Electron interactions for plasma diagnostics and modelling

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The role of low-energy and high-energy electrons in discharges and plasma is well known. In the Electron Plasma Processes Laboratories (EPPL) at the Comenius University in Bratislava we are studying the low-energy processes on atoms, molecules and clusters in gas-phase. Electron ionisations, excitations and corresponding dissociative processes are measured by the means of mass spectrometry and optical emission spectroscopy, as well as a theoretical interpretation of results with quantum chemical calculations is being done. Most recently Plasma-Enhanced Chemical Vapour Deposition (PECVD) and Focused Electron Beam Induced Deposition (FEBID) precursors were studied using crossed electron/molecular beams techniques and theory.

1. Introduction

The EPPL at the Comenius University in Bratislava are dealing with mass spectrometric studies of electron *e* ionisation and dissociative ionisation reactions of molecules *M* and clusters:

$$e + M \rightarrow M^+ + 2e \quad (1)$$

$$e + M \rightarrow X + (M\text{-}X)^+ + 2e \quad (2)$$

electron attachment and dissociative electron attachment studies to the molecules and clusters:

$$e + M \rightarrow [M^-]^{\#} + 2e \quad (3)$$

$$e + M \rightarrow [M^-]^{\#} \rightarrow X + (M\text{-}X)^- + 2e \quad (4)$$

electron induced fluorescence studies via excitation of atoms and molecules and in dissociative excitation of the molecules:

$$e + M(A) \rightarrow M^*(C) + e \rightarrow M^*(B) + e + h\upsilon \quad (5)$$

$$e + M(A) \rightarrow M^*(C) + e \rightarrow X^*(B) + (M\text{-}X) + e \rightarrow X^*(A) + (M\text{-}X) + e + h\upsilon \quad (6)$$

where *X, (M-X)* represent neutral fragments of the molecule, *M**, *X** represent excited states of molecules or fragments in different electronic states.

These studies (1-4) cover measurements of the ionisation functions of the molecules (partial cross sections), determination of the reaction threshold for the reactions and the corresponding bond dissociation energies, mainly on molecular targets relevant to plasma technology, nano technology and radiation chemistry (metal-organic compounds, alkenes, halogenated compounds, amino acids) [1]. The non elastic interactions (5-6) of electrons with atoms and molecules produce emission spectra of atoms, molecules recorded at different electron energies and absolute excitation-emission cross sections, being analyzed by UV/VIS optical spectrometer [2].

2. Results

Last few years a great effort of EPPL has been applied to understand the elementary processes of low-energy electron interactions with precursor molecules relevant to nano-technology [1-5]. We have studied several precursors available for deposition of Fe, Co, Cu, Zn, Ni, Si or W layers. The most extensive studies have been performed with the $Fe(CO)_5$ precursor; with electron induced ionisation (1,2) and dissociative electron attachment (3,4) to understand the fragmentation of ionised $Fe(CO)_5$ and its decomposition to Fe^+ and Fe^- respectively; with electron induced fluorescence the excitation thresholds and Fe and CO emission bands. Most recently the gas-phase experiments were upgraded to cluster measurements of this compound to reveal the behaviour of electron ionisation and electron attachment of a precursor in larger environment.

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