIONAL CROSS SECTIONS OF SF_6 CCl_2F_2 AND MIXTURES
J. P. Novak & M. F. Frechette, Ireq, Varennes, Quebec, Canada

N-5 THE DEVELOPMENT OF AN ELECTRON AVALANCHE: A SELF-CONSISTENT MICROSCOPIC TREATMENT
E. E. Kunhardt & Y. Tzeng, Texas Tech Univ.

N-6 HIGHER ORDER TRANSPORT OF GASEOUS IONS IN THE IDEALIZED CHARGE TRANSFER MODEL
B. M. Penetrante & J. N. Bardsley, Univ. of Pittsburgh

COFFEE 10:00 - 10:30

OCTOBER 14, 1983 FRIDAY MORNING

0: INVITED PAPERS 10:30 a.m.
Lecture Hall 23

Chairperson: A. Garscadden - Air Force Aeronautinautical Labs.

PHYSICS OF CHARGED PARTICLE BEAMS

William F. Bailey - Air Force Institute of Technology

ARCS AND GASEOUS ELECTRONICS

Lawson P. Harris - G. E. Corporate Research and Development

SESSION AA

9:10 a.m., Tuesday, October 11, 1983

RECOMBINATION AND ATTACHMENT

Chairperson: A. P. HICKMAN
SRI International

AA-1 Plasma Screening Effects on Electron-Ion Recombination in a Molecular Gas, W.L. MORGAN, Lawrence Livermore Natl. Lab.*--A molecular dynamics[1] simulation has been performed for electron recombination in the presence of CO_2 and of CH_4. It had been found in previous calculations[2] that both the 2-body (dissociative recombination) and the 3-body rate coefficients are enhanced by inelastic (vibrational excitation) collisions. For CO_2 the computed rate coefficient increases linearly with pressure and agrees with recent experimental data[3] for $p \lesssim 2$ atm. For $n_e = 10^{14}$ cm^{-3} the calculated rate, in contrast to the measured rate at small n_e, peaks between 2 and 8 atm. and then decreases for $p \gtrsim 8$ atm. Reasons for this behavior based on plasma screening arguments will be discussed.

*Work supported by Univ. of California, Lawrence Livermore Natl. Lab. under DOE Contract #W-7405-ENG-48.

[1]W.L. Morgan, J.N. Bardsley, J. Lin, and B.L. Whitten, Phys. Rev. A26, 1696 (1982).
[2]W.L. Morgan and J.N. Bardsley, Chem. Phys. Letts. 96, 93 (1983).
[3]D.A. Armstrong, E.S. Sennhauser, J.M. Warman, and U. Sowada, Chem. Phys. Letts. 86, 281 (1982).

AA-2 Electron-Ion Recombination in the Presence of Water Vapor, W.L. MORGAN, Lawrence Livermore National Laboratory*--A monte carlo simulation of electron recombination in H_2O has been performed. The calculations cover a range of H_2O pressures and are in agreement with published experimental results[1]. As had been found in previous calculations[2] on recombination in NH_3^+, inelastic rotational and vibrational collisions enhance both the 2-body (dissociative recombination) and the 3-body rate coefficients.

*Work supported by the Univ. of California, Lawrence Livermore Natl. Lab. under DOE Contract #W-7405-ENG-48.

[1]J.M. Warman, E.S. Sennhauser, and D.A. Armstrong, J. Chem. Phys. 70, 995 (1979).
[2]W.L. Morgan and J.N. Bardsley, Chem. Phys. Letts. 96, 93 (1983).

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[1]W.L. Morgan, J.N. Bardsley, J. Lin, and B.L. Whitten, Phys. Rev. A26, 1696 (1982).
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[1]J.M. Warman, E.S. Sennhauser, and D.A. Armstrong, J. Chem. Phys. 70, 995 (1979).
[2]W.L. Morgan and J.N. Bardsley, Chem. Phys. Letts. 96, 93 (1983).

AA-3 Negative Ion Formation in SF_6 Spark By-Products,* I. SAUERS, L.G. CHRISTOPHOROU, and S.M. SPYROU, ORNL and U. of Tennessee -- When SF_6 is used in repetitively discharged devices a buildup of by-products results whose electron attaching properties differ from those of SF_6. We have identified a number of long-lived by-products formed by spark discharges in SF_6 at pressures in the range 40-233 kPa and measured quantitatively the concentrations of the by-products SOF_2, SO_2F_2, SO_2, and SOF_4. These by-products are formed via the interaction of transient species in sparked SF_6 with moisture, electrode material and insulators. Each has been studied individually in a time-of-flight mass spectrometer and the negative ion yields as a function of electron energy in the range 0-10 eV are reported. The negative ions and their peak positions (shown in parentheses in eV) are: F^-(0.6), SOF_2^{-*} ($\sim$0) for SOF_2; F^- (3.45), F_2^- (3.3), SO_2F^- (2.95), $SO_2F_2^{-*}$ ($\sim$0) for SO_2F_2; O^- (4.55), S^- (4.0), SO^- (4.8) for SO_2; and F^- (3.3), SOF_3^- ($\sim$0) for SOF_4. [The asterisk (*) indicates lifetimes $>10^{-6}$ s with respect to autodetachment.] Cross sections for electron attachment to SO_2 will be reported and compared with literature data.
*Research sponsored by U.S. DOE under contract W-7405-eng-26 with the Union Carbide Corporation.

AA-4 Isomeric Dependence of the Electron Attachment to Perfluoroalkanes,* S.M. SPYROU, S.R. HUNTER, and L.G. CHRISTOPHOROU, ORNL and U. of Tennessee -- The attachment of low energy ($\leq$10 eV) electrons to the perfluoroalkanes n-C_4F_{10}, i-C_4F_{10}, n-C_5F_{12}, neo-C_5F_{12}, i-C_5F_{12} and c-C_5F_{10}, has been studied using a time-of-flight mass spectrometer and a high pressure swarm technique. Both long-lived parent (autodetachment lifetimes $\tau_a > 10^{-6}$ s) and dissociative attachment fragment anions were observed for all molecules in the mass spectrometric study. The relative cross sections for formation of these anions and the τ_a of the long-lived parent anions were measured as a function of electron energy in the mass spectrometric study and the total electron attachment rate constants and total attachment cross sections in the swarm study. Both studies have shown a strong isomeric dependence of both the dissociative and the nondissociative electron attachment. The observed differences in the cross sections for parent and fragment anions for the various isomers are attributed to the isomeric dependence of the rate of intramolecular distribution of the transient anion's excess energy.
*Research sponsored by U.S. DOE, under contract W-7405-eng-26 with the Union Carbide Corporation.

SESSION AB

9:10 a.m., Tuesday, October 11, 1983

GLOW DISCHARGES I

Chairperson: O. BIBLARZ
Naval Postgraduate School

AB-1 Onset Criteria for Constriction and Filament Formation in Diffuse Glow Discharge Plasmas. GERALD L. ROGOFF, GTE Labs--A linearized stability analysis has been used to derive analytical criteria for the initial formation of localized constricted channels of perturbed electron density in positive column plasmas. Longitudinally uniform steady-state discharges are assumed, with the electron density given by a continuity equation which allows for a variety of electron production and loss processes, including, for example, one- and two-step ionization, collisions of excited particles, externally generated electron or radiation beams, diffusion, attachment, and volume recombination. An external circuit contains a constant voltage source and a series resistor. The analysis describes self-consistently the interaction with the circuit and the effect of the perturbation on the surrounding plasma. The resulting criteria indicate (a) when perturbations can grow with time, (b) the channel radii that can grow, and (c) the perturbation profile. Local deviations from the initial steady-state density can be negative as well as positive. The results describe the large-scale constriction of uniform plasma regions as well as filament formation in either uniform or nonuniform discharges. Generic cases will be described.

AB-2 The Electron Temperature in a Medium Pressure Rectangular Tube Positive Column Plasma, T. KANEDA, N. IMAMATO & T. KUBOTA, Tokyo Denki Univ., Japan, J.S. CHANG McMaster University, Canada -- The electron temperature T_e in a medium pressure ($p>0.1$ Torr) rectangular tube positive column plasma has been studied both experimentally and theoretically. The minor-to-major axis ratio $\ell=(1/10)$ and $(1/2)$ of rectangular DC discharge tube was used in the present investigation, together with radially movable electrostatic probes for plasma density N_e, electron temperature and axial electric field E_z and its profile measurements. Two-dimensional charge transport equation which contains volume recombination, diffusion loss and ionization was used to determine the N_e profiles E_z and T_e for He, Ne and Ar. The results show that: (1) T_e observed and predicted to be, decreases with increasing ℓ; (2) T_e decreases with increasing discharge current (Ne and metastable density) in He gas; (3) the experimentally obtained N_e profiles and E_z/p agree well with the present theoretical model for He gas, but disagree with Ne and Ar results; (4) the experimentally observed T_e increases with increasing recombination effect in Ar and Ne, and agrees quatitatively with the present model.

AB-3 Characteristics of HF and DC, Low-Pressure Argon Discharges, C.M. FERREIRA and J. LOUREIRO, CEL, Lisbon Tech.U.--The maintenance electric fields of hf and dc low-pressure argon discharges have been derived from the Boltzmann equation, using a self-consistent set of cross sections[1], and the balance between the rates of electron production and diffusion loss[2].A general characteristic of E_e/N versus the ratio of the diffusion length to the ion mean free path, Λ/λ_i, was determined which is applicable from dc to microwave frequencies, where $E_e=E\nu_e/(\nu_e^2+\omega^2)^{1/2}$ and $\nu_e=2.13\times10^{-7}N(cm^{-3})$ is an empirical effective value of the electron collision frequency. Corrections arising from stepwise ionization[3] and e-e interactions at high electron densities are considered for a number of cases. The average input power per electron at steady-state decreases with increasing the field frequency and the electron concentration.

[1]C.M.Ferreira and J.Loureiro,J.Phys D:Appl.Phys.(at press)

[2]C.M.Ferreira and A.Ricard,J.Appl.Phys. 54, 2261 (1983)

[3]C.M.Ferreira,J.Loureiro and A. Ricard, Proc. XVIth ICPIG, Dusseldorf (FRG 1983).

SESSION BA

10:30 a.m., Tuesday, October 11, 1983

ELECTRON AND PHOTON INTERACTIONS

Chairperson: R. S. FREUND
Bell Laboratories

BA-1 Elastic Scattering of Electrons by HCN Molecules in a Two-Potential Approach at Intermediate and High Energies, A. JAIN* and S.S. TAYAL, Dept. Applied Math., The Queen's University, Belfast (N. Ireland).--We have recently carried out calculations on electron-linear-polyatomic molecule elastic scattering at intermediate and high energies.[1] A two-potential coherent approach, in which the contributions from the short- and long-range potentials (both spherical) are added coherently and in addition the multiple scattering within the molecule is also included, was employed for this purpose. This time we have extended these calculations to a molecule with a permanent dipole moment. The contribution of this non-spherical part of the long-range potential is evaluated in the first Born approximation and added coherently in the previous two-potential results. This hybrid approach is quite successful for e-HCN elastic scattering and yields qualitative results at 21.6 and 50 eV (where experimental data are available). The effects of multiple scattering is significant at these energies. No other calculation (except in the trivial independent-atom-model (IAM)) exists for this system in this energy range.

*Present address: JILA, Univ. of Colo. & NBS, Boulder.

1. A. Jain and S. S. Tayal, J. Phys. B 15, L867 (1982).

BA-2 Vibrational Excitation of D_2 by Low-Energy Electrons,* S.J. BUCKMAN† and A.V. PHELPS, JILA, U. of Colo. & NBS.--Vibrational excitation of D_2 by low-energy electrons has been measured by adding 0.1 to 0.2% CO or CO_2 and measuring 4.7 or 4.3 μm emission from a drift tube. Measured decay times agree with predictions for gas densities from 7 to 300×10^{24} m^{-3}. The E/n were 5 to 40×10^{-21} Vm^2 for mean electron energies from 0.4 to 2.3 eV. When measured relative excitation coefficients are normalized to calculations at moderate E/n, experiment is high by about 30% at low E/n and low by about 15% at high E/n. When D_2-CO_2 results are normalized to N_2-CO_2 measurements the experimental coefficients for D_2 agree with calculations to ±20%. The Boltzmann calculations used published rotational and vibrational excitation cross sections for D_2 near threshold[1] and cross sections[2] for H_2 above 1 eV.

*Partly supported by Air Force Wright Aeronautical Laboratories.

†Present address: Australian National University.

[1]D.K. Gibson, Aust. J. Phys. 23, 683 (1970); P.D. Burrow and G.J. Schulz, Phys. Rev. 187, 97 (1969).

[2]R.W. Crompton, D.K. Gibson and A.G. Robertson, Phys. Rev. A 2, 1386 (1970).

BA-3 Low-Energy Electron Scattering by Nonlinear Closed-Shell Polyatomic Molecules. A. JAIN* and D.G. THOMPSON, Dept. of Applied Mathematics, The Queen's University, Belfast (N. Ireland).--Elastic scattering, rotational excitation and vibrational excitation processes are studied in CH_4, NH_3, H_2O and H_2S molecules by slow electron impact (0-10 eV). A model potential approach, based on a one-center formalism, is employed in which the three types of interaction forces (the static, the exchange and the polarization) are calculated independently. The static potential is derived accurately; the exchange is included through a local potential plus orthogonalization procedure; for the third force, an ab initio parameter-free polarization potential is proposed. With the new polarization potential all the distinct features in various cross sections of the above molecules are reproduced faithfully. For example, our results give a Ramsauer-Townsend minimum in the e-CH_4 total cross section agreeing in magnitude and position with recent measurements; the shape of the e-NH_3 momentum transfer cross sections agrees accurately with swarm data; in the vibrational excitation of H_2S molecules, a strong shape resonance around 2 eV is reproduced in our calculations.
*Present address: JILA, Univ. of Colo. & NBS, Boulder.

BA-4 Electron Impact Cross Sections for Ionization and Dissociative Ionization of CD_4 and the CD_3 Radical, F. A. BAIOCCHI, R. C. WETZEL, and R. S. FREUND, Bell Laboratories -- A crossed electron beam-molecular beam apparatus has been constructed to measure ionization cross sections of free radicals. The design solves two long-standing problems: 1) nearly pure beams of free radicals are produced by charge transfer neutralization of fast (1-4 keV) ion beams. 2) Complete collection and mass selection of fragment ions are achieved by focusing the diverging beam of fragments with an einzel lens onto the entrance of a hemispherical energy analyzer. Measurement accuracy has been verified by remeasuring the known ionization cross sections of He, Ne, Ar, and Kr. New results will be presented for the production of CD_4^+ and CD_3^+ from CD_4 and CD_3^+ and CD_2^+ from CD_3.

BA-5 The Effects of Electron Correlation Upon Multiple Ionization in Strong Laser Fields*, J. N. BARDSLEY, M. COMELLA and B. SUNDARAM, U. of Pittsburgh and W. L. MORGAN, Lawrence Livermore Laboratory -- Recent experiments using intense picosecond ultraviolet radiation have shown anomalously high levels of multiple ionization from irradiated heavy atoms in a collision-free environment. The effects of electron correlation upon the rate of photoionization are investigated using both quantum and classical methods. The two approaches are compared for a simple two-electron system.

*Work supported by the Office of Naval Research

1. T. S. Luk, H. Pummer, K. Boyer, M. Shahidi, H. Egger and C. K. Rhodes, Phys. Rev. Lett. 51, 110 (1983).

BA-6 Absorption of Ultraviolet Radiation in Microwave Discharges

A. PETELIN and C. WOOD, Fusion Systems Corporation--Absorption of the ultraviolet radiation in a medium pressure (2-5 Atm) microwave discharge of mercury was studied experimentally, both for continuum and line part of a spectrum. Experiment consisted in transmitting light through 2 cm thick plasma and measuring transmittance with and without discharge. Plasma was supported by magnetron with power 1500W at the frequency 2450 MHz. Electron density of plasma was 10^{17} cm^3, temperature 6000 K. Measurements were carried out for the range 2000-4000 Å. Absorption in plasma with metal halide additives was also studied. Data was obtained on Jarrell-Ash monochromator interfaced to a microcomputer. The absorption for continuum part of a spectrum is significantly larger than absorption for line part of spectrum and reaches 98%. Absorption properties of an non-ionized Hg vapor are also briefly discussed.

