The proliferation of GEC cells, the lack of recent newsletters, and the rapid progress being made by many of the research programs have made it increasingly difficult to keep up with the state of GEC-cell-related research. This issue of the newsletter is therefore dedicated to reacquainting everyone with the work being done with GEC RF Reference Cells.

Beginning on page 2 are brief summaries of the research programs using GEC reference cells. The summaries include the address of a primary contact, details of the cell configuration and modifications, brief statements concerning present and future research plans, and lists of other users. The information was obtained from a survey sent earlier this year to known GEC cell operators. The order of the summaries is based upon approximate dates of operation. Some institutions are listed more than once because multiple cells exist at those sites.

After the GEC cell summaries is a list of known publications related to experimental research on GEC RF Reference Cells. This will hopefully be a permanent part of future newsletters. The publication list is organized by approximate date of publication, and includes entries for papers in press, under review, and in preparation. Talks presented at the GEC are not included due to the large number of them, and due to the limited information contained in the GEC abstracts.

MORE INFORMATION

If you would like to be put on the mailing list to receive the GEC RF Reference Cell Newsletter, please contact:

James K. Olthoff
National Institute of Standards and Technology
Building 220, Room B344
Gaithersburg, MD 20899
(301)975-2431
(301)975-4091 (FAX)
olthoff@eeel.nist.gov (e-mail)

If you are working on a GEC RF Reference Cell and are not listed in the Research Summaries, please contact me so that your name can be added to the “official” list of GEC cell users. Thoughts about the content of this newsletter are also invited.

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| **Sandia National Laboratories**  
| **Paul Miller**  
| **Address:**  
| Sandia National Laboratories  
| Department 1128  
| P.O. Box 5800  
| Albuquerque, NM 87185  
| (505)844-8879  
| (505)844-3211 (FAX)  
|  
| **Cell Configuration:**  
| Insulators: Teflon  
| Electrodes: Aluminum  
| Powered Electrode: Either or both  
| Filter box and shunt are used.  
| Plasma values are calculated.  
|  
| **Gases Used:** Ar, Cl₂, HBr, CF₄  
|  
| **Diagnostics:**  
| • Current and voltage waveforms measured at each electrode.  
| • Current measured to walls and ground shields.  
| • Wafer etch analysis.  
|  
| **Significant Modifications:**  
| • A wafer handler, manipulator, and loadlock have been installed to facilitate wafer handling.  
| • A transformer system has been designed and installed to allow balanced excitation of both electrodes.  
|  
| **Experiments:**  
| • Model validation of wafer etching processes.  
| • Use of circuit tuning for increased control of the plasma.  
| • Investigation of subharmonics generated by the interaction of the plasma and rf circuitry.  
|  
| **Other Users:**  
| • H. Pak  
| • J. T. Verdeyen  
|  
| **University of New Mexico**  
| **Harold Anderson**  
| **Address:**  
| Department of Chemical and Nuclear Engineering  
| University of New Mexico  
| Albuquerque, NM 87131  
| (505)277-5661  
| (505)277-6433 (FAX)  
|  
| **Cell Configuration:**  
| Insulators: Teflon  
| Electrodes: Aluminum  
| Powered Electrode: Bottom  
| Filter box and shunt are used.  
| Plasma values are calculated.  
|  
| **Gases Used:** Ar, CF₄, and CHF₃  
|  
| **Diagnostics:**  
| • Current and voltage waveforms measured at the powered electrode.  
| • Parallel optical emission spectroscopy.  
| • Diode laser spectroscopy.  
|  
| **Significant Modifications:**  
| • None  
|  
| **Experiments:**  
| • Spatially- and temporally-resolved optical emission spectroscopy.  
| • Chemometric calibration and plasma monitoring.  
| • Diode-laser spectroscopy for the detection of CF₂, CF₃, and CF₂.  
| • Characterization of a micro-engineered ion energy analyzer (planned).  
| • Dynamic laser light scattering (planned).  
|  
| **Other Users:**  
| • M. P. Splichal  
|  
| **Sandia National Laboratories**  
| **Ken Greenberg**  
| **Address:**  
| Sandia National Laboratories  
| Department 1128  
| Albuquerque, NM 87123  
| (505)844-1243  
| (505)844-3211 (FAX)  
|  
| **Cell Configuration:**  
| Insulators: Alumina (original)  
| Electrodes: Aluminum  
| Powered Electrode: Both  
| Filter box and shunt are available.  
| Plasma values are calculated.  
|  
| **Gases Used:** Ar and He (Cell 1)  
| Ar, He, NF₃, SF₆, CHF₃ (Cell 2)  
|  
| **Diagnostics:**  
| • Current and voltage waveforms measured at powered electrodes.  
| • Microwave interferometer.  
| • Optical diagnostics for the monitoring of absorption and emission in the plasma.  
|  
| **Significant Modifications:**  
| • The electrodes may be driven by a balanced drive rather than grounding one of the electrodes.  
|  
| **Experiments:**  
| • Spatially resolved measurements of electron and metastable densities in rare gas discharges (primarily helium) for comparison with theory.  
| • Use of laser spectroscopic techniques (Laser-induced fluorescence, Raman, absorption) for the monitoring of species densities.  
| • Spatially- and temporally-resolved electric field measurements.  
|  
| **Other Users:**  
| • G. A. Hebner  
| • M. E. Riley  
|  
| **University of New Mexico**  
| **Harold Anderson**  
| **Address:**  
| Department of Chemical and Nuclear Engineering  
| University of New Mexico  
| Albuquerque, NM 87131  
| (505)277-5661  
| (505)277-6433 (FAX)  
|  
| **Cell Configuration:**  
| Insulators: Teflon  
| Electrodes: Aluminum  
| Powered Electrode: Bottom  
| Filter box and shunt are used.  
| Plasma values are calculated.  
|  
| **Gases Used:** Ar, CF₄, and CHF₃  
|  
| **Diagnostics:**  
| • Current and voltage waveforms measured at the powered electrode.  
| • Parallel optical emission spectroscopy.  
| • Diode laser spectroscopy.  
|  
| **Significant Modifications:**  
| • None  
|  
| **Experiments:**  
| • Spatially- and temporally-resolved optical emission spectroscopy.  
| • Chemometric calibration and plasma monitoring.  
| • Diode-laser spectroscopy for the detection of CF₂, CF₃, and COF₂.  
| • Characterization of a micro-engineered ion energy analyzer (planned).  
| • Dynamic laser light scattering (planned).  
|  
| **Other Users:**  
| • M. P. Splichal  
|
National Institute of Standards and Technology
James Olthoff

