

Electron and Positron Induced Chemistry; New Methods for studying chemical dynamics

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Electron and positron induced reactions in both gaseous and condensed phases initiate and drive many of the basic physical and chemical processes in science and technology with applications from industrial plasmas to radiation damage in living tissue. For example, in contrast to previous hypotheses radiation damage in the DNA of living systems has now been shown to arise primarily from collisions of very low energy (sub-ionization) secondary electrons through dissociative attachment to the components of DNA molecules or to the water around them. In the technological field electron induced reactions underpin most of the multibillion dollar modern semiconductor industry since it is those reactive fragments produced by electron impact of etchant gases that react directly with the silicon substrate².

Electron induced processes are also of extraordinary importance for determination of structure and chemical reactivity of species adsorbed on surfaces, while positrons are proving to be a useful new solid state probe for surfaces, interfaces and defect profiling. Indeed recently it has been demonstrated that, using STM based technology, discrete electron reactions may be performed at the individual molecular level thus introducing the prospect of designer synthesis on the nanoscale. New bond-selective molecular fragmentation induced by low energy positrons has also recently been demonstrated, positrons exhibiting a high chemical selectivity in the dissociative ionization of organic molecules. Thus it is now possible to develop a new '*antimatter chemistry*' that can lead to the development of novel chemical synthesis techniques.

The energy region below 3 eV is of particular interest since here the cross sections for both electron and positron-induced processes show a general reciprocal energy dependence. In addition, at energies where the positronium atom Ps (a bound state of an electron and positron) can no longer be formed, chemical reactions may be induced by low lying transient anion and cation states formed by the attachment of electrons and positrons, respectively. These quasi bound states are provided by the short range polarization interaction induced when an electron or positron approaches a target molecule. In the case of dissociative electron attachment (DEA) in many systems a 100 % selectivity with respect to the cleavage of a particular bond can be obtained! Dissociative positron attachment (DPA) is only just beginning to be studied but the first results indicate that hydrocarbons can effectively bind positrons while fluorocarbons do not, for electron attachment the situation is reversed. In particular breaking of single, double or triple bonds can be obtained in ring hydrocarbons by varying the positron energy between a few tenths and a few eV energies much lower than those needed with electrons, while studies of positron impact on halogenated hydrocarbons (eg CH₃F) have shown that ionized fragments emerge with much lower kinetic energy spread than in the case of electron induced ionization. This opens interesting prospects for a selective chemistry induced by electrons and positrons. It should also be noted that electron induced processes are often directly linked to photon induced processes since photons of sufficient energy excite or liberate electrons from targets which may then drive the local chemistry.