BA-7 Dye Laser Intracavity Absorption for Plasma Diagnosis, G.O. BRINK and S.M. HEIDER, State University of New York at Buffalo--Dye laser intracavity absorption (ICA) is one of the most sensitive techniques available for the detection of optical absorption by atoms or molecules. We have been using this technique for the last few years to observe absorption in low densities of species present in an atomic beam, a gas cell, or in a low pressure plasma produced by a microwave discharge. Detailed line shape studies have been carried out, and at this point in time, it can be said that the basic phenomena of ICA is reasonably understood, and the technique is ready for application. The basic phenomena of ICA will be discussed and compared with experimental results obtained in atomic beams of sodium, lithium and barium, in plasmas composed of helium, hydrogen and neon, and in vibrational overtone transitions of methanol. In these absorbers transitions have been observed from electronic ground states, metastable electronic states, and in electronic excited states having lifetimes of the order of 16×10^{-9}sec. In an atomic beam of lithium, it has been possible to resolve the 0.015 nm fine structure separation of the $^2p^o$ state. Various broadening mechanisms of the ICA signal will be discussed as well as the resolution dependence on laser parameters.

BA-8 Zero Core-Contribution Calculation of Photodetachment of Transition Metal Anions* R.M. Stehman, S. Grot, and S.B. Woo, University of Delaware and E.M. Helmy, Delaware State College. - - We have used the zero core-contribution model to calculate (1) the absolute total photo-detachment cross sections as a function of photon energies and (2) the intensities for individual detachment channels for thirteen transition metal anions at a fixed photon energy. A unique character of each transition metal anion is that the photodetachment could occur involving either an "s" or a "d" outermost electron. A method for determining the relative weights of the "s" and the "d" detachment orbitals will be presented. The intensities calculated for different channels are in good agreement with photoelectron spectroscopy measurements[1], both for channels involving s-orbital detachment and d-orbital detachment[1]. Total cross sections agree with the experimental results of Feldman et al[2].

*Work supported by the Army Research Office

1. C.S. Feigerle, R.R. Corderman, S.V. Bobashev, & W.C. Lineberger, J. Chem. Phys. 74, 1580 (1981).
2. D. Feldman, R. Rackwitz, E. Heinicke & H.J. Kaiser, Z. Physik A 282, 143 (1977).

BA-9 Photoemission from Organic Crystal Particulates into Gases Wm. Y. Fowlkes, M. Pope*, L. Altwegg** Eastman Kodak Company, Rochester, NY 14650--Photoemission measurements are made on individual particulates in controlled atmospheres. The particles are suspended electrostatically by a modified Millikan chamber.[1] The observed photoemission yield depends upon the eventual escape of the electrons emitted into the atmosphere. Data and a theory are presented to describe the probability of escape. This probability depends upon the electron kinetic energy, the concentration and nature of the electron scavengers in the gas, the particle size and state of charge, and the magnitude of the external field Attachment is believed to take place before the emitted electron thermalizes. Photoemission measurements of organic molecular crystals using this technique are presented. Comparison of these results with those from high-vacuum photoemission is made.

*Radiation and Solid State Laboratory, New York University New York, NY 10003

**HASLER AG, Belpstrasse 23, CH-3000 Bern 14, Switzerland

[1] L. Altwegg, M. Pope, S. Arnold, Wm. Y. Fowlkes, and M. A. ElHamamsy, Rev. Sci, Instrum., 53, 332, (1982)

SESSION BB

10:30 a.m., Tuesday, October 11, 1983

GLOW DISCHARGES II

Chairperson: J. S. CHANG
McMaster University

BB-1 Energy Balance in a High Pressure Collisional-Radiative Plasma.* P.A. VICHARELLI & A.V. PHELPS, JILA, U. Colo. & NBS.--Energy balance models for collisional-radiative plasmas[1] have been extended to include the effects of collisions of excited atoms with low temperature neutrals in multistep ionization and recombination. These collisions are a significant source of gas heating and electron energy loss in alkali metal-rare gas discharges.[2] More generally, we find that the electron power loss is $P = (\varepsilon_e+3kT/2)k_i N_e N_a + \varepsilon_r \alpha N_e^2 N_+$, where k is Boltzmann's constant, T is the electron temperature, N_a, N_+ and N_e are the densities of atoms, ions and electrons. The rates of multistep ionization and recombination are $k_i N_e N_a$ and $\alpha N_e^2 N_+$. The effective ionization potential ε_e varies from the spectroscopic value for a high degree of ionization, where excited state-neutral collisions are negligible, to much larger values at low ionization, where excited state-neutral collisions oppose multistep ionization by electrons. These results have been incorporated in a complete discharge model.
*Supported in part by U.S. Army Research Office and Air Force Office of Scientific Research.
[1]D.R. Bates & A.E. Kingston, Proc.Roy.Soc.A279,10(1964).
[2]W.L. Morgan & A.V. Phelps (unpublished).

BB-2 Segregation Phenomena in AC Low-pressure Mercury-Argon Discharges. R.A.J. Keijser, J. Mezger and R.L.A. v.d. Heijden, Nederlandse Philips Bedrijven B.V., Eindhoven, The Netherlands.--A study is presented of axial segregation in AC operated Hg-Argon discharges. Segregation phenomena of this type have, up until now, been considered as a second order cataphoretic effect caused by the presence of striations[1,2]. In the discharges studied we have observed strongly non-uniform axial Hg-density distributions. The influence of current waveform, amplitude and frequency has been investigated. From the experimental evidence we conclude that the segregation is due to the combined effect of radial Hg-transports, driven by the time dependent ambipolar diffusion and axial gas flows, driven by longitudinal pressure waves excited in the discharge tube.
A proof for the existence of such waves in low pressure discharges has been obtained by measuring the amplitudes of the pressure fluctuations directly with small microphones mounted inside an Argon discharge tube. An analysis based on these data shows that the proposed segregation mechanism is very efficient.

1. C. Kenty, J.Appl.Phys. 38, 4517 (1967).
2. G.E. Sery and L.M. Chanin, J.Appl.Phys. 50, 683 ('79).

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*Supported in part by U.S. Army Research Office and Air Force Office of Scientific Research.
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A proof for the existence of such waves in low pressure discharges has been obtained by measuring the amplitudes of the pressure fluctuations directly with small microphones mounted inside an Argon discharge tube. An analysis based on these data shows that the proposed segregation mechanism is very efficient.

1. C. Kenty, J.Appl.Phys. 38, 4517 (1967).
2. G.E. Sery and L.M. Chanin, J.Appl.Phys. 50, 683 ('79).

BB-3 Flowing Positive Column Theory for the Ambipolar Diffusion Controlled Glow Discharge at Moderate Reynolds Numbers, J.D. MILLER and J.S. CHANG, McMaster University, Canada -- A two-dimensional model has been constructed for the ambipolar diffusion - controlled positive column of a medium pressure flowing gas discharge. The gas discharge self-sustaining conditions, the electron temperature inside the discharge region, and the plasma density profiles have been calculated for the ambipolar diffusion Reynolds number, Ra, from 0 to 50, and the discharge region length to tube radius ratio, ℓ, from 1 to 8 under laminar flow conditions. Numerical results show that: (1) The slug flow positive column model proposed by Romig (1960)[1] leads to a large error in predicting the glow discharge self-sustaining conditions when $Ra \gtrsim 5$, however, the theories agree within 10% when $Ra<5$; (2) For larger Ra ($Ra>10$), the self-sustaining condition becomes linearly proportional to the flow velocity and inversely proportional to ℓ; (3) The electron temperature inside the discharge region increases and decreases with increasing Ra and ℓ respectively.

[1]Romig, M.F., Phys. Fluids 3, 129 (1960)

BB-4 Measurement of Negative Ion Densities in NF_3 Discharges,* K. GREENBERG and J.T. VERDEYEN, University of Illinois at Urbana-Champaign --Earlier experiments with the NF_3 discharge indicated the existence of large numbers of negative ions which could affect the etch rates of Si and SiO_2. Both F^- and F_2^- (predominantly the former) have been observed by direct ion sampling of the plasma and the photodetachment of the ions has been observed by the optogalvanic effect. Microwave interferometry has been used to determine both the steady-state electron density and the photodetached density produced by irradiation by an excimer laser. These experiments indicate a negative ion density which is one to two orders of magnitude larger than the electron density within the plasma.

*This work was supported by the Joint Services Electronics Program (U.S. Army, U.S. Navy, U.S. Air Force) under contract N00014-79-C-0424.

BB-5 Characteristics of Radio Frequency Glow Discharges in Helium and Helium/Silane Mixtures*, C.B. FLEDDERMANN and J.T. VERDEYEN, U. of Illinois at Urbana-Champaign--The self-bias, short circuit current, electron density and spatial variation of light intensity in a capacitively-coupled r.f. glow discharge in helium and helium/silane mixtures have been measured. The self-bias, which ranges between 0 and 300 V, increases with discharge power, decreases with pressure and is greater in helium/silane than in pure helium. An electron density of $10^{10}/cm^3$ was measured in helium at a discharge power of 10 W. At the same power, the electron density in 1% silane in helium was an order of magnitude lower, indicating that negative ions are being formed. However, the short circuit current between the electrodes is only a factor of two smaller in helium/silane. Spatially resolved measurements of the light emission from the discharge show a dark space and negative glow associated with each electrode, somewhat analogous to a d.c. hollow cathode.

*Work supported by the Joint Services Electronics Program (U.S. Army, U.S. Navy, U.S. Air Force) under contract N00014-79-C-0424.

BB-6 Electron-Beam Controlled Discharges, Theory and Experiment, L. E. KLINE, J. F. LOWRY, and J. V. R. HEBERLEIN, Westinghouse R&D Center -- We have studied the voltage-current (V-I) and decay characteristics of electron beam (EB) controlled discharges in CH_4 and N_2. The experimental apparatus consists of a Wire-Ion-Plasma (WIP) EB gun coupled to a uniform field discharge chamber. The EB gun voltages are 130-150 KV. The EB current densities are 1-100 mA/cm^2. The discharge chamber pressure is 1 atm in all cases. With a peak EB current density of 100 mA/cm^2 and a discharge chamber electric field-to-gas density ratio of 4 Td the measured current gains (discharge curent/EB current) at the peak of the EB current pulse are 50 in N_2 and 190 in CH_4. The current gain early in the pulse, when the EB current density is a few mA/cm^2, is about 1000 in CH_4. These measured current gain values are about twice as large as those predicted by a simple theory which neglects the tortuosity of the beam electron paths. The measured discharge waveforms show that the discharge conductivity decays when the EB is turned off. The measured waveforms agree well with waveforms predicted by a rate equation model of the discharge coupled to a lumped parameter model of the power supply circuitry.

BB-7 The Effect of Negative Ion Processes on the Electron Temperature in Molecular Gas Discharges, S. ONO and S. TEII, Musashi Inst. of Technol., J.S. CHANG, McMaster univ.-- The time dependent effect of electron attachment and dettachment processes on the electron temperature in CO_2-N_2-He mixture gas discharges has been studied. These studies are of interest for improving the efficiency of CO_2 laser excitation. The electron temperature was calculated numerically by taking into account the negative ion reactions involving CO_4^-, CO_3^-, O_2^-, O^- as well as the charge neutrality and some other chemical reactions. Typical results show that the initial electron temperature T_e=1.4 eV immediately after discharge (t≃0 msec) reduces to 0.98 eV (t≃10 msec) by dettachment reaction caused by the CO molecules at total pressure of 10 Torr and electron density of $1\times10^9 cm^{-3}$. Experiment has been also done for comparison. T_e was obtained using the electrostatic probe technique and emission line intensity measurement. The experimental results agree reasonably with the theoretical calculations.

BB-8 Production of Electrons Through Atomic Hydrogen Ionization in Partially Ionized Molecular Hydrogen,* J.A. KUNC and M.A. GUNDERSEN, U. of Southern California --The production of electrons in a partially (1%) ionized molecular hydrogen plasma, with neutral density ~ 10^{16} is found to depend on the degree of dissociation. The primary electron-ion production mechanism is the stepwise ionization of atomic hydrogen. The electron temperature and the degree of ionization play an important role, in that they have a significant effect on both the shape of the electron distribution function and the dissociation degree. A rapid equilibration produces a Maxwellian distribution in the presence of high current. A discussion of these points is presented for this plasma. which is characteristic of the plasma in a high power switch.

* This work was supported by AFOSR, ARO, and DOE.

SESSION C

1:00 p.m., Tuesday, October 11, 1983

POSTER I

Chairperson: H. JURENKA

ASRC, State University of New York

C-1 Effects of Na and K on the Recombination of CuCl and CuBr in a Pulsed Discharge*, W. WINIARCZYK and L. KRAUSE, Dept. of Physics, U. of Windsor, Canada-- Free Cu atoms are produced by a pulsed electrical discharge in cuprous halide vapor. After each discharge pulse the Cu and halogen atoms recombine to form the original compound. The effect of an admixture of Na or K vapor on the recombination process was investigated by a spectroscopic absorption method, in order to gain insight into the recently observed effects of Na and K addition on the properties of the CuCl laser[1].

*Research supported in part by Natural Sciences and Engineering Research Council of Canada.

[1]W. Winiarczyk and L. Krause, Opt. Commun. 43, 47 (1982).

C-2 The Effect of Vibrational Excitations on the Electron Distribution Function* - R.BRAKEL, G.ECKER and K.-U.RIEMANN, Ruhr-Universität Bochum, FRG. We consider a stationary, weakly ionized plasma in a homogeneous electric field, where the electron kinetics is governed by elastic scattering and inelastic energy exchange with neutral molecules. Due to the dominant intraction with vibrational states, the effect of collisions of the second kind cannot be neglected. To account for this process, we develop an approximation procedure which is based on a suitable parameter ansatz for the distribution function within the collision integral. We give an evaluation for a set of simplified model cross sections refering to N_2, the comparison with results from a direct numerical solution of Boltzmann's equation shows good agreement. We calculate the selfconsistent vibrational temperature and discuss the effect of vibrational excitations and deexcitations for various reduced field strengths.

*Work done under the auspices of the SFB 162 of the Deutsche Forschungsgemeinschaft

C-3 $He^*(2^3S)$,$Ne^*(^3P_{2,0})$-HCl Collisional Energy-Transfer Processes, A.J. Yencha†, A.K. Khan and S. Brown, Dept of Chemistry, SUNY at Albany—We have observed the HCl^+ $(A^2\Sigma^+ - X^2\Pi)$ emission produced by Penning ionization (PI) in He*,Ne*-HCl afterglows. No bath-gas-pressure dependence was observed in the vibrational distribution of the HCl^+ (A) state in the He*-HCl system between 0.5-3 Torr He pressure in agreement with previous studies,[1,2] but we found the same distribution to vary strongly below $\sim$ 1 Torr neon pressure in the Ne*-HCl system. The HCl^+ (A) state vibrational branching ratios v'=1/v'=0 and v'=2/v' =0 at 0.1 Torr neon pressure were 1.75 and 0.80, respectively, in good agreement with the 48 meV Ne*-HCl optical emission beam results of Snyder et al.[3] of 1.79 and 0.87, respectively. Based on these emission results in the Ne*-HCl system, PI appears to be a "vertical" process from an essentially unperturbed HCl molecule.

†Also Department of Physics

[1]W.C. Richardson et al., Chem. Phys. Lett. 12, 349(1971)
[2]W.C. Richardson & D.W. Setser, J. Chem. Phys. 58, 1809 (1973).
[3]H.L. Snyder et al., Chem. Phys. Lett. 94, 90(1983)

C-4 Evolution of the Phase-Space Distribution of an Assembly of Electrons at Moderate and High E/N,* Y. TZENG and E.E. KUNHARDT, Texas Tech University--Results are presented from an investigation of the approach to and the characteristics of the equilibrium state of a pulse of electrons, released from the cathode of a nitrogen filled chamber, under the action of an uniform electric field. The investigations were done for $E/N \geq 300$ Td. A Monte Carlo technique has been used to simulate the evolution of the electrons and to determine the time dependence of the phase-space distribution function, the transport parameters and the rate coefficients for e-N_2 reactions. At high E/N (~1500 Td), the coefficients of a spherical harmonics expansion of the distribution function have been found to increase in amplitude with increasing order, at high energies. Runaway electrons have been observed at $E/N \gtrsim 1500$ Td.

*Work supported by the Office of Naval Research under Contract N00-14-81-K-0655.

C-5 The Atomic Fluorine Laser: A Candidate for Nuclear Pumping?, M. J. KUSHNER, Lawrence Livermore National Laboratory* -- Recent experimental results suggest that the high pressure atomic fluorine discharge laser is excited by ion-ion neutralization between He_2^+ and F^-.(1) This method of excitation is attractive for nuclear pumping because of efficient use of the large thermal electron density. A rate equation analysis of a nuclear reactor pumped atomic fluorine laser is discussed where the excitation process is assumed to be $He_2^+ + F^- \rightarrow 2He + F^*$. Small signal gain greater than 0.1 cm^{-1} may be possible with thermal neutron fluxes in excess of $10^{16}/cm^2$-s.

(1) R. Dadighi-Bonadi, F. W. Lee, and C. B. Collins, J. Appl. Phys. 53, 3418 (1982).

*Work performed under the auspices of the U.S. Dept. of Energy by Lawrence Livermore National Laboratory under Contract No. W-7405-ENG-48.