Address:
NIST
Building 220, Room B344
Gaithersburg, MD 20899
(301)975-2431
(301)975-4091 (FAX)

Cell Configuration:
Insulators: Alumina (original)
Electrodes: Aluminum
Powered Electrode: Bottom
Filter box and shunt are used.
Plasma values are calculated.

Gases Used: Ar, He, H₂, O₂, and N₂

Diagnostics:
- Voltage and current waveforms measured at the powered electrode.
- Mass spectrometer with ion energy analyzer.
- Optical emission apparatus for spatial scans of the plasma.
- Langmuir probe.

Significant Modifications:
- Showerhead electrode mounted in bottom position.
- Top electrode assembly modified to allow sampling of ions through the grounded electrode.

Experiments:
- Measurements of energy distributions of ions sampled from plasmas in rare gases and gas mixtures.
- Absolute spatially- and temporally-resolved measurements of optical emission from rare gas plasmas.
- Development of current and voltage measurements as a real-time diagnostic.

Other Users:
- J. R. Roberts
- M. A. Sobolewski
- J. R. Whetstone
- R. J. Van Brunt
- S. Djurovic
- S. B. Radovanov
- J. A. Rees

Wright-Patterson Air Force Base
Peter Bletzinger

Address:
WL/POOC-3 Building 450
Wright-Patterson AFB, OH 45433-7919
(513)255-2923
(513)476-4095 (FAX)

Cell Configuration:
Insulators: Alumina (original)
Electrodes: Aluminum
Powered Electrode: Bottom
No filter box or shunt are used.
Plasma values are calculated.

