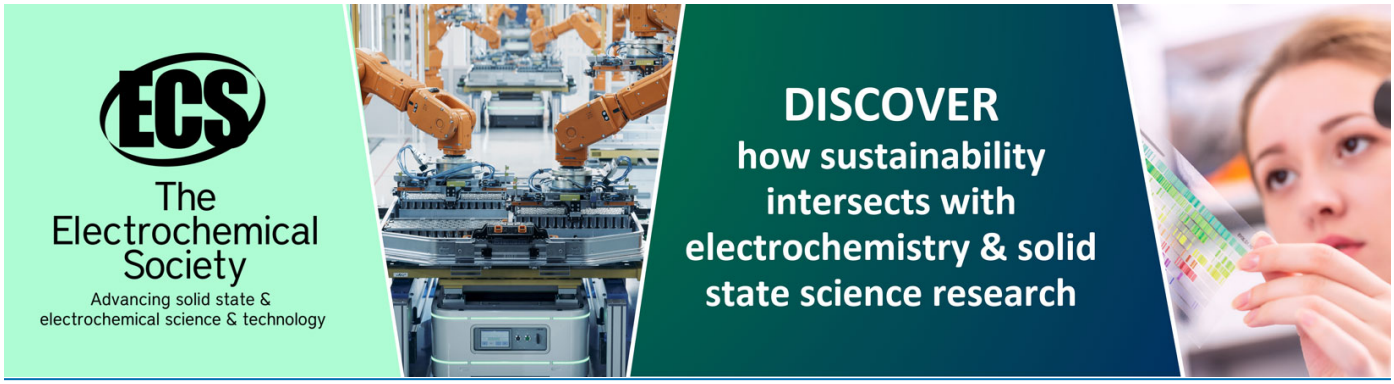
Ammonia ices under low-energy electron irradiation - Towards quantitative desorption rates and effective cross sections



Ammonia ices under low-energy electron irradiation - Towards quantitative desorption rates and effective cross sections

L Sala[1], L Amiaud[1], C Dablemont[1] and A Lafosse[1*]

[1] Institut des Sciences Moléculaires d'Orsay (ISMO), CNRS, Univ Paris Sud, Université Paris-Saclay, Orsay, F-91405, France

Synopsis Low-energy (< 20 eV) electron processing of NH_3 multilayer films, systems of interest in astrochemistry, leads to significant NH_3 desorption, fragmentation, and to a complex chemistry arising from recombination and secondary processes induced by reactive products. Quantitative desorption rates of neutral species and effective cross sections for selected processes were obtained by combining three surface-sensitive techniques: High Resolution Electron-Energy Loss Spectroscopy (HREELS), Temperature Programmed Desorption (TPD) and Electron Stimulated Desorption (ESD) of neutral species.

NH_3 is known to be a major component in ice mantles in molecular clouds with up to ~15 % of H_2O in certain regions of the interstellar medium [1]. Model predictions cannot account for the abundance of NH_3 [2], suggesting that desorption or conversion to other compounds should be considered. Among the various thermal and non-thermal mechanisms responsible [3], this study is dedicated to processes induced by low energy electrons (LEE, energy < 20 eV) [4]. LEE interactions with matter are considered to be the primary driving force in many radiation-induced desorption and chemical reactions in ices [5].

As schematized in figure 1, multilayers of NH_3 isotopologues ($^{14}NH_3$, $^{15}NH_3$, and $^{14}ND_3$) (~10 ML) were deposited on copper at 28 K and crystallized under annealing at 60 K. High-Resolution Electron Energy Loss Spectroscopy (HREELS) and Temperature Programmed Desorption (TPD) were used to control the film morphology and estimate film thickness, respectively. LEE irradiation (1-20 eV) was performed at 28 and 60 K. Electron Stimulated Desorption (ESD) was used to detect neutral fragments/molecules desorbing during irradiation while HREELS and TPD were used to characterize processed residues.

The desorption of intact NH_3 was observed which resulted in the direct erosion of the film proceeding through a mechanism consistent with desorption processes induced by electronic transition (DIET). Different fragmentation and recombination processes were also observed as evidenced by the detection of neutral radicals NH_x (x = 1,2), and stable molecules N_2 and H_2. Aside from desorption, a wealth of chemical processes was also observed at 13 eV. Temporal ESD at this energy allowed for the estimation of the effective cross section of NH_3 desorption and observing the delayed desorption of N_2 and H_2. TPD analysis of the residues also provided evidence of diazene N_2H_2 and hydrazine N_2H_4 synthesis in the film.

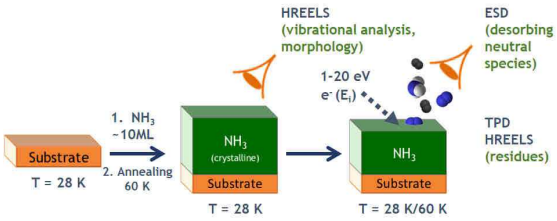


Figure 1. Scheme of the procedure used to study electron-induced processes in molecular layers of ammonia and its isotopologues.

References

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* E-mail: anne.lafosse@u-psud.fr