C-6 Crossed Beam Measurements of Absolute Rate Coefficients in Associative Ionization Collisions between Na*(np) and Na(3s) for $5 \leq n \leq 15$, J. BOULMER†, R. BONANNO and J. WEINER, Dept. of Chemistry, U. of Maryland-- Associative ionization in slow collisions between Na*(np) levels and Na(3s) ground state is studied in a crossed beam experiment. Excited levels are prepared by laser photoexcitation, and ionic species are analyzed by time-of-flight mass separation. Rate coefficients for associative ionization, measured for principal quantum numbers ranging from n=5 to 15, exhibit a pronounced dependence on n with a maximum of approximately 3 x 10^{-9} cm^3 s^{-1} near n=11. Comparisons are made with the theoretical model developed by Duman and Shmatov, and Mihajlov and Janev.

†Permanent Address: Institut d'Electronique Fondamentale, Université de Paris-Sud

C-7 Prompt and Delayed Photolysis of Cs_2,* F. DAVANLOO, A. S. INAMDAR† and C. B. COLLINS, Univ. of Texas at Dallas; A. S. NAQVI, King Saud Univ. of Riyadh--In this work a time-delayed, double resonance technique was used for the study of the state selective photolysis of Cs_2 with particular attention being placed on the production of the fine structure components of the 5^2D and 6^2P states of Cs. Not only were the prompt sources from dissociation and predissociation of excited states of Cs_2 confirmed, but new kinetic channels for delayed photolysis were found. Over the visible wavelength range two delayed processes for the production of Cs (5^2D) and Cs(6^2P) atoms were characterized. They are tentatively identified as proceeding through a precursive state belonging to the 5dX manifold of Cs_2, where X is most probably Π or Δ.

*Supported by NSF Grants PHY80-19525 and PHY82-14273.
†Present address: Physics Dept., Univ. of Alberta.

C-8 Photodissociation of N_2O by Vacuum Ultraviolet Radiation*, L. C. Lee and Masako Suto, San Diego State University -- The optical emissions from the excited photodissociation fragments were observed using synchrotron radiation in the 105-150 nm region as light source. The fluorescence and the photoabsorption cross sections were measured, and the fluorescence quantum yields were determined. In the 105-120 nm region, the emission is mainly the $N_2(B^3\Pi_g \rightarrow A^3\Sigma_u^+)$ system, which is produced from direct dissociation of N_2O. In the 122 - 137 nm, the emission is mainly the $NO(B^2\Pi_r \rightarrow X^2\Pi_r)$ system. This emission is produced from the reaction of N_2O with some excited species produced from direct photodissociation of N_2O. These excited species are quenched fast by He, Ar, H_2, and N_2 with rate constants in the same order of N_2O. These results indicate that the excited species are neither $N(^2D)$ nor $O(^1S)$. The identification of these excited species will be discussed. Several weak vibrational progressions observed in the 105 - 122 nm region were attributed to Rydberg states.
* Work supported by NSF (ATM-8205849) and by NASA (NAGW-319). The Wisconsin synchrotron radiation facilities are supported by NSF (DMR-44-21888).

C-9 Production of Emission at 2,000-12,000 Å by Electron Impact on O_2,* M. B. SCHULMAN, F. A. SHARPTON†, L. W. ANDERSON, and CHUN C. LIN, U. of Wisconsin-Madison --Radiation in the 2,000-12,000 Å wavelength range produced by excitation of O_2 molecules with a monoenergetic electron beam has been studied. The spectrum is dominated by bands of the First and Second Negative Systems of O_2^+ ions, $2p^2 3p\ ^2L(\text{or } ^4L) \rightarrow 2p^2 3s\ ^2L'(\text{or } ^4L')$ and $2p^2 3d\ ^2L(\text{or } ^4L) \rightarrow 2p^2 3p\ ^2L'(\text{or } ^4L')$ transitions of O^+ ions, and $2p^3 np\ ^3L(\text{or } ^5L) \rightarrow 2p^3 3s\ ^3L'(\text{or } ^5L')$ and $2p^3 n\ell\ ^3L(\text{or } ^5L) \rightarrow 2p^3 3p\ ^3L'(\text{or } ^5L')$ transitions of neutral oxygen atoms. The excitation functions show a broad maximum at 200 eV for both the doublet and quartet lines of O^+ ions. For the neutral atomic oxygen lines the excitation functions peak at about 90 eV, and the shape of the excitation functions for the quintet lines differ appreciably from that for the triplet lines. The O^+ lines are in general weaker than the neutral-atom lines. For instance the peak cross section of the 4650-Å multiplet of O^+ is 1.2×10^{-19} cm^2 as compared to 14×10^{-19} cm^2 for the 8446-Å multiplet of neutral oxygen atoms.

*Supported by the Air Force Office of Scientific Research.

†Present Address:Northwest Nazarene College, Nampa, ID.

C-10 A Parameter-free Correlation-polarization Potential for Electron-Molecule Collisions: Application for e-H_2 and N_2 Scattering,*N. T. PADIAL and D. W. NORCROSS, JILA, U. of Colorado and NBS -- We have developed a local, parameter-free model potential[1] that uses the free-electron gas correlation expression at short distances and the asymptotic form of the polarization potential. This potential is augmented by static and exchange terms to complete the total e-molecule interaction. The exchange term is treated both exactly and approximately through a local, free-electron gas model. We have performed calculations for e-H_2 and N_2 collisions from 0.01 to 1.0 Ry. Our total integrated cross sections for e-H_2 collisions are in good agreement with those of more elaborate theoretical treatments and of experiment. For e-N_2 scattering, the position (E_r = 2.16 eV) and width (Γ = 0.47 eV) for the $^2\Pi_g$ resonance are in excellent agreement with more sophisticated calculations provided that exchange is treated exactly. We also obtain good agreement with other methods for the Σ_g and Σ_u symmetries.

*Supported by the U.S. Department of Energy (OBES).

[1]J. O'Connell and N. F. Lane, Phys. Rev. A27, 1893 (1983).

C-11 Ro-vibrational Excitation of HCl by Electrons: The Importance of Polarization and of an Exact Treatment of Exchange,* N. T. PADIAL and D. W. NORCROSS, JILA, U. of Colorado and NBS -- We have calculated vibrational excitation cross sections in the adiabatic nuclei approximation for e-HCl at energies from threshold to 5.0 eV. We used two forms of the interaction potential both of which contained the static term. In the first case exchange effects were introduced through a local, free-electron gas model potential. In the second case, the exchange term was augmented by a parameter-free model polarization potential. For the static-exchange model, the cross sections had the wrong shape and were an order of magnitude too low when compared with experiment.[1] The introduction of polarization effects is much more important than for the vibrationally elastic excitation and greatly improved the agreement in shape although the magnitude was still too low by a factor of two. Calculations with an exact treatment of exchange will also be discussed.

*Supported by the U.S. Department of Energy (OBES).

[1]K. Rohr and F. Linder, J. Phys. B9, 2521 (1976).

C-12 Dissociative Recombination of HCO^+ Ions and Electrons*, B. GANGULI, M. A. BIONDI and R. JOHNSEN, U. of Pittsburgh -- The recombination rate of HCO^+ ions with electrons, of interest for modelling the ionospheres of the outer planets and molecular formation in interstellar clouds, has been determined over a wide range of electron temperature T_e using a microwave afterglow/mass spectrometer apparatus employing microwave electron heating. Hydrogen-carbon monoxide mixtures (0.16-0.64 m Torr) in neon buffer gas ($\sim$ 12 Torr) have been used to obtain afterglows dominated by HCO^+ ions. The electron density decays, which track well with the HCO^+ ion wall currents in recombination-controlled afterglows, have been fitted by computer solutions of the continuity equation containing recombination and diffusion loss terms to obtain values of the rate coefficient α. The results of the determinations are

$$\alpha(HCO^+)=(2.4 \pm 0.2) \times 10^{-7}\left[\frac{T_e(K)}{300}\right]^{-0.64 \pm 0.06} \quad cm^3/sec,$$

valid over the range 293 K $\leq T_e \leq$ 4900 K and $T_+ = T_n =$ 293 K.

*This research was supported, in part, by NASA.

C-13 Ion-Ion Neutralization in a Radiation-Induced Oxygen Discharge, H.E. ELSAYED-ALI and G.H. MILEY, Fusion Studies Lab., U. of Illinois -- The relative importance of ion-ion neutralization reactions in an oxygen discharge has been studied by measuring O_3 yield for O_2 and O_2:SF_6 mixtures. The discharge was created by irradiation with high-energy (MeV) He and Li ions created by neutron-induced nuclear reactions in Boron-10. Dose rates in the range of 10^{18}-10^{20} $eVg^{-1}s^{-1}$ were studied. Radiolysis of oxygen in this intermediate range of energy deposition rate has not previously been studied. In pure O_2, ion-ion neutralization involving O_3^- is found to be dominant. Such neutralization reactions do not contribute to O_3 production. Neutralization reactions involving two oxygen molecules, which contribute to O_3 production, increase with dose rate but do not dominate at the studied dose rate range. The addition of SF_6 replaces all neutralization reactions by other reactions involving negative species resulting from the dissociative attachment of SF_6. Such neutralization reactions do not contribute to O_3 production. However, SF_6 also suppresses chain O_3 decomposition which is initiated by negative species, including electrons and O_2^-. The net effect of SF_6 addition was an enhanced O_3 yield.

C-14 Highly Accurate Diffusion Treatment for Recombination of General Systems,* M. R. FLANNERY, Georgia Institute of Technology --A new and highly accurate diffusion treatment for the rate of recombination between general systems, or of any chemical relaxation, association or dissociation process in a gas is formulated. The essential reason for failure of the Pitaevskii result[1] to general system becomes apparent. The method involves use of an approximate energy-distribution function of the reacting species in the exact expression for the current in which the energy-change frequency of collisions between ion pairs and the gas is treated exactly. Excellent agreement with the exact quasi-equilibrium treatment is obtained.

*Sponsored by the U.S. Air Force Office of Scientific Research under Grant No. AFOSR-80-0055.

[1]L. P. Pitaevskii, Soviet Phys. - JETP 15 (1962) 919.

C-15 Potassium-Seeded Arc Source for Stark Broadening Studies,* J. P. HOHIMER, Sandia National Laboratories--We have developed a potassium-seeded argon wall-stabilized arc source in order to measure the Stark broadening and shift coefficients for potassium excited-state transitions in the ns-4p and nd-4p series. This arc source was designed to operate at a low pressure (20 Torr Argon) in order to minimize the contribution of argon collisional broadening to the potassium excited-state line shapes.[1] A ceramic channel wall with indepenent heating was used to reduce radial cataphoresis and maintain a high on-axis potassium number density (up to optically thick for the 4s-4p resonance line). Far-infrared interferometry at 118 m was used to determine the on-axis electron density which varied linearly from 2.0×10^{14} to 1.6×10^{15} cm^{-3} as the arc current was increased from 5 to 40A. A two-laser modulated absorption technique was used to measure the Stark-broadened excited-state line shapes with high spectral resolution.

*Work supported by U.S. Department of Energy under contract number DE-AC04-76DP00789.

[1]J. P. Hohimer and J. Gee, Phys. Rev. A 25, 1404 (1982).

C-16 Time-Dependent Boltzmann Calculations for Model Cases* L. C. PITCHFORD and T. A. GREEN, Sandia National Laboratories--Calculations of spatially uniform, time-dependent electron transport coefficients for four model cases have been performed using a multi-term Legendre expansion, time-dependent Boltzmann equation. We find that after a sudden change in the applied field for the constant collision frequency model, the initial Maxwellian relaxes toward equilibrium through a series of Maxwellian distributions. For the constant cross section model, the transient drift velocity exhibits an undershoot or overshoot as the electric field is suddenly changed. Qualitative conclusions of the response of the distribution to a change in the applied field will be drawn from these and two other model calculations.

*Supported in part by the U. S. Department of Energy under contract number DE-AC04-76DP00789 and in part by the Air Force Wright Aeronautical Laboratories.

C-17 Experimental and Theoretical Investigation of the Plasma Parameters and Particle Components in the Oxygen Glow Discharge Positive Column, R.L.C. WU, T.O. TIERNAN, AND Y. ICHIKAWA, Wright State University--Combined experimental and theoretical studies have been accomplished in order to elucidate features of the oxygen glow discharge positive column. A single probe technique and a mass spectrometer were utilized to characterize the plasma parameters and particle components. The experiments were carried out in a cylindrical discharge tube (radius of 1cm) and the total pressure range from 0.1 to 10 torr. The discharge model for the positive column is a stationary, slightly ionized plasma. Under typical glow discharge conditions (electron density = 10^9 to 10^{10} cm^{-3}, and total pressure = 0.1 to 10 torr), the results yield the following conclusions: 1) the electron temperatures determined experimentally were slightly larger than the values calculated from the theory. The discrepancy is due to the effect of the negative ion on the probe characteristics. 2) Excellent agreement was observed between the theoretical and found values of E/N, and 3) the experimental results in terms of ion compositions agree qualitatively with the calculations based upon a numerical analysis.

SESSION D

3:00 p.m., Tuesday, October 11, 1983

WORKSHOP I: GASEOUS ELECTRONICS PHENOMENA IN PLASMA PROCESSING

Chairperson: J. T. VERDEYAN
University of Illinois

D: WORKSHOP ON
GASEOUS ELECTRONICS PHENOMENA IN PLASMA PROCESSING

3:00 p.m.
Assembly Hall

Chairperson: J. T. VERDEYEN - Univ. of Illinois

OVERVIEW

Professor H. Oskam
Department of Electrical Engineering
University of Minnesota
Minneapolis, MN 55455

I. Plasma Deposition

IA "Ion-Surface Interactions During Semiconductor Growth by Sputtering"
Professor Joseph Greene
Coordinated Science Laboratory
University of Illinois at Urbana-Champaign
Urbana, IL 61801

IB "Plasma-Assisted CVD - Gas-Phase Diagnostics and Film Formation"
Dr. John C. Knights
Xerox Corporation
Palo Alto, CA 94304

II. Plasma Etching

IIA "Plasma Etching - The Role of Ions"
Dr. John Coburn
IBM Research Laboratory
San Jose, CA 95114

IIB "Gaseous Electronics and Plasma Etching Research"
Dr. Daniel Flamm
Bell Laboratories
Murray Hill, NJ 07078

III. Plasma Kinetics

IIIA "Discharges and Plasma-Chemistry Models for Silane Discharges"
Professor Alan Gallagher
JILA
Boulder, CO 80309

IIIB "Status Report of Relevant Cross-Sections and Transport Properties of Silane Discharges"
Dr. Alan Garscadden
Air Force Wright Aeronautical Laboratories
Wright-Patterson AFB, OH 45433

SESSION E

9:00 a.m., Wednesday, October 12, 1983

ARCS I

Chairperson: I. M. COHEN
University of Pennsylvania

E-1 Measurement of Zero-Field Electron Thermal Emission into a Low-Pressure Arc, JOHN M. ANDERSON, General Electric R&D Center, Schenectady, NY--Zero-Field emission has been measured by various procedures and with varying degrees of success since the early work of Found[1]. We present here a novel extension to low pressure arcs of a scheme used recently by Chen, et. al. for the high pressure arc. During normal cathode/plasma operation, the overall discharge voltage is periodically and abruptly clamped for short times at varying potentials less than the maintenance value. The resulting v/i characteristics give zero-field emission during normal operation. Application to Ar/Hg discharges shows zero-field emission to be a small fraction of total discharge current, as expected, but the decay of emission after clamp gives in addition an indication of temperature drop and thus power balance at the cathode surface.

1) C.G. Found, Phys. Rev., 45, p. 519-26 (1934)
2) M.M. Chen, R.E. Thorne, and E.F. Wyner, J. Appl. Phys., 47, p. 5214-17 (1976)

E-2 Effects of Low Ambient Gas Pressures on Cathode Spot Operation, L.P. HARRIS, General Electric Corp. R&D--A model is proposed for the operation of cold cathode arc spots on metal cathodes in the presence of ambient gas at pressures below those generated in the cathode spot plasma. According to this model, the jet of cathode material emanating from the cathode spot is brought to rest near the cathode surface at ambient pressure by a shock system approximated here by a simple normal shock. The stagnated plasma then diffuses back to the cathode surface and deposits its thermal and chemical energy over a diameter approximately equal to the shock diameter. This additional heating of the cathode increases the effective background temperature of the cathode near the emitting spot, thus hampering heat conduction into the bulk of the cathode and limiting the current that can be carried by one cathode spot. Calculated maximum spot currents for copper cathodes agree qualitatively with available crude experimental data. The experiments indicate somewhat stronger effects at very low pressures.

