Identifying the Dominant Ions In Argon Plasmas: DEI, DAI, and Ar_2^+

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Although argon plasmas are among the most studied in plasma physics, many basic studies in argon neglect molecular ion species. These species can play a key role in the high pressure regime, particularly above 200 mTorr. Modeling this regime reveals the importance of dissociation by electron impact (DEI), dissociation by atom impact (DAI), and the importance of the Ar_2^+ ion in the discharge. The Kinetic Global Model framework (KGMf) is a flexible spatially independent model including plasma reactions via the convolution of cross sections with an electron energy distribution function, coupled to the electron energy equation and the continuity equations of all species coupled by reaction terms [1-2]. The energy equation can include AC and DC power sources, and produces scaling information for the electron energy distribution function (EEDF). The shape of the EEDF is determined by other means, which presently includes use of a Monte Carlo or particle-in-cell Monte Carlo scheme, but in the near future will also include a Boltzmann module to compute the EEDF intermittently. The KGMf can model hundreds of species, with thousands of reactions, to study detailed reaction chains.

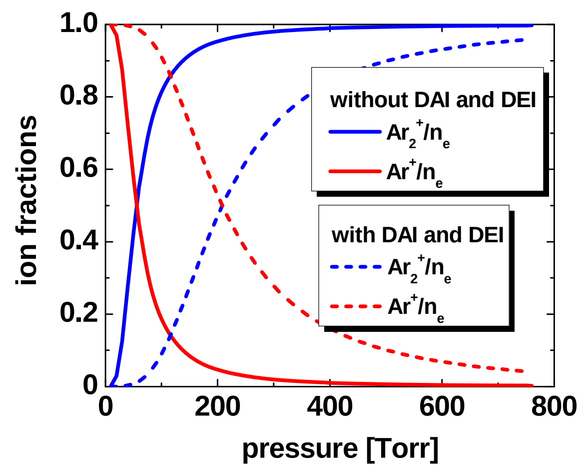

Figure 1 – Atomic and molecular on fractions with and without dissociative electron and ion impact reactions in Ar up to760 Torr.

Applying the KGMf to a capacitively driven argon plasma up to 760 Torr, we can compare the consequences of the dissociative electron impact and the dissociative atom impact reactions on the atomic and molecular ions in the plasma.

As shown in Figure 1, without the DEI and DAI reactions, the Ar^+ ion dominates at low pressure, dropping rapidly, while the Ar_2^+ ion conversely rises rapidly from being negligible at low pressure. The ion fractions cross just below 100 Torr, and each respective trend continues until they each saturate. As shown, the DEI and DAI reactions serve to delay the trend, shifting the dominance of Ar_2^+ to a higher pressure.

References

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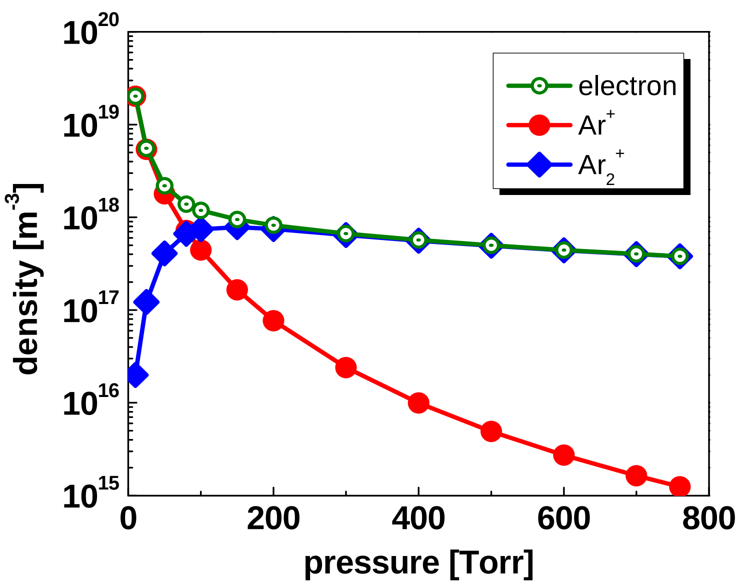
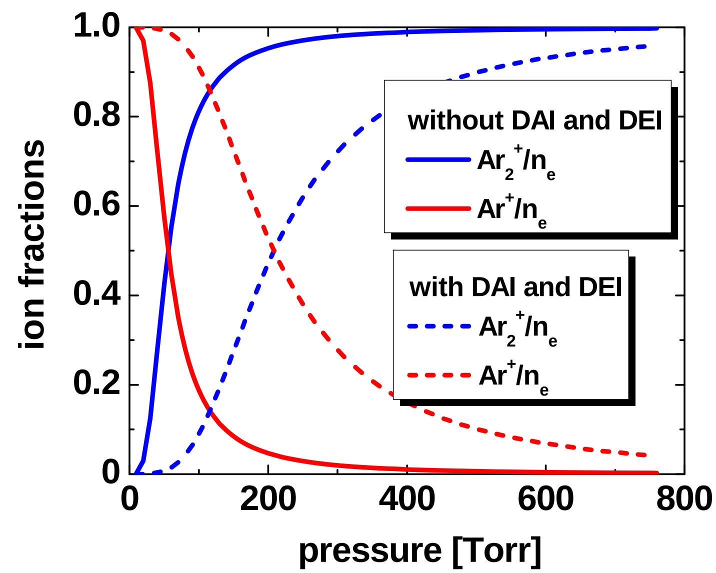
IDENTIFYING THE DOMINANT IONS IN ARGON PLASMAS: DEI, DAI, AND Ar_2^+

