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Investigation of metal diffusion into polymer films by measurement of quantitative LA-ICP-MS depth profiles

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Polymers are nowadays part of uncountable aspects of our daily lives, reaching from relatively trivial applications, e.g., packing materials, to highly demanding technological applications. An application where the polymer properties have to meet specific requirements is the use for electrical insulation and corrosion prevention in electronic devices. The electric fields, the increased temperature, and ambient humidity during operation can cause degradation of the polymer but also induce the diffusion of the conducting materials into the polymer. The introduction of metals into the polymer layer is of particular interest since it leads to an increased conductivity and thereby an increased risk of component failure.

To investigate the diffusion of metals into polymers, suitable testing equipment, as well as analytical techniques, are required. Conventional methods for elemental analysis of polymers, i.e., sample combustion or digestion followed by liquid ICP-MS/OES analysis, are not appropriate since they do not allow a differentiation between the metal on the surface and the metal ions that have diffused into the polymer. Moreover, these approaches require work-intensive sample preparation and provide only bulk information. To overcome these limitations, LA-ICP-MS is a very attractive method for direct solid sampling, offering high sensitivity and the possibility of spatially resolved analysis.

This work investigates the diffusion of aluminum and copper into polyimide. Polymer films with a thickness of 6 µm and attached metal electrodes were weathered within a climate chamber, exposing them to increased temperature, humidity, and an electrical bias. Additionally, samples were treated on a heating stage with temperatures from 100 to 300 °C for different time intervals. Subsequently, quantitative determination of Al and Cu depth profiles in the aged samples was performed via LA-ICP-MS. The measurements were performed with a 193 nm Excimer laser, offering a sufficiently high depth resolution in the order of 100 nm. Derived findings give insight into the metal diffusion into the polymer and the influence of temperature, humidity, bias, and time.

LA-ICP-MS, metal diffusion, polymer analysis