E-3 Experimental Study of Arc Spot Motion on a Conical Cathode-- H.P. Mercure, R.J. Rajotte, M.G.Drouet IREQ, Varennes, Canada-- An experimental study of the motion of arc spots on a conical cathode in an axial magnetic field is reported. The experiment is conducted in a cylindrical glass vessel with a coaxially symmetric magnetic field using a pulsed arc current between a flat anode and a conical cathode (5 cm, ϕ).

Uniform, quite reproducible, spiral patterns are generated at the surface of the conical cathode. High-speed photography also confirms that the resultant motion of the spots occurs in neither the IxB nor the -IxB direction.

Measurements of the drift angle accounting for the departure from the expected retrograde direction at reduced pressure ($0.1 < p < 100$ torr, He) are obtained as a function of external magnetic field ($\lesssim$ 1T), total arc current ($\lesssim$ 10 kA) and cone tip angle.

E-4 Arc-Generated Hollow Cathodes in a Nitrogen Plasma Torch - HARALD L. WITTING, General Electric Company R&D--Arc-generated electrode cavities have been observed that localize the arc terminus and stabilize the discharge of a plasma torch. The electrodes are made of tungsten containing 2% zirconia or thoria. They are rods of 2.4 mm diameter, initially with rounded ends. The discharge is operated in nitrogen gas at 1 atm between a pair of nearly parallel electrodes spaced 6 mm apart. The arc is blown into an elongated shape of 40 mm length by means of nitrogen jets along each electrode. Arc voltage is typically 120V at 20A and 10 kHz AC. It was found that the arc terminus initially moves about the electrode surface, but within 30 sec it invariably forms a cavity on the electrode tip and becomes anchored there. On subsequent arc operation the arc terminus quickly localizes at the cavity. The electrode tips were examined by SEM and showed cavity diameters of 0.25 to 1 mm, with fine structure and evidence of partial melting.

E-5 Channel Model of Rotating Arc Roots, R.J. Zollweg, Westinghouse R&D Center--A channel model is used to describe the 3-dimensional arc root section of a dc plasma torch discharge between cylindrical electrodes. The root section of the arc acquires a radial spiral configuration as a result of the axial and swirl gas flows and the Lorentz force of an applied axial magnetic field. The channel contour can be solved numerically in steady state using a rotating coordinate system and a system of equations representing the energy and force balances with suitable boundary conditions. Major energy loss terms include the heat transfer to the colder gas as a result of the axial gas flow and the azimuthal channel rotation. Major force terms arise from the gas dynamic drag and from Lorentz forces associated with both the applied and self magnetic fields.

E-6 Conductivity Studies of Magnetically Controlled Metallic Plasma Arcs,* J. L. LEE, M. NIKOLICH, D. R. DETTMAN and R. DOLLINGER, St. U. of N.Y. at Buffalo -- Salient operational characteristics in parameter space for two types of magnetically controlled matallic plasma arcs have been derived and will be presented. One type of arc is between butt electrodes with a perpendicular magnetic field. The other arc is between a small cathode cylinder and an axially aligned hollow anode with a axial field. The arc medium is provided by the metallic plasma/vapor ejected from cathode spots. Basic plasma concepts (e.g., magnetic pressure, anode sheath and terms of the conductivity tensor) will be related to experimental data by the use of plasma physics based characteristic curves including: (1) arc current vs. arc voltage with applied magnetic field as a parameter, (2) arc voltage vs. applied magnetic field with collision frequency as a parameter, (3) arc current vs. applied magnetic field with collision frequency as a parameter and (4) arc resistance arc current vs. applied magnetic field with arc current as a parameter. Ramifications to potential scaling relative to plasma instabilities will be discussed in some detail.

*Partially supported by Electric Power Research Inst.

SESSION F

10:30 a.m., Wednesday, October 12, 1983

PLASMA BOUNDARIES

Chairperson: J. J. EWING
Math. Science NW

F-1 Attachment Induced Contraction in the Cathode Fall - A Myth?. G. L. Duke, AFWAL/POOC-3, WPAFB, OH -- The Boltzmann transport equation has been solved self-consistently for the electric field and electron distribution as functions of distance through the cathode fall region for He/HCl, Ar/HCl and Xe/HCl mixtures. It was observed many years ago that the addition of a small amount of an attaching gas caused the cathode fall region to contract.[2] Our results indicate that even though the attachment coefficient may be larger than the ionization rate very near the cathode, the presence of negative ions in the cathode fall does not cause it to contract. The contraction in He/HCl mixtures is due to the ionization of HCl which has a much lower ionization potential. Attachment tends to increase the electric field throughout the cathode fall region resulting in a slightly higher cathode fall voltage. No contraction is predicted for argon or xenon mixtures with up to 5% HCl.

[1] Long Jr., W.H., "Plasma Sheath Processes", AFAPL-TR-79-2038.

[2] Emeleus, K.G. and Woolsey, G.A. (1970), "Discharge in Electronegative Gases", Taylor & Francis, London.

F-2 Consistent Theory of the Core and Sheath of a Plasma Column* - K.-U. RIEMANN, Ruhr-Universität Bochum, FRG. We investigate a weakly ionized plasma with Boltzmann-distributed electrons (T_- = const.). The ion kinetics is governed by symmetric charge exchange with cold neutrals; the mean free path is small compared with the electron Debye length. For this plasma model we have solved in the past the selfconsistent potential problem of the plasma boundary layer [1]. The corresponding density variation can be combined with the density profiles of the plasma body given by Frost [2] (field dependent mobility) to construct a consistent unified theory of plasma and sheath. The profiles of the Schottky theory - however - cannot account for the strong electric field in front of the wall.

[1] K.-U. Riemann, Phys. Fluids, 24, 2163 (1981).
[2] L.S. Frost, Phys. Rev., 105, 354 (1957).

*Work done under the auspices of the SFB 162 of the Deutsche Forschungsgemeinschaft

F-3 Relaxation of Fast Electrons in Front of a Wall* - A. SCHUMACHER, Ruhr-Universität Bochum, FRG. We study the kinetics of fast electrons in a weakly ionized plasma in front of a negative wall. For a small Debye length the potential variation can be approximated by a potential jump representing the sheath. We propose an approximation method to calculate the electron distribution function which accounts for general boundary conditions (absorption, reflection and emission) and anisotropic cross sections. This method is based on a parametrization of the angular dependency. The unknown parameters are determined by a special adaption of the Method of Weighted Residuals, the error is discussed and shown to be small. As result we get a straight-forward analytic representation of the electron distribution function in the boundary layer. For the case of a totally absorbing wall a comparison with exact analytical solutions in the literature yields excellent agreement.

*Work done under the auspices of the SFB 162 of the Deutsche Forschungsgemeinschaft

F-4 The Cathode Fall in Electron Beam Ionized Discharges. P.Bletzinger, AF Wright Aeronautical Laboratories.-- The voltage across the cathode fall in an E-beam ionized discharge (EBD) may be non-negligible relative to the discharge voltage. If the EBD is used as a switch, this will add to the voltage loss. The cathode fall was measured for a number of gases and gas mixtures, including added attaching gases. In contrast to low pressure self sustained normal glow discharges, the EBD cathode fall depends strongly on discharge voltage, external ionization and discharge current density as well as on the gas and the cathode material. In agreement with theory, the cathode fall voltage increased with discharge voltage, until the electric field in the cathode sheath was large enough for Townsend ionization, then it decreased again. The cathode fall voltage at which ionization in the sheath occurs depends on E-beam current density. Added attaching gases did not change this characteristic appreciably, even though they decreased the conductivity in the volume of the EBD. Extrapolating to large E-beam current densities, the cathode fall voltage still is on the order of several hundred volts for methane or nitrogen. Low work function cathode materials were also tested.

F-5 Spectroscopic Investigations of the Sheath Regions in an RF-plasma Reactor. C. DEJOSEPH, JR. and P. BLETZINGER, AF Wright Aeronautical Laboratories. Plasma chemical processes in parallel plate reactors have become very important in the semiconductor industry. While the bulk volume of these RF plasmas has been investigated in detail, the sheath regions close to the electrodes are more difficult to analyze. Plasma reactions within these sheath regions greatly influence the processes on the electrode surfaces, high energy electrons generated in the sheaths may introduce defects in the material being processed. Using nitrogen as both a major gas and as a trace gas, we have obtained spatially resolved spectra of these sheath regions. While the detailed sheath structure can be quite complex, in general the vibrational temperature increases in the sheath. Also the intensity of ion lines increases relative to neutral line intensities in the sheath regions, indicating the presence of electrons with higher energy. The experimental parameter range covered pressures from .1 - 1 Torr, RF powers from 0.05 - 0.5 w/cm^3 and frequencies from 1 - 13.6 MHz.

F-6 Computer Simulation of SF_6 Plasma Etching of Silicon, L. E. KLINE, Westinghouse R&D Center -- SF_6 plasma etching of Si in an RF discharge reactor has been studied using a rate equation model. Electron transport coefficients are estimated by calculating the electron energy distribution corresponding to the average RF field. The calculations are performed for the experimental conditions of Ref. 1. Under these conditions the average field is about 2.5 times the limiting field where the ionization and attachment rates are equal. Hence the ionization rate is much larger than the attachmnent rate, and diffusion is the dominant electron loss process. Charged and neutral particle fluxes to the Si wafer surface are estimated by using ambipolar and free diffusion rates, respectively. All SF_6 electronic excitation is assumed to be dissociative, with SF_5^* + F as the dominant product channel in analogy with the known product channels in ionization. With these assumptions the particle flux to the Si wafer surface is dominated by neutral F and SF_5 and the predicted etching rate due to F atoms alone is 1500 A/min. This rate is at the low end of the range of etching rates observed experimentally in Ref. 1.

1. K. M. Eisele, J. Electrochem Soc., 128, 123(1981).

F-7 Laser-Induced Deposition of Silicon Using Abnormal Discharges in Silane,* P. J. HARGIS, JR., and J. M. GEE and J. D. VERDEYEN**, Sandia National Laboratories -- Silicon can be deposited on a variety of substrates using the combination of a dc abnormal glow discharge and KrF laser photons at an intensity of $\sim 10^7$ W/cm^2. Both the glow and the photons are necessary to obtain deposition. We have found that the potential of the substrate with respect to the plasma has little if any affect on the laser deposition rate in spite of the large photoelectric emission from the substrate. This implies that the neutral components of the plasma are responsible for laser deposition. When the substrate is biased negative with respect to the floating potential a subnormal discharge is set up between the substrate and the main discharge and silicon is deposited independent of the laser. This deposition appears to be associated with the ionic component of the plasma and is almost totally independent of the photon induced process. The ionic deposition rate is almost two orders of magnitude lower than the photon deposition rate.

*This work was performed at Sandia National Laborabories supported by the US Department of Energy under contract number DE-AC04-76DP00789.

**Permanent address: University of Illinois

F-8 Differences in Optical Spectra for A Spatially Varying Cd-Neon Low Pressure Discharge. R. Y. PAI, GTE Lighting Products, Danvers, Mass. Differences in the relative intensities of 2288A and 3261A UV lines of a low pressure Cd-Ne discharge have been measured. Measurements were made before (cathode side), within and after (anode side) an $\sim$ 3 mm constriction in an $\sim$ 38 mm id quartz tube filled with $\sim$ 2 torr neon. These relative intensities change with partial pressure of Cd. The relationship between these relative intensities and the energy relaxation length of electrons in the discharge will be discussed.

SESSION GA

1:15 p.m., Wednesday, October 12, 1983

LASERS

Chairperson: M. J. KUSHNER
Lawrence Livermore Lab.

CA-1 Kinetic Processes in E-Beam Excited XeF(C→A) Lasers* - W. L. NIGHAN - United Technologies Research Center, and Y. NACHSHON, F. K. TITTEL and W.L. WILSON, JR., Rice University. Improved understanding of kinetic processes in e-beam excited mixtures has led to a significant increase in XeF(C→A) laser energy and efficiency[1]. Blue/green laser pulse energy density on the order of 1 J/ℓ, corresponding to an intrinsic efficiency of 0.25 percent, has been obtained using a mixture containing both F_2 and NF_3. These values are almost three orders-of-magnitude higher than prior levels. Analysis of experimental data indicates that the improvement is due primarily to a reduction in absorption by Ar and Xe related excited species. The primary issues affecting XeF(C→A) laser performance will be discussed, with particular attention directed toward factors influencing the identity and concentration of absorbing species.

1. W. L. Nighan, Y. Nachshon, F. K. Tittel and W. L. Wilson, Jr., Appl. Phys. Lett. 42, 1006 (1983).

*Supported in part by the Office of Naval Research, the National Science Foundation and the Robert A. Welch Foundation.

CA-2 Preionization Studies of Rare Gas Halide Lasers, R.S. TAYLOR and K.E. LEOPOLD, National Research Council of Canada, Ottawa, Ontario --Several years ago the authors demonstrated that ~1 mJ/cm^2 of soft uv radiation from a KrF laser could produce the electron densities necessary for the preionization of a second rare gas halide laser.[1] Since the preionization source is external to the laser, this technique affords a unique capability of varying the preionization electron density in the direction of the discharge electric field. It also provides a simple means of varying the discharge volume, while keeping the energy transferred to the discharge constant. Some of the remarkable discharge and lasing effects which result from such complete control over the spatial distribution of the preionization will be described.

When the second laser was operated as a XeCl oscillator, preionization of a 4 x 2.5 x 50 cm^3 discharge volume resulted in an output energy of 1.7 J and an efficiency of 1.7% based on the energy stored on the primary capacitor.

[1]R.S. Taylor, A.J. Alcock, and K.E. Leopold, Opt. Lett., 5, 216 (1980).

GA-3 Vibrational Relaxation of the $B^2\Sigma$ Upper State of the HgBr/$HgBr_2$ Dissociation Laser,* A. C. ERLANDSON AND T. A. COOL, CORNELL UNIVERSITY --Laser induced $HgBr(B^2\Sigma-X^2\Sigma)$ fluorescence spectra were recorded for HgBr in the presence of He, Ne, Ar, Xe, and N_2 collision partners. Computer simulations of the observed spectra were used to calculate the corresponding vibronic state distributions of the $HgBr(B^2\Sigma)$ molecules. Vibrational relaxation of the states v'=0 to v'= 65 following selective excitation of the v'=52 level by absorption of 3371Å N_2 laser photons was modeled by numerical integration of the master equations describing vibrational relaxation and radiative decay. Excellent agreement was found between model predictions and observed LIF spectra at all stages of vibrational relaxation. The ratios of rate constants for V→T vibrational deactivation of the $HgBr(B^2\Sigma)$ v'=1 state by He, Ne, Ar, Xe, and N_2 were found to be approximately 1:1:1.9:13:13 at 415 K, with the value $k_{1,0}=3.89\times10^{-11}$ cm^3/sec for the He case.

*Supported by the Office of Naval Research under contract N00014-83-K-0294.

GA-4 Metal Hydride Dissociation Lasers with Visible Wavelengths,* A. C. ERLANDSON and T. A. COOL, CORNELL UNIVERSITY --Atomic indium and aluminum lasers operating at 451 and 396 nm, respectively, have been pumped by photodissociation of InH and AlH by an ArF laser. Segmented discharges in room temperature hydrogen cells with electrodes of the metal of interest were used to generate the metal hydride vapors. Laser operation was also observed when the metal hydrides were generated at the metal surface in a plasma induced by the focused pump beam radiation. These lasers are the first dissociation lasers based on diatomic metal hydrides; additional experiments with other metal hydrides will also be reported.

*Partially supported by the Office of Naval Research under contract N00014-83-K-0294.

GA-5 Electron-Ion Recombination in CO_2 Laser Gas Mixtures-I.M. LITTLEWOOD, and M.C. CORNELL, University of Missouri-Rolla.--The electron-ion recombination rate has been measured for He:CO_2:N_2 gas mixtures in the ratios 0:1:1, 0:4:1, 3:1:1, 3:1:2, 12:4:1, 8:1:1, and 1:1:1. Measurements were made in a pulsed e-beam sustained discharge at electric field strengths in the E/N range 2 to 20 Td, and at gas pressures between 100 and 600 torr. For the two mixtures containing only N_2 and CO_2 the separate effects of two and three body recombination were inferred from the pressure dependence of the recombination rate. No such pressure dependence was observed for any of the mixtures containing helium.

GA-6 Origins of Photoionisation in CO_2 TEA Lasers,* S.J. SCOTT and A.L.S. SMITH, Strathclyde U. Scotland, UK --In sealed CO_2 spark preionised lasers the preionisation is largely due to photoionisation of NO and NO_2[1], in seeded TEA lasers it originates from the low ionisation potential additive used[2]. Unseeded and flowing gas lasers can still be successfully preionised but the source of this preionisation has remained a mystery; previous attempts to isolate and identify low I.P. gaseous impurities have failed[3]. We have now identified these, using mass spectrometry with cryogenic impurity concentration techniques, and found them to be a complex mixture of hydrocarbons (C_2-C_7). Of these hydrocarbons, the alkenes are found to be predominantly responsible for the photoionisation and are present in concentrations ~0.2 ppm.