- **Roles of molecular and atomic ions were investigated in different gas-pressure regimes using the Kinetic Global Model framework, considering dissociation by electron impact (DEI) and dissociation by atom impact (DAI).**
- **DEI and DAI will generally decrease the molecular ion fraction and increase the atom ion fraction, shifting the intersection point, where the molecular and atom ion densities are the same, to higher pressures.**



- **Intersection of the molecular and atom ion densities**



- **Influence of DAI and DEI on the ion fractions**

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HIGHLIGHT

MICHIGAN STATE UNIVERSITY

Center for Predictive Control of Plasma Kinetics: Multi-Phase and Bounded Systems

Department of Energy Plasma Science Center

DOE Plasma Science Center
Control of Plasma Kinetics

Generation of Energetic Electrons in Microplasma at Moderate Pressures

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Microplasmas have emerged over the last decade as an important direction for plasma source development, providing moderate (≥ 1 Torr) and atmospheric pressure discharges with modest power input, that may someday be exploited in applications for catalysis, reforming processes, remediation and manufacturing [1]. Plasma kinetics and plasma-surface interactions are key, but poorly understood, processes in microplasmas. Our research is aimed at studying these processes and their control through the use of biased walls [2,3] and investigating sheath phenomena in the presence of secondary electron emission from the electrodes of the microdischarge.

Our experiments demonstrated that in a DC microdischarge with a cylindrical hollow anode – flat cathode configuration, it is possible to produce and control a fraction of relatively high energy electrons outside of the discharge, in areas important for plasma applications. Calculations showed that with operating pressures of 1-10 torr, the energy relaxation distance is 0.1–1 cm, on the order of or greater than the characteristic dimensions of the microdischarge. The electron mean free path is 0.01–0.1 cm. Therefore, this microdischarge is expected to have a non-local electron energy distribution (EEDF) and can be exploited as a source of energetic electrons that could be extracted from the discharge. Measurements with electrostatic probes and optimical emission spectroscopy revealed the presence of 12 – 14 eV electrons outside the microdischarge in N_2 gas at 3 Torr. The formation of these energetic electrons in microdischarges is not well understood, but may be due to secondary electron emission from the electrodes [3]. To study these processes and their control, we developed a two-electrode hollow microdischarge configuration (Fig. 1a) with a biased substrate as the third electrode to control EEDF outside of the discharge. Recent measurements demonstrated the flexibility of this source to produce two different plasmas with different electron temperatures and densities at each side of the discharge above the substrate (Fig. 1b).

