Cathodoluminescence analysis of space used polymers

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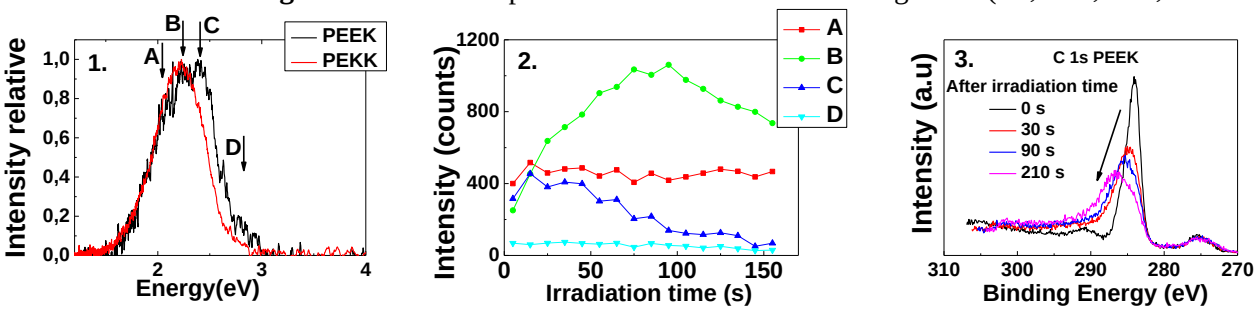
Dielectric materials used on spacecraft have to cope with strong levels of charging under electron irradiation in space environment. This charging process could lead to potential hazardous discharges and electric arcs on different parts of the satellite generating anomalies, such as electromagnetic disturbances, power losses, and, in worst case, the destruction of some on-board systems. It is therefore essential to test and qualify space materials under representative conditions and to assess their electrical and optical properties.

It has been shown previously [1], that charging effect is usually smoothed by ionization processes due to high energy electron irradiation that enhances significantly the bulk electrical conductivity in space materials (Radiation-Induced Conductivity "RIC"). Models based on solid-state physics have been developed at ONERA to describe and predict charge and ionization effects of space materials. These models take into account the effects of: charge carrier generation, trapping-detrapping and recombination. Some physical mechanisms are however not taken into account such as: radical formation, energy transfer processes, ageing effect. To improve our understanding of charge transport mechanisms in space used materials, we have developed several experimental techniques including cathodoluminescence spectroscopy (CL). This technique is interesting for extracting transition energies and bringing into evidence ageing processes. CL is the photon emission from electron bombardment that induces energy transfer to and from the material. This technique is relevant to characterize several mechanisms (radical formation, recombination, trapping, defect and impurities) occurring in irradiated materials. In this paper, we present the results of two polymers having a close chemical structure, PEEK (poly-ether-ether-ketone) and PEKK (poly-ether-ketone-ketone). These materials are used as wiring, insulating parts and mechanical support on spacecraft. Charge transport in these polymers is very complex and CL would bring new information on radiation processes occurring during irradiation. A parametric study on PEEK and PEKK was carried out (chemical structure, irradiation time/dose and temperature) in order to improve our knowledge on the nature and occupation of trapping sites, and creation and influence of radical formation and recombination processes.

PEEK and PEKK showed the same spectral contributions (A → D) but at different intensities (Fig.1). This observation means that the trapping or recombination centers at the origin of the radiative transitions are identical (in relation to the chemical structure) but at different yields. These discrepancies on their spectra could be assigned to ether and ketone groups. Fig. 2 shows the evolution of each contribution as a function of the irradiation time with electron beam. This behavior was attributed to the degradation of the material (chemical bond scission, crosslinking …)[2]. To support our analysis, we performed XPS (X-ray Photoelectron Spectroscopy) tests to assess the chemical degradation of materials. Fig. 3 shows one of the spectra (C1s) obtained on the PEEK. This evolution reveals a modification of the chemical structure. The increase of the shoulder towards high binding energies could be attributed to the creation of new chemical groups (carboxylic acid - ester - aldehyde ...) following the scission of the main chain[3]. CL tests were also performed at 150 K to 300 K (not shown here). For PEEK, the lowering of luminescence intensity with decreasing temperature could be related to oxygen due to polymer fragmentation possibly quenching the luminescence[4].

Figure 1: CL spectra of PEEK and PEKK. – **Figure 2:** Evolution of contributions (A to D) as a function of irradiation time. – **Figure 3:** XPS C 1s spectra for PEEK for the following times (0 s, 30 s, 90 s, and 210 s).



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