*Work supported by SERC and Barr and Stroud.

[1]S.J. Scott and A.L.S. Smith, Appl. Phys. Lett. 41, 783 (1982).
[2]D.C. McKen, H.J. Seguin and J. Tulip, IEEE J. Quantum Electron. QE12, 470 (1976).
[3]R.V. Babcock, I. Liberman and W.D. Partlow, IEEE J. Quantum Electron. QE12, 29 (1976).

GA-7 Performance of Wall Ballasted Dielectric Electrodes for Large Volume CW CO_2 EDL's,* M.J. YODER, D. G. YOUMANS AND J. P. REILLY, W. J. Schafer Associates, Wakefield, MA, B. H. BURZLAFF, J. S. CHIVIAN AND A. B. WELCH, Vought Corporation, Dallas, Texas -- Large volume CW laser discharges (e.g., 5-10 cm x 5-30 cm x L) can be obtained without external ionization sources by use of distributed ballasting along the electrodes. There are three drawbacks to this type of device. (1) wall-ballasted electrode designs are often bulky and complex, (2) power losses in the ballast can be large and (3) cathode-fall energy deposition is a significant loss at the low pressures characteristic of these devices (10-75 torr) and results in a thick thermal boundary layer.

We report experimental results using simple electrodes which are coated with a dielectric material. This design addresses the above drawbacks. (1) the dielectric electrode is simple, (2) reactive ballast power loss is $\leq$ 0.1% and (3) measurements show that these electrodes at 50 KHz result in a decrease in the total anode + cathode-fall power loses by a factor of about two compared to metal electrodes at 10 KHz discharge pumping frequencies.

* This research supported by the Air Force Wright Aeronautical Laboratory, the Vought Corporation and W. J. Schafer Associates.

GA-8 Scaling Experiments with a 60 Liter Self-Sustained CO_2 Laser Discharge,* M. J. PECHERSKY, J. F. ROACH, R. J. SPREADBURY and R. V. BABCOCK, Westinghouse R&D Center--A series of scaling experiments have been performed on a 60 liter, UV-preionized self-sustained CO_2 laser discharge. The electrode gap was 15 cm; the discharge was 22.5 cm wide by 178 cm long. A planar array of 1440 sparks located behind a grounded screen anode was used as the preionization source. Typical operating parameters were: 1:7:8-CO_2:N_2:He at 800 Torr; pulse width of 8 μsec and energy loadings of approximately 200 J/liter-atm. The measured current and voltage waveforms are consistent with previous subscale experiments.[1] Experiments have also been performed with a 1:14:0.5-CO_2:N_2:H_2 gas mixture. This helium free mixture operates at about a 50% higher glow voltage.

* Supported by DoD Contract DAAH01-81-A914 from the U.S. Army Missile Command.

[1] M. J. Pechersky and R. J. Spreadbury, "Performance Measurements of an 8 Liter Self-Sustained Discharge TEA Laser," 35th GEC Paper K-1.

GA-9 Travelling Wave Excitation of Helical TE N_2 Laser, S.H. CHANG, S. MATSUMURA and S. TEII, Musashi Institute of Technology, Tamazutsumi, Setagaya-Ku, Tokyo, Japan. --Travelling wave excitation has been achieved in a helical TE N_2 laser with a capacitor transfer pulse generator. The helical electrode system was first used by K.H.Krahn[1] to obtain a homogeneous and circulary symmetric beam output from a pulsed TE N_2 laser. We have applied this type of discharge to the laser of travelling wave excitation by dividing the discharge into ten sections. The helical electrode system of each section consists of ten pairs of 10 Ω resistor with a dumping capacitor. The total length of the discharge is 50 cm. The discharge time interval between sequent section is controlled by the coaxial cable length. The primary experimental results show that the output in the direction of the travelling wave is at least 2 times that in the other direction over a range of 40~80 Torr. Theoretical calculations of the laser output for this type of excitation have been also done for comparison.

1. K.H. Krahn, J. Appl. Phys., 50, 6656 (1979).

SESSION GB

1:15 p.m., Wednesday, October 12, 1983

ARCS II

Chairperson: G. FRIND

G. E. Research and Development Center

GB-1 Arc in Convection-- Formulation. B.K. CHOUDHURY, G.E., and I.M. COHEN, U. of Penna.--The thermal and electrical characteristics of a high temperature arc confined in a straight tube have been investigated. It is assumed that a steady stream of cold gas enters the tube. The gas mixes with the arc and leaves the arc region. The wall of the tube is held at a constant temperature . The purpose of the study is to understand the effect of convection on the arc behavior. For the axisymmetric arc in a one-dimensional electric field, the governing equations were written in terms of streamfunction,vorticity and temperature. Axial conduction, work of compression and viscous dissipation terms have been retained in the formulation. In order to investigate the effect of inlet conditions on the arc performance, a polynomial type of boundary conditions have been incorporated. By varying the index of the polynomial a wide class of velocity and temperature conditions may be prescribed. Property variations with temperature have been allowed. Numerical solutions to the full elliptic equations are obtained by the Galerkin method. It is shown that due to ill-conditioning of the resulting matrices some care is necessary in obtaining the solutions.

GB-2 Arc in Convection -- Results. B.K. CHOUDHURY, G.E., and I.M. COHEN, U. of Penna.--The effects of axial convection on an arc confined in a tube were investigated. It was found that the heat transfer to the wall increases as the inlet temperature or inlet velocity profiles are varied from parabolic to a uniform profile. The axial velocity and mass flow in the tube were found to have "M-shaped" profiles. Starting from the centerline, the profiles decrease steadily up to one-third of the tube radius, then increase for the next third, reach another peak, and then rapidly fall to zero at the wall. The degree of distortion depends upon the arc current, Reynolds number and the entry conditions. As the flow Reynolds number increases, more heat is removed from the arc, and consequently, the arc volume shrinks. The current-voltage characteristic thus depends also on the Reynolds number, the higher the Reynolds number the higher would be the power required to sustain the arc. An important aspect of the work is a comparision between a plug flow solution and the full Navier-Stokes solutions. The plug flow solutions were found to overestimate the temperature by about 15-20%. This disagreement is greater in the Nusselt and in the current-voltage characteristics.

GB-3 Experimental and Theoretical Results for Low Current D.C. Arc in Various Nozzle Geometries*, H.T. Nagamatsu and H. Whang, Rensselaer Polytechnic Institute. To increase the basic knowledge concerning the interaction between the arc near current zero and cold flow, investigations were conducted to determine the D.C. arc characteristics for a current of approximately 100 A in various nozzle geometries. Conservation of mass and energy were applied to a differential slice of arc utilizing a channel flow model with a constant arc temperature of 20,000°K. Analytical expressions were derived for the arc radius, electric field strength, arc voltage, resistance, and power as functions of the cold flow properties, current and axial distance. The calculated results agreed well with the experimental measurements. It can be concluded that the convection cooling of the arc is the dominant arc cooling process for low currents.

* Work supported in part by General Electric Corporate Research and Development and Electric Power Research Institute.

GB-4 Thermal Boundary Layer and Arc Column in Pulsed Plasmas*, N. BRATES, J. RAVI, and D.M. BENENSON, State University of New York at Buffalo--The radial distributions of temperature within the thermal boundary layer and the sizes of the thermal layer and arc column have been obtained for a 8.8 bar, abs., single flow, pulsed air plasma. An orifice nozzle, 12.7mm throat diameter, was employed; distance between the upstream electrode and the nozzle was 9.7mm. The sinusoidal current pulse contained a peak of 2kA and a slope of 15A/μs at current zero. The present work, emphasized the determination of these variables (1) downstream (3.5mm) as well as upstream (5mm) of the nozzle throat and (2) during arc extinction as well as prior to current zero. Upstream of the throat, during arc extinction, the size of the residual column decreased monotonically with time; at 97μs after current zero, the diameter of the residual column was 0.9mm. Initial measurements downstream of the throat indicated the column to be 2.5mm diameter at 1150A, 1.4mm diameter at current zero with column to thermal layer area ratios of 0.5 and 0.18, respectively.

* Research supported by National Science Foundation Grants CPE 8008101 and CPE 8007187 and Electric Power Research Institute Contract RP 246-2.

GB-5 Temperature at Lower Currents in a Pulsed Air Arc*, S. AGGARWAL, J. RAVI, and D.M. BENENSON, State University of New York at Buffalo--Experiments have been carried out to determine the space (radial) and time-resolved temperature distributions at the stagnation point of a 22.7 bar pulsed air arc. A dual flow orifice nozzle arrangement, having a throat diameter of 12.7mm and nozzle spacing of 7.6mm was employed. The sinusoidal current pulse had a peak value of 2kA with a slope of 15A/μs at current zero. Continuum radiation at 508.4nm was monitored. Radiation data were obtained from about 30μs (∿ 400A) before current zero to around 2μs after current zero (during arc extinction). At current zero, the centerline temperature was about 13000K, with a rate of decay of 400K/μs; arc diameter was 2.2mm. Calculations of temperature, according to the one-dimensional model of Tuma, were within about 15% of the experimental results. Computed arc diameters, however, were smaller than experiment - by a factor of around two.

*Research supported by National Science Foundation Grant CPE 8008101 and Electric Power Research Institute Contract RF 246-2.

SESSION HB

2:10 p.m., Wednesday, October 12, 1983

ARCS III

Chairperson: E. BARRETO

ASRC, State University of New York

HB-1 Anomalous High Current Behavior in an E-Beam Controlled Switch,* A. J. Palmer, R. J. Harvey, H. E. Gallagher, Hughes Research Laboratory --This paper covers issues raised during an experimental study of the performance of an electron beam controlled switch (EBCS). Experimental studies were carried out using an electron beam generated by a wire-anode-plasma electron-gun (WIP e-gun) as the ionization source for a small (64 cm^2) switch discharge through several gas mixtures. Switch current densities in excess of 10 A/cm^2 were measured in methane gas at current gains of about 600, for switch voltage drops of less than 2 kV. Our theoretical studies, as well as earlier theoretical studies reported in the literature, predict switch current densities at least a factor of three below the values we have measured for external ionization rates of $> 2 \times 10^{18}$ cm^{-3}. One explanation to be offered for the high current anomaly is based on avalanche ionization of e-beam-produced metastables.
*Work supported in part by the Air Force Wright Aeronautical Laboratories.

HB-2 Experimental Study of Parameters Determining the Characteristics of an Electron-Beam Controlled Switch,* H.E. GALLAGHER, R.J. HARVEY, A.J. PALMER, Hughes Research Laboratories -- Experimental studies were performed using an electron beam generated by a wire-anode-plasma-electron gun (WIP e-gun) as the ionization source for a small (64 cm^2) switch discharge. Gasses used for the switch discharge include nitrogen, methane, and methane with trace amounts of attaching gasses. Measurements were made for gas pressures up to 3 atmospheres. Ionization-current densities up to 25 $mA\text{-}cm^{-2}$ and lasting for over 100 μs were used. Switch-current densities in excess of 10 $A\text{-}cm^{-2}$ were measured in methane at current gains of ~600, and switch-voltage drops of $\lesssim$ 2 kV. Measurements of the rise and fall times of the switch current confirm that fast (μs) current-rise and fall times can be obtained using methane gas mixed with trace amounts of attaching gasses.

*Work supported in part by Air Force Wright Aeronautical Laboratories.

HB-3 The Effect of an Attacher with a Rate, Increasing with E/N on the Performance of an Electron Beam Sustained Discharge Switch-Theoretical Considerations, G. Schaefer, K.H. Schoenbach, H. Krompholz, M. Kristiansen, Texas Tech University*, Lubbock, Texas, and A.H. Guenther, AFWL, Kirtland AFB, New Mexico.--Calculations are presented, showing that an attacher with a rate increasing with E/N in an e-beam sustained discharge can produce discharge bistabilities in specific circuits. As an example, N_2 with admixtures of N_2O is discussed. Steady state characteristics are presented for a set of different discharge parameters. The transient behavior during switch closing and opening is calculated for different discharge and circuit parameters. Additional control mechanisms are discussed to improve the transient behavior.

* Supported by AFOSR and ARO

HB-4 Quasi Stable Operation of Hg/He Ebeam Preionized Discharge,* A. Mandl and M.W. McGeoch, Avco Everett Research Laboratory --The I/V characteristics of an electron beam preionized quasi stable discharge in Hg/He mixtures have been determined. Pulse durations of several microseconds for discharge electric fields of several KV/cm have been observed. A comprehensive kinetic model of the Hg/He self-sustained discharge has been developed. A Bolzmann solution is used which includes both inelastic and superelastic collision processes between all possible pairs of the neutral Hg states. Molecular Hg formation is included. The model has provided a detailed picture of the volumetric arcing mechanism which compares well with the experimentally measured energy loading. The largest source of ionization just prior to arcing is a three-step channel.

*Work supported by Ballistic Missile Defense Systems Command.

HB-5 Conductivity Measurements in High Pressure Air Afterglows,* D. J. ECKSTROM and J. S. DICKINSON, SRI International--A transient microwave cavity perturbation technique is being used to measure both the real and imaginary conductivity decay histories in air following excitation by a Febetron 706 pulsed electron beam (600 keV, 5000 A, 3 ns). The cavities used are sensitive to conductivities in the range 10^6-10^8 sec^{-1}; the plasma decay rates are such that these conductivities occur in time scales from microseconds at 1 atm to milliseconds at 10 torr. Decay rates follow approximately a p^{-2} dependence for $p \gtrsim 100$ torr, and a p^{-1} dependence at lower pressures. Decay rates in laboratory (humid) air are 4 to 8 times higher than in dry air. Combining of the real and imaginary components of conductivity give electron density and collision frequency histories, with electron temperatures deduced from the later parameter. The high pressure results indicate that the conductivity is due to ions rather than electrons. Results will be compared with the air chemistry model of A. W. Ali of the Naval Research Laboratory.

*Work supported by DARPA ONR Contract N00014-81-C-0208.

SESSION I

9:00 a.m., Thursday, October 13, 1983

CORONA

Chairperson: R. A. DOUGAL
University of South Carolina

I-1 Two-Dimensional Numerical Simulation of Space-Charge-Controlled Transport at High Charge Densities,* S.K.Dhali and P.F.Williams, Texas Tech -- Streamers (ionizing wavefronts) and other space-charge-controlled transport phenomena play an important role in many aspects of electrical breakdown of gases. Quantitative modelling (either analytical or numerical) of these phenomena has proven quite difficult, and as a result there are many long-standing, fundamental questions in this area still unresolved. We present here the results of applying the flux-corrected transport (FCT) technique to the numerical modelling of these phenomena. This technique has allowed us to successfully model streamer propagation in a two-dimensional calculation with high free charge density (10^{14} cm^{-3}). We will describe the FCT algorithm and discuss the results of numerical simulations carried out with it. To our knowledege this represents the first application of FCT techniques to two-dimensional problems of this type.[1]

*Work support by AFOSR.

[1]For a discussion of the application of FCT algorithms to one-dimensional problems see R.Morrow and J.J.Lowke, J.Phys. D 14, 2027 (1981).

I-2 Production of SOF_2 and SO_2F_2 in SF_6/H_2O Mixtures by Corona Discharges,* R. J. VAN BRUNT, T. C. LAZO, and W. E. ANDERSON, National Bureau of Standards -- The production rates of SOF_2 and SO_2F_2 for point-to-plane corona discharges in SF_6 containing trace quantities of water vapor at total gas pressures from 50 to 300 kPa have been measured quantitatively with a gas chromatograph-mass spectrometer. Pressure, polarity, and discharge power dependences of these rates have been investigated. For a given polarity and gas pressure, the production rates tend to decrease with increasing discharge power, but are nearly proportional to the current. Discharge currents in the range of 1.5 to 64 μA were considered. The production rates for both species increase with time, or equivalently with total energy dissipated in the discharge, and approach values between 0.1 and 5.0 n moles/J. Variations in the H_2O concentrations during discharge operation were monitored and are discussed in terms of competing factors that determine equilibrium including expected reactions leading to HF, SOF_4, SOF_2 and SO_2F_2 formation.

*Supported by U. S. Department of Energy

I-3 Self-Consistent Mathematical Model for Steady Point-Plane Corona Discharges, B. L. HENSON, Dept. of Physics, U. Missouri-St. Louis--Starting with the steady-state current continuity equation combined with the time-independent Maxwell's equations, a solution for the steady corona current density in terms of a vector potential is obtained for the space-charge region. The analysis yields the electric field and potential distributions in the space-charge region in terms of quadratures which results in a mapping of the predicted equipotentials and field lines. The theory also predicts the characteristic relation for the steady corona current which is shown to vary as the square of the potential drop across the region containing the space charge. This solution, which satisifies all the boundary conditions, is shown to be consistent with a Warburg's law where the current density at the plane electrode varies as the fifth power of $\cos\theta$. Furthermore, the solution satisfies the power balance equation which is necessary for consistency with conservation of energy. The theory is shown to be valid for corona discharges whose space-charge distributions have either finite or infinite bounds.