Gases Used: Ar, He, N₂, and H₂

Diagnostics:
- Voltage and current waveforms measured at the powered electrode.
- Scanning laser-induced fluorescence (LIF) system for two-photon excitation and measurement.
- Scanning of time-averaged emission profile.
- Microwave interferometer to measure line integrated electron density.

Significant Modifications:
- None.

Experiments:
- Two photon LIF measurements of H atom concentrations using 205 nm laser radiation. Laser beam is scanned vertically to measure concentration profiles.
- Time-averaged emission profiles are measured with separate scanning photomultiplier/filter.
- Measurements of current and voltage transients with pulsed rf amplifier (no matching network) for switch-on and switch-off.
- Measurements of electron density in Ar, He, and N₂ plasmas using a microwave interferometer.

Other Users:
- A. Garscadden
- J. R. Roberts

University of Michigan
Mary Brake

Address:
Dept. of Nuclear Engineering
University of Michigan
Ann Arbor, MI 48109-2104
(313)764-1976
(313)763-4540 (FAX)

Cell Configuration:
Insulators: Teflon
Electrodes: Aluminum
Powered Electrode: Bottom
Filter box and shunt are used.
Plasma values are calculated.

Gases Used: Ar, O₂, CF₄, and He

Diagnostics:
- Current and voltage waveforms measured at the powered electrode.
- Optical emission apparatus for time and spatially-resolved (vertical and horizontal) scans of the plasma.
- Laser-induced fluorescence.

Significant Modifications:
- A cryo pump is used to achieve the base vacuum and a turbo pump is used to maintain the gas flow while running a discharge.

Experiments:
- Optical emission spectroscopy using a diode array detector to make spatially-resolved measurements. Photon-counting electronics are being installed to allow time-resolved measurements.
- Etch rates and species production for silicon in CF₄ and O₂ have been measured and compared to those in a commercial reactor.
- Preliminary LIF experiments in Ar and He have been performed.
- Experiments using an electrostatic probe have been initiated, including electron energy distribution function calculations.
University of Texas at Dallas
Lawrence Overzet

Address:
University of Texas at Dallas
P.O. Box 830688, EC33
Richardson, TX 75083-0688
(214)690-2154
(214)690-2710 (FAX)

Cell Configuration:
Insulators: Alumina
Electrodes: 304 Stainless Steel
Powered Electrode: Top
Filter box and shunt are used.
Plasma values are calculated.

Gases Used: Ar, N₂, and CF₄

Diagnostics:
- Voltage and current waveforms measured at the powered electrode.
- Retarding potential analyzer for measurement of kinetic energy of ions striking the grounded electrode.
- Microwave interferometer.
- Optical emission apparatus (future).

Significant Modifications:
- The showerhead electrode is powered and the grounded electrode has been modified to allow sampling of ions.

Experiments:
- Comparison of Langmuir probe and microwave interferometry results.
- Measurement of ion kinetic-energy distributions from various gases.
- Current and voltage are measured at the powered electrode in real time.

Other Users:
- M. B. Hopkins
- M. Turner

Michigan Technology University
Jacek Borysow

Address:
Department of Physics
Michigan Technology University
1400 Townsend Drive
Houghton, MI 49931
(906)487-2092
(906)487-2933

Cell Configuration:
Insulators: Teflon
Electrodes: Aluminum
Powered Electrode: Bottom
Filter box is used, but not a shunt.
Plasma values are calculated.

Gases Used: Ar, CF₄, and O₂

Diagnostics:
- Voltage and current waveforms measured at the powered electrode.
- Infrared absorption spectrometer based on the tunable diode laser.
- CF₄(O₂) plasma etch rate interferometric system.

Significant Modifications:
- None.

Experiments:
- Spatially-resolved (vertical and horizontal) absorption by argon metastable states as a function of pressure and rf power. Absolute densities are determined.
- Saturation doppler-free absorption measurements of argon metastable states.

Other Users:
- E. Augustyniak
- S. Filimonov

National Institute of Standards and Technology
Mark Sobolewski

Address:
NIST
Building 221, Room B312
Gaithersburg, MD 20899
(301)975-2980
(301)869-5924 (FAX)

Cell Configuration:
Insulators: Alumina (new)
Electrodes: Aluminum
Powered Electrode: Bottom
Filter box and shunt are used.
Plasma values are calculated.