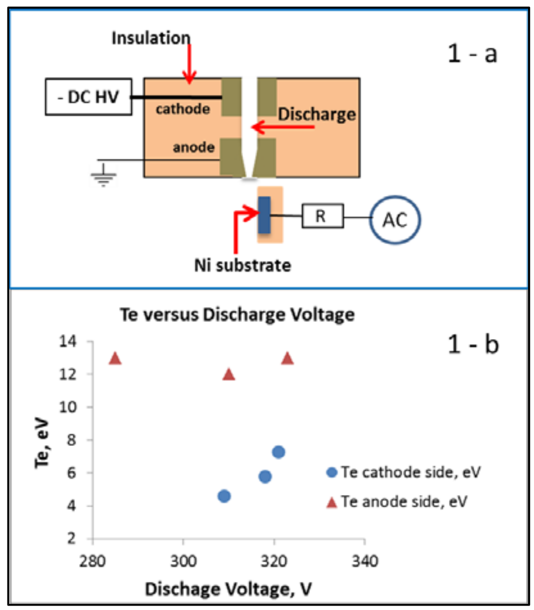

Figure 1 – (a) Hollow microdischarge setup. (b) Electron temperature above the nickel substrate for two substrate positions.

References

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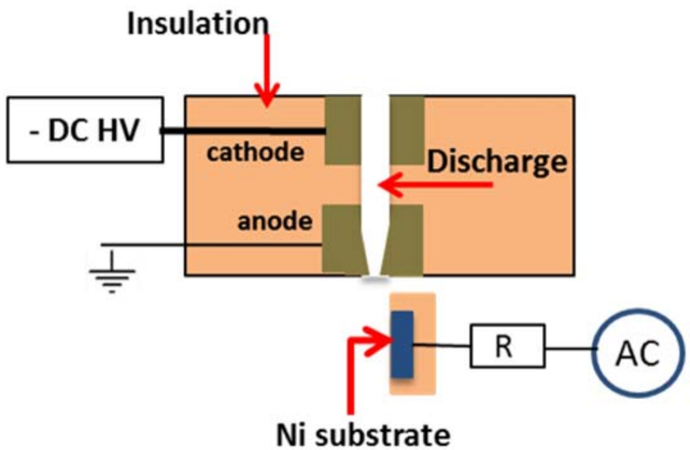
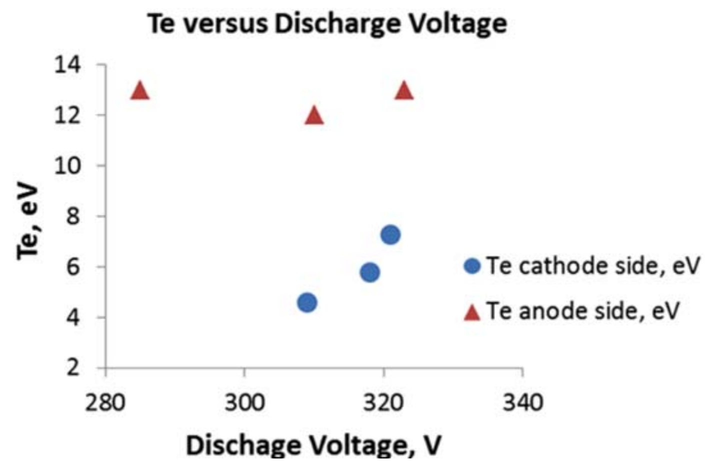
[2] V. I. Kolobov and A. S. Metel, J. Phys. D: Appl. Phys. **48**, 233001 (2015).
[3] D. Sydorenko, I. D. Kaganovich, L. Chen and P. L. G. Ventzek, Phys. Plasmas **22**, 123510 (2015).

GENERATION OF ENERGETIC ELECTRONS IN MICROPLASMA AT MODERATE PRESSURES

- Microplasmas at moderate (≥ 1 Torr) and atmospheric pressures are important to applications in catalysis, reforming processes and manufacturing.
- OES and probe measurements demonstrated the presence of energetic electrons (12 – 14 eV in N_2 at 3 Torr) outside a DC microdischarge; and the feasibility of their control using biased wall/substrates/ and geometry.
- The source of energetic electrons is unclear. Calculations show the origin could be secondary electron emission from the cathode accelerated by the sheath and escaping through the microplasma.



- Microdischarge setup



- Electron temperature outside the N_2 microdischarge at 3 Torr

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