I-4 Corona discharge under a packed solid particle condition, J. S. Chang and H. YOSHIDA, Dept. Eng.Physics McMaster Univ., Canada -- The studies of the charge density ρ_c and the electric field E profiles between parallel electrode with a packed dielectric particle under the corona discharge condition has been studied both theoretically and experimentally. The charge transport equation was solved together with the Poission's equation analytically in a 1-D condition. The results yield $\rho_c E=I/\mu_c A$ and $E^2=2Iz/\mu_c\varepsilon_\phi A + S$ when $\mu E/U_g>1$, where μ_c is the ion modibility, ε_ϕ is the two-phase dielectric constant, A is the surface area of electrode, I is the corona current and S is the function dependent only on discharge current-voltage characteristics which determine through experimentally. Experimental studies have been conducted in humidity free environment under flowing pure Nitrogen gas at atmospheric pressure. The results covers for the gas velocity from 0 to 30cm/sec., the electrode gap distance from 1 to 20 cm, the particle size from 40 to 4000 μm in N_2 gas.

I-5 Discharge development in high pressure SF_6 in a three-electrode system, F. PINNEKAMP, BBC-Brown Boveri research center, Baden, Switzerland -- Leader propagation in SF_6 in a large coaxial three electrode system at a voltage of about 1 MV is observed by time and spatial resolved electrooptical measurements. The jerkily propagation of the discharge with time steps between 5 ns and 20 ns is clearly observed. It is shown that the branching of the discharge is essential for the development in the three electrode gaps. The influence of the electrode geometries and the voltage pulse form can be understood from model description of the leader discharge [1,2].

[1] L. Niemeyer and F. Pinnekamp, J.Phys.D: Appl. Phys. 16 (1983) 1031-1045.

[2] F. Pinnekamp, 4th Int. Symp. High Voltage Engin., Athens 1983, paper 31.04.

SESSION J

10:30 a.m., Thursday, October 13, 1983

BREAKDOWN

Chairperson: T. M. PROUD
GTE Labs.

J-1 Formation and Decay of Nanosecond Discharges in Electron Attaching Gases,* W.W. BYSZEWSKI, M.J. ENRIGHT, J.M. PROUD, GTE Labs, Inc., Waltham, MA -- Experimental and theoretical investigations of the formation and decay of transient electrical discharges in electronegative gases will be reviewed. Phases of the discharge to be discussed include: the formation period, the period of voltage collapse, the phase where the electron production is balanced by electron attachment loss, the transition from glow to arc discharge conditions, and the decay of the plasma after the applied voltage has been terminated. Different electrical properties of molecular gases can be deduced from studies of each of these phases. Experimental results obtained in a pulse transmission line system in several attaching gases and in nitrogen will be presented. Two simple theoretical models have been developed to predict current waveforms and good agreement with experimental data has been achieved for the first three phases of the discharge. Later phases will require more complex modeling.

*Work supported in part by the Office of Naval Research and by the Naval Surface Weapons Center.

J-2 Stochastic Models for Avalanche Breakdown in Gases, D. M. Cap, General Electric Co. LBG -- Although potentially very useful, the mathematical theory of stochastic processes has played a minimal role in the analysis of gas discharge physics and chemistry problems. In this paper the usefulness of the theory is illustrated by constructing a model which is a generalization of the theory normally used in the analysis of Townsend discharge experiments. With a model based upon a blend of Galton-Watson and Bellman-Harris branching processes, both the usual and the unusual observations, reported in the studies utilizing the current multiplication and light flux measurement methods to estimate the first and second Townsend ionization coefficients in rare gases, are readily described.

J-3 Computer Simulation of the Growth of Transient Gas Discharges, K.C. CHUNG, W.W. BYSZEWSKI, GTE Labs, Inc. -- Development of fast gas discharges between plane-parallel electrodes were numerically modeled using the method of characteristics. The simulation model for nitrogen was based on the continuity equations for electrons, positive ions and on Poisson's equation. The axisymmetric system was solved with boundary conditions governed by the circuit equation and by secondary processes on electrodes. The electron and total charge densities were integrated in time along the characteristic curves for electrons. Backwardly directed characteristics were used for most of the problem domain except the electron front where the spatial gradient of electron density may be sharp. This work is an extension of the authors' previous upwind finite difference scheme[1] which gave a stable solution but with the effect of numerical diffusion. A comparison will be made between these approaches and with Davies' et al.[2] method of characteristics.

[1]W.W. Byszewski, K.C. Chung, J.M. Proud, GEC 1982, Bulletin APS, V. 28, N. 2, 186 (1983).
[2]A.J. Davies, C.J. Evans, P. Townsend, P.M. Woodison, Proc. IEE, V. 124, 179 (1977).

J-4 Laboratory Studies of Beam Plasma Discharges,* B.D. GREEN, L.G. PIPER, E.R. PUGH, Physical Sciences Inc. W.A.M. BLUMBERG, Air Force Geophysics Laborary -- Although BPD was recognized over twenty years ago, it is not currently understood quantitatively. A series of experiments conducted at the NASA Johnson Space Center, in which the threshold for BPD was empirically correlated to experimental parameters has provided theoretical understanding. We present here our recent experiments on the LABCEDE facility located at the Air Force Geophysics Laboratory. Using optical fluorescence as our primary diagnostic, we have obtained thresholds for and quenching of the BPD over a wide range of parameters including pressure, voltage, current, applied magnetic field and gas composition. The UV-visible spectrum varies significantly with excitation conditions. Correlations with previous studies and theory will be presented.

*Supported by the Air Force Geophysics Laboratory through Contract #F19628-80-C-0168.

J-5 Fundamental Processes in Laser-Triggered Electrical Breakdown,* R.A.Dougal** and P.F.Williams, Texas Tech, -- Diagnostics of coaxial, laser-triggered (Nd:YAG, 1.06μ), electrical breakdown in nitrogen have shown a laser-assisted streamer propagating from the laser fireball to the opposite electrode. Streak photography shows that the streamer propagates initially at about 10^8 cm/sec, but slows to about $2x10^7$ cm/sec as it advances in the focal cone to regions of lower laser intensity. Two distinct regions can be detected in the spark channel: one laser-assisted, showing an abrupt, uniform appearance of continuum luminosity, and the other not laser-assisted, appearing much like a weakly overvolted breakdown process.[1]

*Work supported by AFOSR.

**Present address: Dept. of Elect. Eng., Univ of South Carolina, Columbia, SC 29208.

1 A.A.Doran, Z.Physik 208, 427 (1968).

J-6 TIME CONSTANTS ASSOCIATED WITH GASEOUS RECOVERY R. N. DEWITT Naval Surface Weapons Center--In the post-discharge phase of gaseous spark gaps, the dielectric strength of the gas is increasing due to cooling, charge particle recombination and metastable decay. If the spark gap is operating in a repetitive-pulse mode, then succeeding pulses see a heated region of gas in the plasma state. To circumvent writing a breakdown criterion for such a complex state, a time dependent expression is obtained for the percent recovery in terms of time constants associated with the physical processes.

J-7 Mass Spectrometry of Gaseous Breakdown, D.L. SWINGLER, CSIRO Division of Chemical Physics, Australia.--The precursor ionic speciès involved in avalanche ion-pair production have been identified by nanosecond mass spectrometry in high and low pressure transient discharges. Ions were sampled from the high pressure, 1 mm, cell in a mass spectrometric facility with three stages of pumping. The discharge cell could be maintained in a non-discharge state at overvoltages proportional to the p.d values remote from the Paschen minimum and then triggered at will by radiation to discharge a capacitor within 80 ns. This period was shorter than the ion transit time to the cathode and hence eliminated secondary ion emission from the extracted ions. The precursor ion yield from the low pressure Penning arrangement was sampled directly in a compact facility and again was triggered by an adjacent source of Hg 1849 Å radiation. The ion currents on selected species were integrated over some hundreds of firings to reveal the presence of Na^+ and K^+ as those ions involved in the precursor "α" avalanche processes existing between the moment of breakdown and the fall to a position on the Paschen curve.

SESSION KA
1:30 p.m., Thursday, October 13, 1983

EXCITED STATES, LIFETIMES, AND QUENCHING

Chairperson: J. STEVEFELT
Universite d'Orleans

KA-1 Determination of Number Densities of Metastable Atoms Produced by Electron-Beam Excitation,* J. E. GASTINEAU, M. H. PHILLIPS, L. W. ANDERSON, and CHUN C. LIN, U. of Wisconsin-Madison--Using the technique of laser-induced fluorescence we have developed a method for measuring the number densities of metastable atoms produced by electron-beam excitation. Neon atoms are excited by an electron beam to the $1s_5$ metastable level ($2p^5 3s\ ^3P_2$) and a N_2-driven dye laser pumps the metastable atoms to the $2p_2$ level ($2p^5 3p$, J=1). Measurement of the transient component of the $2p_2 \rightarrow 1s_2$ ($2p^5 3s$, J=1) emission after cessation of the laser pulse enables us to determine the metastable-atom number density. By combining the number density data with the previously measured excitation cross sections we obtain the effective lifetime for the metastable atoms. Similar experiments are performed for the $1s_3$($2p^5 3s\ ^3P_0$) atoms. At 35 mTorr radiation trapping increases the lifetime of the $1s_2$ and $1s_4$ ($2p^5 3s$, J=1) atoms sufficiently so that their number densities can be determined by the same method.

*Supported by the Air Force Office of Scientific Research.

KA-2 Radiative Lifetimes of Electronically Excited Rare Gas Dimers by Neutralized Ion-Beam Spectroscopy,* GREGORY I. GELLENE, N. KLEINROCK SCHNEIDER, RICHARD F. PORTER, Cornell Univ. -- Radiative lifetimes of electronically excited rare gas dimers (X_2, where X = He, Ne, Ar) were measured by the technique of neutralized ion-beam spectroscopy. A fast beam of rare gas dimer ions was neutralized in the near-resonant electron transfer reaction

$$X_2^+ + K \rightarrow X_2^* + K^+$$

where X_2^* represents a metastable electronic state of the neutral dimer. Evidence that neutral dimers decay by radiative emission is obtained from measurements of the kinetic energy released in the products of dissociation. From the fraction of molecules undergoing dissociation during their flight time, the radiative lifetimes were obtained. For the species Ar_2^*, Ne_2^*, and He_2^*, the lifetimes were found to be 1.5, 3.5 and >1.5 μsec, respectively.

*Work supported by The National Science Foundation

KA-3 Determination of the Quenching Rates of $N_2^+(B^2\Sigma_u^+$ v=0,1) by N_2. J. JOLLY, A. PLAIN and A. RICARD, Lab. Physique Plasmas, Univ. Paris-Sud, 91405 ORSAY-FRANCE.--Time resolved fluorescence laser induced spectroscopy was used to determine the quenching of the vibrational levels v=0 and v=1 of $N_2^+(B^2\Sigma_u^+)$ by N_2. N_2^+ ions, created in a d.c. discharge, were selectively excited to the electronic state $N_2^+(B^2\Sigma_u^+,v)$ by a nitrogen pumped dye laser. Time-resolved measurements were obtained by a fast multichannel event counter (3.5 ns per channel). The rate coefficients of the quenching reactions for the v=0 and v=1 states are reported to be (8.2 ± 1.2) and (15 ± 2.3) $10^{-10}cm^3s^{-1}$ respectively and are observed to be constant over the temperature range 300-500 K.

KA-4 VUV-Emissions from Condensed Rare Gases Bombarded with Metastables, G. NOWAK and J. FRICKE, Phys. Inst. Univ. Würzburg, W.-Germany
Ar, Kr and Xe were condensed onto a cooled (T = 15 ... 77 K) surface and bombarded with the metastables $Ar(^3P_2)$, $Kr(^3P_2)$ and $Xe(^3P_2)$. VUV-emissions of the well-known excimers Ar_2^*, Kr_2^*, Xe_2^* and $KrXe^*$ were detected by a spectrograph. Bombardment of condensed Xe with $O(^5S)$ only produced the Xe_2^* -emission. Thus the existence of a bound $XeO(^5\Sigma)$-state is very unlikely. For the first time, we detected the heteroatomic excimers $ArXe^*$ and $ArKr^*$ with binding energies of 30 meV and 160 meV, respectively. (The correlation of a 135 nm-emission with $ArKr^*$, suggested by Verkhovtseva et al.[1] is contradicted by our results.)

Work supported by Deutsche Forschungsgemeinschaft.

[1] E. T. Verkhovtseva, A. E. Ovechkin, Y. M. Fogel', Chem. Phys. Lett. 30, 120 (1975).

KA-5 Electronic energy transfer between state selected rare gas metastable atoms and some atoms and simple molecules, N. Sadeghi, T.D. NGuyen, T.D. Dreiling and H. Ben Kraiem, Laboratoire de Spectrométrie Physique, Université Scientifique et Médicale de Grenoble, France. We report several results concerning the excitation of some atoms (H,Kr,O) and molecules (N_2,H_2,O_2) by state selected ($^3P_2$ and $^3P_0$) argon and neon metastable atoms. The experiments were conducted in the afterglow of a pulsed low pressure rare gas-reagent (≃ 0.01%) discharge in a cell or with a flowing afterglow apparatus. A CW tunable dye laser was used to selectively depopulate one of the metastable levels by optical pumping technique[1] and the products state of the reagent, excited by collision with the left over metastable species, were observed by the emission spectroscopy. Comparison of emission intensities from excited states was used to assign relative rate constants for excitation by $^3P_2$ and $^3P_0$ metastable atoms. In some cases a very large difference between the reaction products of two metastable species was observed. For exemple in Ar*-Kr collision the total reaction rate of Ar*($^3P_0$) is 40 times slower than for Ar*($^3P_2$). Simple curve-crossing models are involved to explain experimental results. 1. J. Derouard, T.D. NGuyen and N. Sadeghi J. Chem. Phys. 72 (1980) 6698.

KA-6 Infrared Spectra (2-16 μm) of Ar I Rydberg Emission from a Microwave-Discharge Plasma,* W.T. RAWLINS, A. GELB, and L.G. PIPER, Physical Sciences Inc., and R.A. ARMSTRONG, Air Force Geophysics Laboratories -- Infrared (2 to 16 μm) emission from atomic Ar Rydberg atoms, excited in a conventional low-pressure microwave discharge plasma, has been observed in the cryogenic COCHISE reactor/spectrometer facility. The observed spectrum is very complex but is identifiable using the detailed energy level structure and optical selection rules for ArI. Detailed transition probabilities for dipole-allowed transitions between 2 and 16 μm were computed using the Coulomb approximation. Comparisons of observed and predicted spectra show that substantial LWIR emission (~ 12 μm) arises from Rydberg states near the ionization limit; these states must have kinetically enhanced populations in order to account for the observed emission intensities. The results are interpreted in terms of a radiative/collisional cascade sequence initiated by dissociative recombination of Ar_2^+ with energetic electrons in the active discharge.

*Sponsored by the Air Force Geophysics Laboratories through contract #F19628-82-C-0050.

KA-7 Products from Microwave Discharges in N_2O/Ar,* L.G. PIPER and W.T. RAWLINS, Physical Sciences Inc. -- We have studied the products of Ar/N_2O microwave discharges using discharge-flow techniques. For N_2O feed rates below 10-20 μmol s^{-1}, the discharge converts about 75% of the N_2O to atomic oxygen, and in addition produces small quantities of atomic nitrogen. At higher N_2O feed rates the O-atom production efficiency decreases, and nitric oxide accompanies the O-atoms out of the discharge. The N_2O feed rate at the cross-over between N and NO production is a function of the discharge power, and the Ar/N_2O mixing ratio. Molecular nitrogen in the discharge eliminates NO product, but with a reduced O-atom production efficiency. We have developed a kinetic model of the discharge which reasonably well reproduces our experimental observations only if the electron-impact dissociation of the N_2O in the discharge proceeds through a spin-forbidden channel to produce $O(^3P)$, and if, in addition, about 20% of the N_2O dissociations result from collisions between metastable argon atoms in the discharge and N_2O.

*Sponsored by the Air Force Geophysics Laboratories through contract #F19628-82-C-0050.