Gases Used: Ar, He, and SF₆ (future)

Diagnostics:
- Voltage and current waveforms measured at the powered and grounded electrodes.
- Mass spectrometer with ion energy analyzer (future).
- Planar laser-induced fluorescence imaging (future).
- Optical instrumentation for surface characterization (future).
- Langmuir probe (future).

Significant Modifications:
- None.

Experiments:
- In-situ surface characterization of Si wafers during SF₆-plasma etching.
- Correlation of current and voltage measurements to ion densities and kinetic energies.

Other Users:
- J. R. Whetstone
- B. K. McMillin
- J. E. Maslar
IBM-East Fishkill
Michael Passow

Address:
IBM-East Fishkill
Z/53C, Route 52
Hopewell Junction, NY 12533
(914)894-4626
(914)892-6035 (FAX)

Cell Configuration:
Insulators: Alumina (new)
Electrodes: Aluminum
Powered Electrode: Bottom
RF electronics to be determined.

Gases to be Used: NF₃, Cl₂, HBr, Freon

Diagnostics:
• To be determined.

Significant Modifications:
• Anticipate installing mass spectrometer in grounded electrode.

Experiments:
• To be determined.

Other Users:

University of Illinois
Joseph Verdeyen

Address:
Gaseous Electronics Laboratory
University of Illinois
607 E. Healey
Champaign, IL 61820
(217)333-2480
(217)244-5422 (FAX)

Cell Configuration:
Insulators: Alumina (original)
Electrodes: Aluminum

All else to be determined.

Gases to be Used: Ar, He, and H₂

Anticipated Diagnostics:
• Voltage and current waveforms measured at the powered electrode.
• Mass and kinetic energy analysis through the grounded electrode.
• Time-resolved optical emission.
• Compensated Langmuir probe.

Significant Modifications:
• None

Anticipated Experiments:
• Correlation of Langmuir probe, ion energy, and optical emission measurements.
• Studies of electronegative gases.
• Lower frequency operation.

Other Users:
• Nick Braithwaite (Open University, UK)
GEC RF REFERENCE CELL LIST OF PUBLICATIONS

1. “Electrical characterization of rf plasma discharges”

2. “The GEC RF Reference Cell: Diagnostic techniques and initial results”

3. “Measurements on the NIST GEC Reference Cell”

4. “Status of the GEC Reference Cell / Laser diagnostics of plasma etching discharges”

5. “Mass spectrometric and Optical Emission Diagnostics for rf plasma reactors”

6. “Electrical characterization of rf plasmas”

7. “Application of chemometrics to optical emission spectroscopy for plasma monitoring”

8. “Electrical isolation of radio-frequency plasma discharges”

9. “Period-doubling bifurcation in a plasma reactor”

10. “Diagnostic measurements in rf plasmas for materials processing”

11. “Ion kinetic-energy distributions and electrical measurements in argon-oxygen rf glow discharges”

12. “Ion kinetic-energy distributions in rf glow discharges”


14. “Measurements and analysis of the equivalent circuit of the GEC RF Reference Cell”

15. “Electrical measurements for monitoring and control of rf plasma processing”
16. “Absolute spatially- and temporally-resolved optical emission measurements of rf glow discharges in argon”

17. “Electron and metastable densities in parallel-plate radio-frequency discharges”


20. “Hydrogen Balmer Alpha line shapes for hydrogen-argon mixtures in a low pressure rf discharge”

21. “Kinetic-energy distributions of ions sampled from argon plasmas in a parallel-plate rf reference cell”

22. “Use of an ion energy analyzer-mass spectrometer to measure ion kinetic-energy distributions from rf discharges in argon-helium gas mixtures”

23. “Spatially resolved optical emission measurements of the UM GEC Reference Cell”
J. Pender, M. Buie, J. Holloway, and M. Brake, in preparation.

J. Pender, M. Buie, and M. Brake, in preparation.


26. “Spatial dependencies of the electron concentration in the Gaseous Electronics Conference reference reactor”

If you have published or are working on a paper that you would like included in this list, please send a preprint or reprint to J. K. Olthoff at the address given on the first page of this newsletter.
May 1993

RF Reference Cell Gasous Electronics Conference