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Electron Interactions with Plasma Processing Gases

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1 Introduction

To assess the behavior of gases in their uses in manufacturing semiconductor devices and other applications and to promote the modeling of these processes, it is necessary to have accurate information on the fundamental interactions of low energy (< 100 eV) electrons with process gases. NIST has begun the formation of a database containing fundamental electron-interaction data for gases of interest to the plasma community. In support of this effort, we have undertaken the assessment and evaluation of the available information on cross sections and rate coefficients for collisional interactions of electrons with three groups of gases: those used in etching, deposition, or cleaning (e.g., CF_4, CHF_3, C_2F_6, C_3F_8 Cl_2, and HBr), those used as buffer gases (e.g., Ar, He), and those that are present in practical systems as impurities (e.g., 0_2, N_2, H_2O). In this paper, we summarize our recommended data on cross sections and rate coefficients for the gases CF_4, CHF_3, C_2F_6 and CCl_2F_2, based upon our assessment of available data, and indicate specific electron-interaction data needs for these gases. The assessed data for the four gases are available via the World Wide Web at *http://www.eeel.nist.gov/811/refdata.*

2 Reference Data Sets

Carbon Tetrafluoride (CF_4) - Figures 1 and 2 show the assessed electron scattering cross section data [1] and the assessed electron attachment, ionization, and effective ionization coefficients for CF_4, respectively. The data on electron scattering cross sections for CF_4 are reasonably complete, as indicated by the good agreement between the total scattering cross section and the sum of the individual cross sections shown by the dotted line in Figure 1. The coefficient data are also of good quality. The few data needs include the experimental determination of direct and indirect vibrational excitation, and investigation of the apparent discrepancy between the measured cross section for dissociation into neutrals and other related cross sections (recent unpublished measurements indicate that the experimental cross section values shown here for dissociation into neutrals are much smaller than the true values).

Trifluoromethane (CHF_3) - Figure 3 shows the meager electron scattering-cross section data [2] for this important plasma processing gas. With the possible exception of the data for total dissociation and total ionization, the rest of the data in Figure 3 are approximate. Basic measurements and calculations are needed for virtually all elastic and inelastic electron scattering processes, including momentum transfer, vibrational excitation, elastic scattering, differential scattering, and electron transport, attachment and ionization coefficients. Confirmation is needed of the cross section for total electron scattering and total ionization measurements. Resolution is also needed of the discrepancy between the measured cross section for dissociation into neutrals and other related cross section data.

Perfluoroethane (C_2F_6) - Figure 4 shows the electron-interaction cross sections for this molecule [3], although many of these are still preliminary (e.g., the cross section for momentum transfer at low energies). Only the cross sections for dissociative attachment and total dissociation are recommended, nonetheless, the cross sections in Figure 4 are the most reasonable values presently available. Figure 5 shows our recommended data for attachment, ionization and effective ionization coefficients for this molecule. Cross section data are needed especially for dissociation into neutrals and vibrational and electronic excitation. Additional data are needed for the momentum transfer, elastic integral, total ionization, and total scattering cross sections.

Dichlorodifluoromethane (Freon-12, CCl_2F_2) - The available cross section data [4] for the CCl_2F_2 molecule are shown in Figure 6. They are reasonably complete but still limited. No cross section data exist on momentum transfer and dissociation into neutrals. Further measurements are needed of the total ionization cross section, and measurements of the elastic integral cross section over a broader energy range are indicated. The attachment, ionization and effective ionization coefficients are satisfactory (Fig.7).

References

[1] L. G. Christophorou, J. K. Olthoff, and M. V. V. S. Rao, *J. Phys. Chem. Ref. Data* **25**, 1341 (1996)

[2] L. G. Christophorou, J. K. Olthoff, and M. V. V. S. Rao, *J. Phys. Chem. Ref. Data* **26**, 1 (1997)

[3] L. G. Christophorou and J. K. Olthoff, *J. Phys. Chem. Ref. Data* (in press)

[4] L. G. Christophorou, J. K. Olthoff, and Y. Wang, *J. Phys. Chem. Ref. Data* **26**, 1205 (1997)