KA-8 Quenching of N_2^+ ($A\ ^2\Pi_u$) v' = 2, 3, and 4 by Air and v' = 2 by Nitrogen and Oxygen,* L.G. PIPER and B.D. GREEN, Physical Sciences Inc., and W.A.M. BLUMBERG and S.J. WOLNIK, Air Force Geophysics Laboratory -- We have used a Stern-Volmer technique, to measure the rate coefficients for quenching the Nitrogen Meinel bands by air, nitrogen and oxygen. The ratio of the intensities of the nitrogen first-negative band at 391.4 nm to the various Meinel bands was monitored as a function of pressure (≤ 10 mtorr) in a large vacuum tank. An electron gun (3-6 kV, 5-20 mA) was the excitation source. The rate coefficients for quenching by air are (7.0 ± 0.4), (7.5 ± 1.0), and (7.0 ± 1.0) x 10^{-10} cm^3 $molecule^{-1}$ s^{-1} for vibrational levels 2, 3 and 4, respectively. Nitrogen and oxygen quench vibrational level 2 with rate coefficients of (7.5 ± 0.8) and (6.2 ± 0.6) x 10^{-10} cm^3 $molecule^{-1}$ s^{-1}, respectively.

*Supported by the Air Force Geophysics Laboratory Through Contract #F19628-80-C-0168

SESSION KB

1:30 p.m., Thursday, October 13, 1983

ARCS IV

Chairperson: H. P. STORMBERG

Philips GmbH Forschunglaboratorium

KB-1 Modeling of Plasma Bore-Filling in Xenon Flashlamps, M. J. KUSHNER, Lawrence Livermore National Laboratory* -- Experimental results have shown that the arc in a pulsed xenon flashlamp does not completely fill the bore. A radiative-hydrodynamic-electron kinetics model which describes a pulsed xenon arc has been developed to study this issue. Arc filling fractions calculated with the model decrease with increasing fill pressure, decreasing energy loading, and are dependent on the location of the breakdown filament. Axial variations in light output from the flashlamp are found to be a result of the random location of the breakdown filament. The off-axis location of this filament also accounts for asymmetric deposition of energy in the walls of the tube.[1] This asymmetric loading causes strain on the flashlamp envelope and may limit the scaling of lamps to very large diameters.

(1) L. P. Bradley, A. E. Orel, and H. T. Powell, paper CA-5 35th Gaseous Electronics Conf., 1982.

*Work performed under the auspices of the U.S. Dept. of Energy by Lawrence Livermore National Laboratory under Contract No. W-7405-ENG-48.

KB-2 Radiation Decay Times from Pulsed Xenon Arcs, M. J. KUSHNER, A. E. OREL AND H. T. POWELL, Lawrence Livermore National Laboratory* -- For an arc in LTE, the radiation decay time is a measure of the thermodynamic state of the plasma. This time was measured for a pulsed xenon arc (FWHM of current $\sim$ 500μs) by quickly terminating the discharge with an ignitron switch. The decay time of radiation as measured by a broad-band pyroelectric detector was found to vary from 20μs to 50μs. The decay time was a more-or-less unique function of instantaneous power deposition in the arc after a critical period of time had elapsed after breakdown. This delay behaves similarly to the hydrodynamic expansion time required for the arc to develop. The measured decay times were compared to a simple model which relates the energy content of the arc and its radiated power to the input electrical power.

*Work performed under the auspices of the U.S. Dept. of Energy by Lawrence Livermore National Laboratory under Contract No. W-7405-ENG-48.

KB-3 Characteristics of Large Bore Xenon Flashlamps,* L. P. BRADLEY and H. T. POWELL, Lawrence Livermore National Laboratory --We have investigated the performance of flashlamps over the range of bore diameters from 1 to 10 cm. The capacitance and inductance of a modular 1 MJ bank were selected so that the pulsewidth and pulseshape varied identically for each case with the ratio of the input energy to the calculated explosion energy. This explosion fraction typically ranged from 0.05 to 0.5. Using calorimetric techniques we closely bounded the overall radiant efficiency of each lamp. Since we are primarily interested in using very large flashlamps to pump Nd:glass fusion lasers, we also compared their efficiencies for Nd pumping.

*Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract W-7405-ENG-48.

KB-4 Temperature Measurements in the Anode Region of a High-Intensity Argon Arc,* K. ETEMADI and E. PFENDER, University of Minnesota--For studying deviations from LTE in atmospheric pressure argon arcs, temperatures have been measured in the anode region of such arcs (150A). From the Boltzmann plot and the assumption of PLTE electron temperatures may be derived using five argon lines (4259, 4300, 6871, 6965, and 7147 Å). The excitation and heavy particle temperatures are determined by combining the electron temperatures with the line and continuum emission coefficients measured at 4300 Å and 4312 Å, respectively, a three-temperature Saha equation, and the equation of state. Excitation temperatures are lower than the corresponding electron temperatures, but substantially higher than the heavy particle temperatures. In the arc core LTE temperatures are below the electron temperatures, but higher than the excitation temperatures. This trend reverses in the arc fringes.

*Work supported by NSF under CPE 80089500

KB-5 Frequency Dependence of the Pulsed High-Pressure Sodium Arc Spectrum, J.T. DAKIN, T.H. RAUTENBERG General Electric Corporate Research and Development-Spectral energy distributions are calculated and measured for a wall-stabilized high-pressure Na-Hg-Xe arc in pulsed operation. These and other quantities are studied as a function of the pulsing frequency over the range 60-6000 Hz for a 5.2 mm diameter channel with peak currents up to 10 amps, and a gas mixture of 70 torr Na, 340 torr Hg and 190 torr Xe. The fully time-dependent energy balance model assumes local thermodynamic equilibrium and one-dimensional cylindrical symmetry. The radiation transport calculation includes the effects of 28 Na lines in the visible and infrared, 20 of which are treated as optically thick. This work extends the model of Chalek and Kinsinger[1], and the experimental data of Johnson and Rautenberg[2].

1 C.L. Chalek and R.E. Kinsinger, J. Appl. Phys. 52, 716 (1981).

2 P.D. Johnson and T.H. Rautenberg, Jr., J. Appl. Phys. 50, 3207 (1979).

KB-6 Optogalvanic Detection of Acoustic Resonances in High-pressure Sodium Discharges, M.J. JONGERIUS and A.J.M.J. RAS, PHILIPS Research Labs, Eindhoven -- Modulation of the power supplied to high-pressure discharges may cause acoustic resonances inside the tube leading to arc instabilities[1] if the modulation depth exceeds a threshold value. We studied longitudinal acoustic resonances well below threshold using optogalvanic detection.[2] A dye-laser excites the resonances and the resulting changes in the discharge voltage are detected. The excitation strongly depends on the axial position of the laser beam. We developed a discharge model to derive the acoustic properties from this experiment. Combining the data so obtained with the instability threshold value the instability is calculated to occur for acoustic amplitudes in the ventral segments larger than about 5 kPa.

[1]H.L. Witting, J. Appl. Phys. 49, 2680 (1978).

[2]W.J. van den Hoek and J.A. Visser, J. Appl. Phys. 51, 5292 (1980).

KB-7 Optical determination of the mercury pressure in high pressure lamps, H.-P. STORMBERG and R. SCHÄFER, Philips GmbH Forschungslaboratorium Aachen/ Germany -- An experimental set-up is described which allows to determine the mercury pressure in high pressure lamps from the absorption of the frequency doubled 514.5 nm Ar^+ laser line (257.3 nm), which is absorbed by the mercury ground state (wing of the 253.7 nm resonance line). To get independent from physical constants as transition probability and broadening constant the set-up has been calibrated by measuring the absorption of mercury vapour with known pressure. Measurements on the frequency dependence of the pressure fluctuations in a 400 W high pressure mercury lamp are presented for sinusoidal as well as for pulsed supply voltages. Comparison of these measurements with results from a numerical model[1] yields good agreement.

[1]H.-P. Stormberg and R. Schäfer, to be published in J. Appl. Phys. 1983

KB-8 Hg & Na Pressures from the Maxima of the "D-Line" in a Na Arc. -P. A. Reiser and E. F. Wyner, GTE Sylvania Lighting Center, Danvers, MA 01923 - DeGroot & Van Vliet in a sodium-mercury vapor arc have related the pressures to the shifts of the maxima of the sodium resonance line $\Delta\lambda_B$, $\Delta\lambda_R$. Hiriyama measured activity coefficients of the amalgam in the range 771-889°K. We have extended the coefficients to the temperature range of DeGroot's pressure measurements. Vapor pressures were calculated as a function of temperature and related to the shifts $\Delta\lambda_B$, $\Delta\lambda_R$. Experimental measurements of $\Delta\lambda_B$ $\Delta\lambda_R$, agree to within 1% in amalgam ratio over the sodium molar fraction .51 - .75, 30 - 200 A overall separation. Best agreement would be obtained if the mercury pressures were 20% higher. In the literature values as much as 3 and 4 times greater have been reported for mercury pressure. The agreement of this work with the pressures determined from line broadening indicates that the Hirayama's data provides the best basis for calculation of vapor pressures in sodium arcs.

1. DeGroot J.J. and al, "Determination of the Sodium and Mercury Vapour Pressure in HPS Lamps" Second International Symposium on Light Sources, Enschede (1979).

2. Hirayama et al. Thermochemica Acta, 45, 23 (1981).

SESSION L

2:50 p.m., Thursday, October 13, 1983

POSTER II

Chairperson: H. JURENKA
ASRC, State University of New York

L-1 Triple-beam apparatus for electron impact experiments,* W.B. WESTERVELD, P. ZETNER, G.C. KING and J.W. McCONKEY, Physics Department, University of Windsor--A novel apparatus has been developed in which an electron beam from a hemispherical monochromator and a tunable nitrogen-laser-pumped dye laser beam run co-axially and are crossed by a pulsed supersonic gas jet. Metastable and photon detection channels probe the resulting interaction. Results will be presented on the optimum operation of the supersonic jet and on the use of the system to measure atomic and molecular lifetimes and to study excitation and deexcitation processes.

*Work supported by Natural Sciences and Engineering Research Council of Canada and N.A.T.O. Division of Scientific Affairs (RG220-80).

L-2 Two- and Three-Body Reactions of Atomic and Molecular Ions with Methane and Ethane at Near-Thermal Energies,* S. DHEANDHANOO, R. JOHNSEN, and M. A. BIONDI, U. of Pittsburgh -- A selected-ion-drift-apparatus (SIDA) and a variable-temperature drift tube have been employed for measurements of several ion-molecule reactions with methane and ethane. In the case of the fast reactions of N^+, H^+, and D^+ with CH_4 considerable variations of the product ion distributions with ion energy are observed, even though the total rate coefficients are nearly independent of energy (0.04 to 0.2 eV). In a second set of measurements, clustering of CH_5^+ and $C_2H_5^+$ to CH_4 was found to occur at low temperatures (80 to 130 K) with strongly temperature-dependent rate coefficients ($k\alpha T^{-3}$ to T^{-4}). Measured rate coefficients for several reactions of CH_5^+ and $C_2H_5^+$ with CH_4 and C_2H_6 will be presented also.

*Work supported, in part, by NASA.

L-3 Experimental Study of Ion Molecule Reactions at Elevated Temperatures and Atmospheric Pressures,* J.M. POUVESLE, A. BOUCHOULE and J. STEVEFELT, U. of Orléans, France, and C.B. COLLINS, Z. CHEN +, V. GYLYS, H. JAHANI, and R. SADIGHI-BONABI, U. of Texas at Dallas -- The resolution of options in the modeling [1] of ion molecule reactions requires a data base more extended in pressures and temperatures than has been previously published [2,3]. This work reports results obtained by extending techniques recently introduced [3] that exploit the large dynamic range and high data rates available from time resolved spectroscopic studies of preionized stripline discharges. First attention has been focused upon the reactions of He_2^+ with N_2 for comparison with theory [1].

* Supported in part by CNRS and in part by NSF Grants ECS 8018730 and INT 8116436.

+ Permanent address, Nanjing Technical Institute, PRC.

1 C.B. Collins, F.W. Lee, W.M. Tepfenhart, and J. Stevefelt, J. Chem. Phys., 78, 6079 (1983).
2 F.W. Lee, C.B. Collins, and R.A. Waller, J. Chem. Phys. 65, 1605 (1976).
3 J.M. Pouvesle, A. Bouchoule, and J. Stevefelt, J. Chem. Phys. 77, 817 (1982).

L-4 * Modeling of Ion Molecule Reactions at High Pressures, C. B. COLLINS and C. D. EBERHARD, U. of Texas at Dallas and J. STEVEFELT, GREMI, U. of Orléans, France-- Recent modeling of ion molecule reactions[1] has suggested that the dynamics of the complex formed from the initial encounter between the reactants may control the overall rate at which the products appear. At atmospheric pressures both coherent and incoherent collisional processes of excitation and deexcitation of the complex contribute substantially to the yield of products. A phenomenology is predicted that largely agrees with observations of termolecular rate coefficients for ion molecule reactions in the 10(-28) to 10(-30) $cm^6 sec^{-1}$ range.[2,3] A primary variable is the dependence of the energy transfer function upon parameters describing collisions with the complex.

*Supported in part by NSF Grants ECS8018730 and INT 8116436 and in part by CNRS.

1. C. B. Collins, F. W. Lee, W. M. Tepfenhart and J. Stevefelt, J. Chem. Phys. 78, 6079 (1983).
2. F. W. Lee, C. B. Collins, and R. A. Waller, J. Chem. Phys. 65, 1605 (1976).
3. J. M. Pouvesle, A. Bouchoule and J. Stevefelt, J. Chem. Phys. 77, 817 (1982).

L-5 A Generalised Method for Arc Modelling, ZHONG-JIE, LI** Dept. of Electrical Eng. and Electronics University of Liverpool-- A generalised method based on the mean value theorem of integration simplifies the calculation of arc conducting core properties by representing the real radial temperature profile by an equivalent rectangular profile. Both the average electrical conductivity and the average radiation coefficient in the arc core are empirically created according to the generalised principle. The average electrical conductivity determines the arc core size from the electric property of the arc. The average radiation coefficient has been employed in the new arc integral model. Computations for the Brown Boveri 2000A Nitrogen DC arc and decaying arc show that the results are in good agreement with the experiment.

** On leave of absence from Seventh Designing Institute, Ministry of Machine Building, Xian, People's Republic of China.

L-6 Simulation of Circuit Breaker Arc-Circuit Interactions by Defined Test Circuit Parameters", ZHONG-JIE LI,Dept. of Electrical Eng. and Electronics, University of Liverpool, U.K. -- A dynamic arc theoretical analysis of TF tests for the performance of a circuit breaker has been studied in detail. Comparing the deformations of arc current and voltage obtained in the testing circuit and in the power system network, shows that the traditional method used to determine the test circuit parameters does not represent arc-circuit interactions correctly. This classical method calculates the test circuit parameters on the assumption of a linearly ramped current to zero. A new method of calculating test circuit parameters based on the theoretical analysis improves the simulation of arc-circuit interaction. The new method set up the test circuit parameters so that the high voltage inductance in the test circuit is equivalent to the actual inductance in the power system network. This agrees with published experiment results[1]. The accuracy of results is tested using the integral arc model. The analysis is also a valuable aid in the understanding of other synthetic testing circuit validity.

1.P. Heroin et al, CIGRE, Paper No. 13-12, 1970.

L-7 Near Threshold Excitation of Kr and Xe by Electron Impact.* K.L. STRICKLETT, A.R. JOHNSTON and P.D. BURROW, University of Nebraska.--A trapped electron technique[1] has been used to study the total inelastic cross sections in Kr and Xe to 2 eV above threshold. The ratio of the inelastic cross section to the ionization cross section is determined by tracing the excitation and ionization curves on the same apparatus. Known values of the ionization cross sections[2] are used to normalize the inelastic cross sections. The value obtained for Kr is 1.93×10^{-17} cm^2 ± 5% at 11 eV, which is substantially larger than that obtained using the Maier-Leipnitz technique[3]. The results for Xe will also be discussed.

*This work supported by the National Science Foundation.

1. G.J. Schulz, Phys. Rev. 112, 150 (1958).
2. D. Rapp and P. Englander-Golden, J. Chem. Phys. 43, 1464, (1965).
3. M. Schaper and H. Scheibner, Beit. Plasma Phys. 9, 45 (1969).

L-8 Sensitive, Non-Intrusive, In-Situ Measurement of Plasma Electric Fields, RICHARD A. GOTTSCHO, GLENN P. DAVIS, and CAMERON A. MOORE, Bell Laboratories, Murray Hill, N.J -- We have developed a laser-induced fluorescence technique for measuring time- and space-resolved plasma electric fields. The technique relies upon Stark-induced mixing of different parity levels in an excited molecular electronic state. Depending upon the field strength, the zero field level splitting, and the molecular dipole moment, fields as small as 10 V cm^{-1} or as large as 10^4 V cm^{-1} can be measured in the same system. Initial results on low frequency (10-100 kHz) BCl_3 plasmas will be reported. Generally, for such discharges the sheath electric fields are observed to oscillate in phase but non-linearly with the applied potential. At the sheath-plasma boundaries, spikes in the local electric field are observed to occur periodically after the applied voltage has reached its most negative magnitude. These results are generally consistent with previous measurements of ion concentrations in similar discharges[1] and are indicative of periodic sheath expansion and contraction.

