Depth Profiling Analysis of Metallic Nanolayers on Polymer Films for Microelectronics Applications by Secondary Ion Mass Spectrometry

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The characterization of solids, surfaces and thin films has represented a great challenge in many fields and it has been faced by several disciplines, such as Material Science, Solid State Physics or Analytical Chemistry, among others. Furthermore, most of the developments achieved in nanotechnology have been inevitably linked to the availability of characterization techniques allowing a deep knowledge of the chemical composition, morphology and interfacial chemistry of multilayered samples in the sub-micron scale. In this context, secondary ion mass spectrometry (SIMS) has been consolidated as one of the most powerful techniques due to its outstanding capabilities in terms of sensitivity, specificity and spatial resolution, both lateral and in-depth resolutions.

The in-depth analysis of nanometric metallic layers deposited over thin polymeric films by secondary ion mass spectrometry (SIMS) is presented in this work. These metallized polymer films are used in the capacitor industry, offering a great number of advantages over other types of film capacitors, such as paper-foil or plastic films, mainly derived from their customized size and improved technical performance. The capacitors are made of a thin polymer film acting as the dielectric material, typically biaxially oriented polypropylene films (BO-PP) or polyethylene terephthalate (PET), with thicknesses ranging between 5 and 15 µm. These polymer films are metallized by physical vapour deposition (PVD) with nanometric metallic layers composed of pure Al, pure Zn or a dual- metallization Zn/Al. The thickness of the metallic layer ranges between 5 to 100 nm. The metallized film capacitors are susceptible to modifications in the metal/polymer interface structure and composition which may strongly decrease their functionality [1].

Dynamic SIMS (d-SIMS) depth profiling provides layer-by-layer analysis of the metallized film with subnanometric resolution and complete atomic/molecular information generated by the analysis of the fragments emitted during the sputtering process. Furthermore, the secondary ion yield is very sensitive to modifications in the oxidation state of the elements present in the specimen, representing an excellent alternative to monitor possible oxidation processes along the multimaterial structure. However, several experimental considerations must be taken into account due to the presence of isobaric interferences coming from the different matrices ($^{27}Al^+$/$^{43}AlO^+$ from the metallized layer and $^{27}C_2H_3^+$/$^{43}C_3H_7^+$ from the polymer film) and the different electrical behaviour of the involved layers. The development of an energy-resolved depth profiling method has allowed the discrimination of these isobaric species according to the different kinetic energy distribution of the secondary ions from the involved matrixes [2].

SIMS has provided important results about the origin of the morphological and chemical degradation of metallized polymer films, relating the surface and interstitial chemistry modifications with severe failures in the capacitors performance. Although the polymer film is a hydrophobic material, it exhibits significant permeability to moisture and oxygen, allowing the oxidation from both sides of the vapour-deposited metallic layer. The presence of the diverse oxidized species related to the main constituents of the metallization layer has been identified in degraded samples. The in-depth analysis of these altered regions shows high contents of oxides and hydroxyl species (AlO^+ and $AlOH^+$).The presence of interstitial moisture and demetallization processes have been also related to the capacitance losses during capacitor testing and service life [3,4].

References:

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