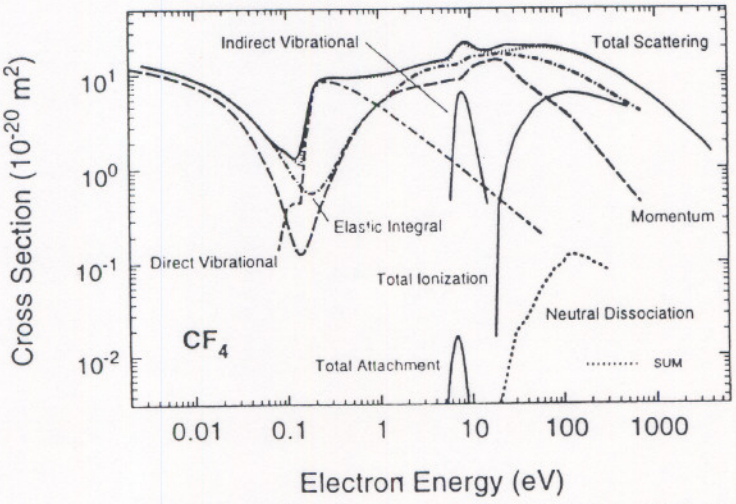

Figure 1: Electron-interaction cross sections for CF_4 [1].

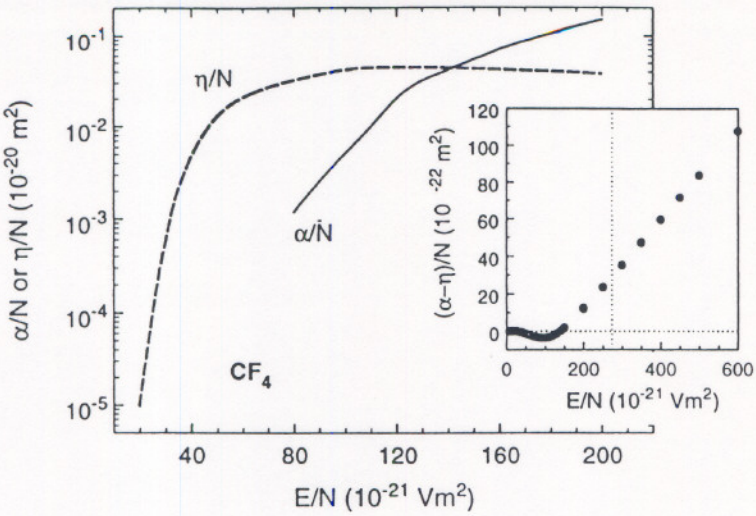

Figure 2: Electron-interaction coefficients for CF_4 [1].

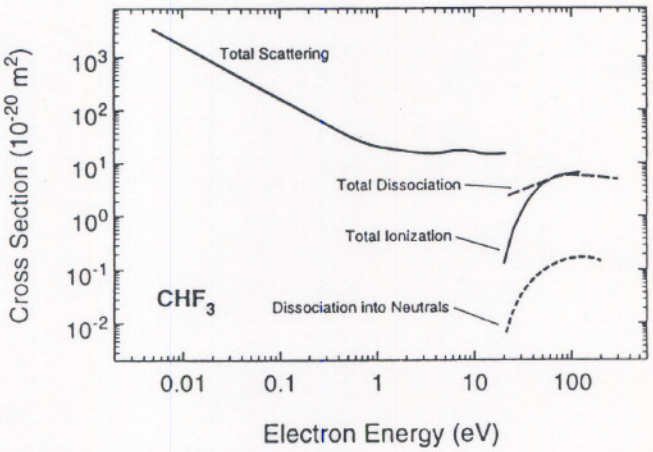

Figure 3: Electron-interaction cross sections for CHF_3 [2].

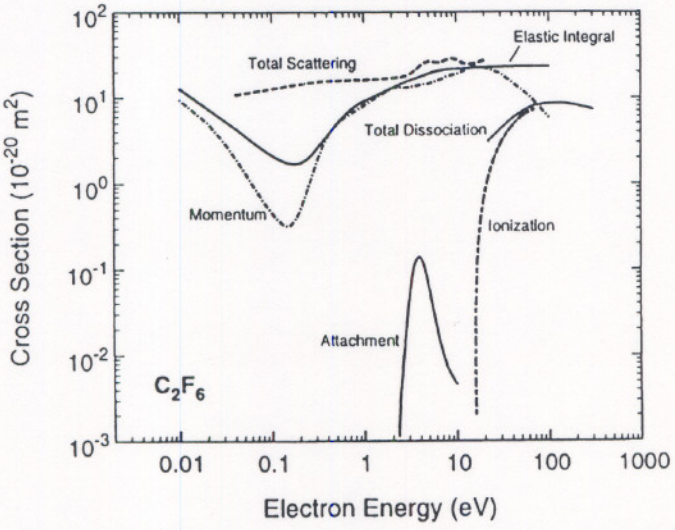

Figure 4: Electron-interaction cross sections for C_2F_6 [3].