[1]R. A. Gottscho, R. H. Burton, D. L. Flamm, V. M. Donnelly, and G. P. Davis, J. Appl. Phys. (submitted).

L-9 Spectroscopic Diagnostics of a Silane Glow Discharge,* P. J. HARGIS, JR., and J. M. GEE, Sandia National Laboratories -- Emission spectroscopy and pulsed-ultraviolet laser Raman spectroscopy have been used to study abnormal glow discharges used to deposit amorphous and polycrystalline silicon. Emission spectra recorded at the top of the negative glow of a 10-kv discharge sustained in 30 mTorr of silane show the presence of H, Si, SiH, H_2, and Si^+. Four molecular bands near 560 nm, 570 nm, 600 nm, and 610 nm were also observed. These four molecular bands are only observed at the top of the negative glow. Pulsed-ultraviolet laser Raman spectra obtained at the top of the negative glow show that the silane density decreases with increasing discharge voltage. The observed decrease in silane density correlates with the increase in intensity of the four molecular bands. We have attributed two of the molecular bands to SiH_2. Identification of the two remaining bands is complicated by spectral interferences from Si^+ emission.

*This work was performed at Sandia National Laboratories supported by the US Department of Energy under contract number DE-AC04-76DP00789.

L-10 Complex Potential Model for Dielectronic Combination,* A. P. HICKMAN, SRI International--The process of dielectronic recombination (DER) is formulated as a coupled channel electron scattering problem in which the energies of the closed channels have an imaginary component to represent the radiative decay. This procedure correctly models the essential physics of DER: a core-excited Rydberg state produced by electron impact can decay by the competing channels of autoionization and radiation. No assumptions about the relative rates of autoionization and radiation are invoked, and the theory explicitly gives the cross section as a function of incident electron energy with no averaging. Overlapping resonances are easily handled. Model calculations including electric field effects will be discussed.

*Work supported by SRI IR&D.

L-11 A Preliminary Study of Ion Diffusion in SF_6 at High E/N[x=] J.de Urquijo, I.Alvarez C.Cisneros and A.Morales, Instituto de Física, UNAM, México--A full analysis of longitudinal diffusion of positive ions in an homogeneous field discharge gap has been used to fit transients in SF_6 at $9.1\times10^{-19}<E/N<3\times10^{-18}$ V m^2 . The ionization and drift velocities are compared with previous measurements in which diffusion was ignored[1], and the discrepancies are discussed. Also, present diffusion coefficients are compared with theoretical estimates[2], showing agreement to within 20%.

[x]Work partially supported by CONACyT, Grant PCCBCNAL 100658

[=]The experimental part of this work was carried out at UMIST, Manchester, UK

[1]J.de Urquijo, PhD Thesis, 1980 U.of Manchester

[2]E.W.McDaniel and J.T.Moseley, Phys.Rev.A, 3, 1040 (1971)

L-12 Spectroscopy and Photodissociation of Br_2^+ - C.H. KUO, I. MILKMAN, AND J.T. MOSELEY, Physics Dept. and Chemical Physics Institute, University of Oregon.
Two electronic transitions in the bromine diatomic positive ion, $\underline{X}^2\Pi_g \rightarrow \underline{A}^2\Pi_u$ and $\underline{A}^2\Pi_u \rightarrow \underline{B}^2\Sigma_g^+$ are being studied using a flow tube and tunable dye lasers. The first transition is observed by detection[1] of the O_2^+ from charge exchange with O_2, which is exothermic for the A state but endothermic for the X state. Results so far are consistent with previous emission studies, and it is anticipated that the high sensitivity of the charge exchange technique will allow an extension to previously unobserved levels. The second transition is observed by detection of the Br^+ fragment from dissociation of the B state. Ions can be formed in the A state either by the first transition, or by near resonant charge exchange with N_2O^+.

[1]J.C. Hansen, C.H. Kuo, F.J. Grieman and J.T. Moseley, J. Chem. Phys. (in press).
Research supported by NSF Grant No. CHE-7918074.

L-13 Multiphoton Ionization Mass Spectrometry of Methylamines [1] J. D. GANIERE[2], Y. ONO and J. T. MOSELEY Chemical Physics Institute, University of Oregon. The multiphoton ionization and fragmentation patterns of methyl-, dimethyl-, and trimethylamine have been investigated at 193 and 248 nm. Mass spectra as a function of photon flux were obtained using both a static gas and a pulsed molecular beam, and are compared with results from previous work and electron impact ionization. All ions observed with electron impact were detected by MPI with photon fluxes in the order of 10^{23}-$10^{24}/cm^2 sec$. At 193 nm, the photon flux dependence of dimethyl and trimethylamine fragments indicate at least two different pathways involving competition between photodissociation and photoionization to form the products. A rate equation model is used to interpret the dynamics of these MPI data. Negative ions formed by electron attachment have also been observed, and are being investigated.

(1)This work supported by ARO and AFOSR
(2)Supported by the Swiss National Fund of Research

L-14 Electron Excitation Cross Sections of Xenon* KEITH G. WALKER, Bethany Nazerene College.
The 6p and 6p' optical excitation cross sections of xenon have been measured from onset to 100 eV's. Particular interest has centered on their pressure dependence. Most of the levels betray a pressure sensitivity for electron energies greater than 25 eV's. Higher np, ns and nd levels have been measured and many of these excitation functions exhibit a pressure dependence. Reasonant type structure around 20 eV has also been observed in many of the functions. The xenon excitation functions have been measured when various amounts of helium are mixed with the xenon. Some functions are changed drastically while others appear 'inert' against the helium. Possible mechanisms for the above behavior will be discussed.

* This work partially supported under AFOSR Summer Faculty Researcher Program.

L-15 Laser-Induced Fluorescence Studies of XeF,* H. HELM, L. E. JUSINSKI, M. J. DYER, D. C. LORENTS, and D. L. HUESTIS, SRI International--The spectroscopy and vibrationally resolved kinetics of XeF(B,C,D) are being investigated by the technique of laser-induced fluorescence. A KrF laser is used to photodissociate XeF_2 producing XeF(X) in various excited vibrational levels. A time-delayed frequency-doubled dye laser is used to excite specific B-X and C-X vibrational bands. Accidental coincidence between the KrF laser profile and the 7-1, 8-3, and 9-6 bands of the D-X system also results in excitation of XeF(D) during the KrF laser pulse. By observing the broad-band B-A and C-A and the discrete B-X and D-X emission features we have obtained (1) the first resolved spectroscopic information on XeF(C), placing it 775 cm^{-1} below XeF(B); (2) vibrationally resolved radiative lifetimes and quenching rates; and (3) the first direct observation of relaxation of $XeF(B)_{v=1}$ to $XeF(B)_{v=0}$.

* Work supported by DARPA and ONR through Contract No. N00014-80-C-0506

L-16 Vibrational Relaxation and B/C Mixing in XeF,* D. C. LORENTS, D. L. HUESTIS SRI International, M. DURRETT, L. HOUSTON, and G. WALTERS, Rice University--The relaxation and B/C mixing of vibrationally excited XeF in Ar and Ne has been modeled a including 4 C-levels, 2 B-levels, plus a reservoir level. The model allows collisional coupling between adjacent levels of B nd C states and within each state. The uv and bg (blue-green) emission intensities from each level are computed from the populations. Rate constants for the model were obtained by fitting the uv and bg time dependent synchrotron data and integrated uv/bg intensity ratios as a function of Rg pressure from 25 to 3500 torr. The major result is that the downward relaxation of levels in both states is faster than the B $\leftrightarrow$ C mixing, in spite of the larger level separations. The model works equally well with Ar and Ne buffers using rate constants for Ar that are 8 times those of Ne.

*Supported by DARPA through ONR and by DoE BES.

L-17 Symmetric Charge Transfer between Singly and Doubly Charged Ions*, P. GANGOPADHYAY and J. N. BARDSLEY, U. of Pittsburgh -- The asymptotic theory of symmetric charge transfer is adapted to allow for curved trajectories and is applied to the reaction $X^{+} + X^{++} \rightarrow X^{++} + X^{+}$, where X is He, Mg, Ca, Sr or Ba. The effect upon experimental measurements of the total cross section of limits on the acceptance angle for ion detection is demonstrated. For He^{+}-He^{++} collisions, the results are compared with the accurate ab initio calculations[2] and experiment[3].

*Work supported by the National Science Foundation.

1. J. N. Bardsley, Comm. At. Mol. Physics
2. C. A. Falcon, J. Phys. B 16, 1793 (1983)
3. A. Jognaux, F. Brouillard and S. Szucs, J. Phys. B 11, L669 (1978).

SESSION M

8:00 p.m., Thursday, October 13, 1983

WORKSHOP II: FAST GAP BREAKDOWN

Chairperson: A. V. PHELPS
Univ. of Colorado

OCTOBER 13, 1983 THURSDAY EVENING

M: WORKSHOP ON FAST GAP BREAKDOWN

8:00 p.m.
Assembly Hall

Chairperson - A. V. Phelps - Univ. of Colorado

OVERVIEWS

H. A. Blevin - The Flinders University of South Australia

Professor Blevin will summarize what we know experimentally about non-equilibrium effects and the limits of validity of equilibrium concepts such as ionization coefficient and drift velocity. (20 min.)

E. E. Kunhardt - Texas Tech. University

Professor Kunhardt will talk about non-equilibrium effects in avalanche development with space charge consideration. (15-20 min.)

L. C. Pitchford - Sandia National Labs.

Dr. Pitchford will talk about modeling non-equilibrium effects and attempts to introduce transients into circuit equations. (15-20 min.)

CURRENT RESEARCH

Chatham Cooke - Massachusetts Institute of Technology

Dr. Cooke is studying avalanching in gases on short time scales. He is also looking into the problem of a macroscopic description of circuit equations with transient effects included. (12-15 min.)

W. W. Byszewski - GTE Labs.

Dr. Byszewski has done experiments on discharge formation in highly overvolted gaps. He has also seen evidence of runaway electrons in the same apparatus.

R. A. Alvarez - Lawrence Livermore National Laboratory

Dr. Alvarez is now doing experiments designed to measure microwave power transmitted through a partially evacuated waveguide for very high power, short pulses input.

SESSION N

9:00 a.m., Friday, October 14, 1983

TRANSPORT PHENOMENA

Chairperson: W. H. LONG

Northrup Res. and Tech. Center

N-1 Electron Longitudinal Diffusion Coefficients in Argon*, F. Li and L. C. Lee, San Diego State University--The diffusion coefficients of electron in Ar were measured in the E/N = 50-350 Td region, using a parallel-plate drift-tube apparatus. An ArF excimer laser was used to irradiate on cathode. Photoelectrons thus generated were drifted under uniform electric field toward anode. The electron movement is monitored by the electron current which induces a transient voltage across an external resistor connecting anode to ground. The electron longitudinal diffusion coefficients, D_L, were derived from modeling the transient pulses with electron density equations given by Huxley[1] and Wealton et al[2]. At a constant E/N, D_L is nearly constant for the Ar pressure (<8 torr) studied in this experiment. This constancy indicates that the e-Ar collision numbers are not large enough to affect D_L. At E/N = 70 Td, D_L is about $9 \times 10^5 cm^2/s$. The space charge effect on D_L is examined by varying laser energy over a factor of 5, and found that it is negligible.

* Sponsored by AFOSR under Grant No. AFOSR-82-0314.

1. L.G.H. Huxley and R.W. Crompton, The Diffusion and Drift of Electrons in Gases (Wiley, NY 1974) p. 301.
2. J.H. Wheaton, D.S. Burch, and A.V. Phelps, Phys. Rev. A, 15, 1685 (1977).

N-2 Electron Drift Velocities in Silane-Helium and Silane-Argon Mixtures. A. GARSCADDEN, AF Wright Aeronautical Laboratories, and K.A. KIRKENDALL* and M.L. ANDREWS*, Wright State University.--The interpretation of drift velocity (W) characteristics in pure silane has been that there is a Ramsauer minimum in the momentum transfer cross-section and a sharply increasing vibrational cross-section around 0.1 eV. In order to confirm this interpretation and to avoid considerations of higher order expansions in Boltzmann transport theory, electron swarm experiments have been made in silane-helium and silane-argon mixtures over a wide range of E/N. The addition of both gases reduces W substantially. In dilute silane-helium mixtures W becomes monotonically increasing with E/N; however in dilute silane-argon mixtures the differential negative conductivity is maintained. The maximum in W is sharpened but reduced in amplitude with increasing concentration of argon, and shifts to lower E/N values. Comparison with theoretical analysis shows that the W maximum still occurs about the same mean energy. It is concluded that silane does have Ramsauer characteristics.

*Supported by AF Contract F33615-81-C-2011, Task 12 through SCEEE

N-3 Non Equilibrium behaviour of an Electron Swarm in SF_6. J.P. BOEUF, E. MARODE, Laboratoire de Physique des Décharges, ESE, Gif/Yvette, FRANCE. - A space and time dependent Monte-Carlo code has been used to study the evolution of an electron swarm in SF_6 in a drift tube under a uniform electric field. The evolution toward equilibrium is analysed for E/P ranging from 50 V/cm/torr to the critical reduced field. Results show that there is a large non equilibrium region in front of the cathode, where the macroscopic parameters present strong spatial oscillations and attachment is very localized. For example at E/P = 50 V/cm/torr, the non equilibrium region is larger than 2 cm.torr. This non equilibrium behaviour is analysed using energy-position characteristic trajectories. It appears that electrons which are to be attached can drift a long time in the direction of the field, leading to negative values of the first anisotropy of the distribution function for low energies.

Results concerning steady state and pulsed experiments will be presented.

N-4 Transport Coefficients and Collisional Cross Sections of SF_6, $CC\ell_2F_2$, and Mixtures, J.P. NOVAK and M.F. FRECHETTE, IREQ, Varennes, Québec, Canada - Ionization and attachment coefficients (α and η), drift velocity (V), and diffusion coefficient (D) have been calculated using Boltzmann equation for SF_6, $CC\ell_2F_2$ and their mixtures with N_2. An attempt to reconcile a discrepancy between our calculations and the measured values of η for SF_6-N_2 mixtures[1] has been made, which resulted only in a minor change to the calculated values. On the other hand, new experimental data reported by Dincer and Raju[2] are substantially lower than those of Ref. 1; our results are found to lie between the values given in Refs. 1 and 2. — Revised collisional cross sections of $CC\ell_2F_2$ improved the agreement between the theoretical and experimental values of V and D for pure gas, while theoretical values of η are too high at both high and low electric fields. In the case of $CC\ell_2F_2$ mixtures, fair agreement between the theoretical and experimental transport coefficients has been obtained. All calculations have been performed in the range $50 \leq E/p \leq 220$ (V cm^{-1} $torr^{-1}$).

1. M.C. Siddagangappa, C.S. Lakshminarasimha and M.S. Naidu, J. Phys. D 15, L83 (1982).
2. M.S. Dincer and G.R.G. Raju, Private Communication.

N-5 The Development of an Electron Avalanche: A Self-Consistent Microscopic Treatment,* E.E. KUNHARDT and Y. TZENG, Texas Tech University --In this paper, results are presented from an uniform electric field, starting from one or more initiatory electrons. The state of the charged particles (electrons and ions) in the gas at any time is determined from the six dimensional phase-space distribution of electrons $f(\underset{\sim}{r},\underset{\sim}{v},t)$. This distribution is obtained from a Monte Carlo simulation of the dynamics of the electrons in phase-space taking into account, self-consistently, collective effects due to the space-charge electric field is determined from solution of the Poisson equation assuming cylindrical symmetry. The effect of photoionization in a gas with impurities on the development of the avalanche will also be presented.

*Work supported by the Office of Naval Research under Contract N00014-81-K-0655.

N-6 Higher Order Transport of Gaseous Ions in the Idealized Charge Transfer Model,* B. M. PENETRANTE and J. N. BARDSLEY, U. of Pittsburgh -- Expressions are obtained for the higher order longitudinal transport coefficients of gaseous ions in the idealized charge transfer model by means of the free path (FP) method and the density gradient expanded velocity distribution function (DGEVDF) solution of the Boltzmann equation. The FP values, confirmed by Monte Carlo simulations, are in disagreement with the DGEVDF values, possibly indicating that the spatial cumulant (or correlation function) definition of the transport coefficients is not entirely equivalent to velocity integral of the DGEVDF.

*Supported by the Office of Naval Research.

O: INVITED PAPERS

10:30 a.m.
Lecture Hall 23

Chairperson: A. Garscadden - Air Force Aeronautinautical Labs.

PHYSICS OF CHARGED PARTICLE BEAMS

William F. Bailey - Air Force Institute of Technology

ARCS AND GASEOUS ELECTRONICS

Lawson P. Harris - G. E. Corporate Research and Development

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