Two-Dimensional Images of CF₂ Density in CF₄/Ar Plasmas by Laser-Induced Fluorescence in a GEC RF Reference Cell

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Abstract—Spatially resolved two-dimensional (2-D) maps of the relative CF₂ density in low-pressure CF₄/Ar RF discharges, generated within a parallel-plate gaseous electronics conference (GEC) reference reactor, have been obtained using planar laser-induced fluorescence imaging (PLIF). The results illustrate the changes in CF₂ density and distribution in the central plane of the discharge region as flowrate is varied over 10–100 sccm at constant power and pressure, and as pressure is varied over 13.3–133.3 Pa at constant flowrate and power.

Planar laser-induced fluorescence (PLIF) imaging was used to map the spatially resolved two-dimensional (2-D) planar density distribution in low-pressure RF CF₄/Ar etching plasmas. The discharges examined here, as in our previous studies [1], were generated within a capacitively coupled parallel-plate asymmetrically driven gaseous electronics conference (GEC) reference cell. The objective of this work was to obtain two-dimensional (2-D) concentration maps of the CF₂ radical over a range of conditions for benchmarking and verification of plasma chemistry models. In fluorocarbon etching plasmas, which are widely used in microelectronics integrated circuit manufacturing, the CF₂ radical is an important species because it influences the balance between polymer deposition and etching of silicon and silicon dioxide [2]. Additional details and results of these experiments are available elsewhere [3] and will be discussed in a future publication.

In this investigation, a thin sheet (5 × 25 mm) of quadrupled Nd:YAG laser light (266 nm) was used to illuminate the central vertical plane of the discharge, and thereby excite transitions in the A(0, 2, 0) → X(0, 1, 0) band of CF₂. The resulting broadband fluorescence over 300–400 nm was imaged at a 90° angle to the illumination plane using a better-gated cooled charge-coupled device (CCD) camera using an f/4.5 ultraviolet (UV) lens. The spatial resolution of these measurements was determined by the laser sheet thickness of ~5 mm and the imaged dimensions of the camera pixels in the object plane (~0.2 × 0.2 mm). Note that these measurements, therefore, are not line-of-sight integrated through the discharge.

To relate the signal in the raw fluorescence images to the relative CF₂ number density [CF₂], the plasma emission was first subtracted and then the images were normalized for spatial variations in laser energy and detector response. No corrections for fluorescence yield were necessary here because no signifi-

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rate primarily depends on the CF₂ (and F) concentration. The decrease in [CF₂] at low flowrates is therefore attributed to increased losses by diffusion, either by surface losses or by transport out of the imaged region. This increase in diffusional losses may result from an increase in the neutral gas temperature and, hence, diffusion coefficient (note that diffusion coefficient \( \propto T^{3/2} \)). An increase in the temperature is expected as the flowrate is reduced, because with a constant RF power and a reduced enthalpy efflux, more thermal energy accumulates within the discharge. Such an increase in the contribution of diffusion and surface recombination reactions at low flowrates has been indicated in a previous modeling of F-atom concentration in CF₂/O₂ plasmas [5].

Increasing the pressure at constant power and flowrate [Fig. 1(d)-(f)] leads to increased CF₂ density and rather dramatic changes in its distribution. These changes are due to a complex interaction among the high energy electron impact production and the various transport and loss mechanisms of CF₂. While axial (\( r = 0 \)) argon emission profiles suggest that the CF₂ production profile changes from a peaked asymmetric to a fairly uniform profile as the pressure is increased from 13.3 to 133.3 Pa, the relative roles of diffusion, gas-phase recombination, and convective losses are not as obvious. Due to these complexities, the understanding of these observed pressure-dependent CF₂ distributions would clearly benefit from detailed modeling studies.

REFERENCES