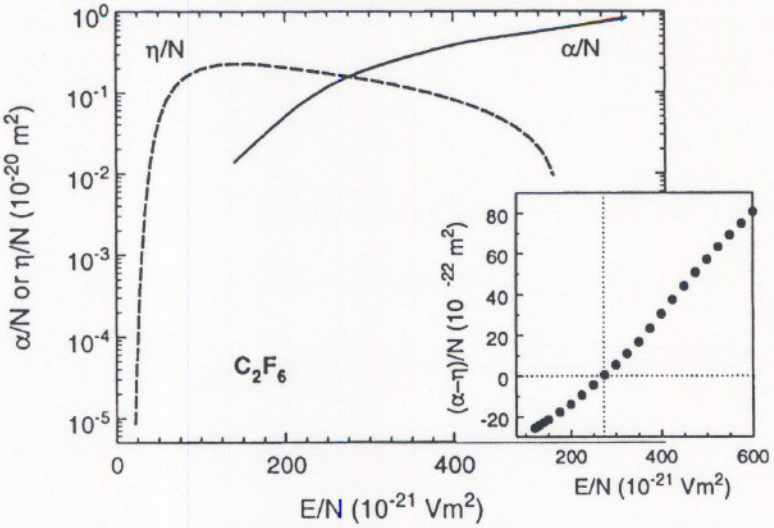

Figure 5: Electron-interaction coefficients for C_2F_6 [3].

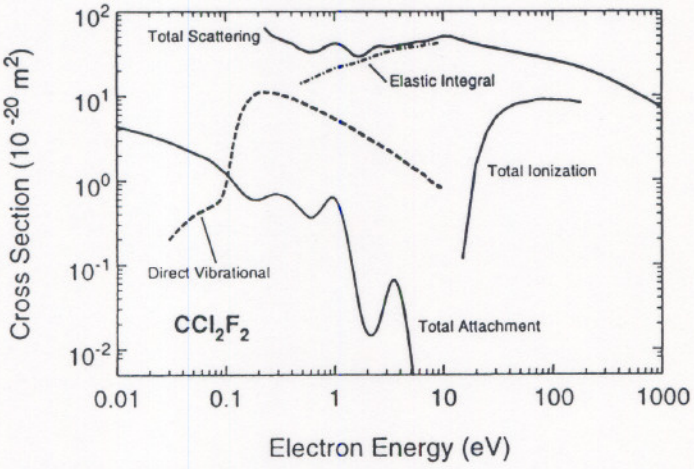

Figure 6: Electron-interaction cross sections for CCl_2F_2 [4].

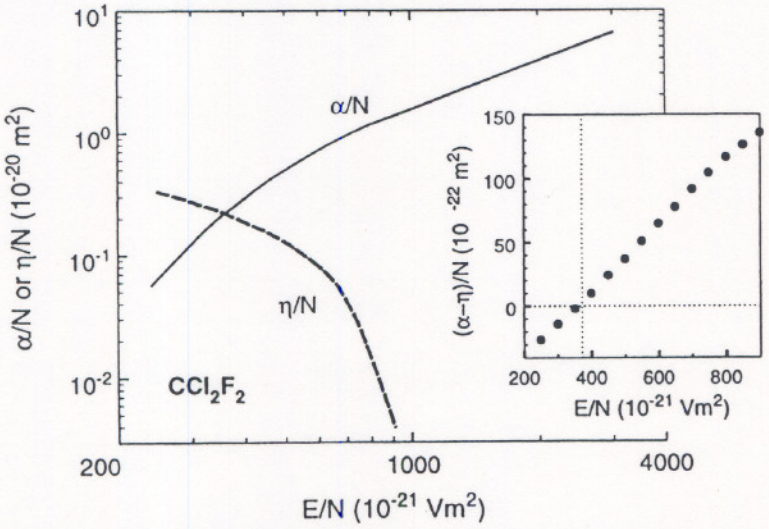

Figure 7: Electron-interaction coefficients for CCl_2F_2 [4].