

Mapping the ionic conductivity of a solid polymer electrolyte by non-contact AFM

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The study of the physical properties at the nanometer scale is becoming a key aspect for understanding the relations between the molecular organization and physical behavior in nanostructured polymers. For example, AFM-based electrical measurements in polymers are increasingly used to map the nanoscale conductivity in systems with potential applications, as semiconductors and electrolytes. Typically, this requires setting-up an electrical contact with the polymer surface, usually done by bringing the AFM probe into direct contact with the sample. However, since polymers are soft materials, these contact-based techniques might lead to sample scratching and plastic deformation. To overcome this issue, in this work we present “nanoDielectric Spectroscopy (nDS)”. [1,2] This non-contact AFM technique allows the electrical mapping of surfaces, by applying an AC bias to the AFM probe at a fixed electric field frequency (f). nDS provides maps with information related to the components of the complex dielectric permittivity (ϵ^*) of the samples. In addition, it is possible to carry out dielectric spectroscopy measurements ($f = 1 \text{ Hz} - 100 \text{ kHz}$) at fixed points on the sample's surface (Figure 1). These measurements can be analyzed under the framework of classical electrodynamics and allow the study of transport properties. As a case of study, we will present nDS experiments on poly(ethylene oxide) (PEO) thin films. PEO is a semicrystalline polymer that at room temperature shows a dielectric relaxation signal related to charge trapping between amorphous/crystalline interfaces. This phenomenon is connected to the ionic conductivity of the amorphous phase of the material. We will present nDS images and spectra of PEO at room temperature, with 40 nm lateral resolution, and in a humidity range of 15 – 60%. The nDS results were analyzed taking into consideration the role of the tip/sample geometry and allowed us to obtain the material's complex dielectric function. We modeled our results following the Maxwell-Wagner-Sillars theory. This provided relevant physical parameters such as the DC-conductivity of the amorphous phase, and its dependence with relative humidity.

References

- [1] L. A. Miccio, M. M. Kummali, G.A. Schwartz, A. Alegria and J. Colmenero. Journal of Applied Physics 115 (2014)184305
- [2] D. E. Martínez-Tong, L. A. Miccio and A. Alegria. Soft Matter 13 (2017) 5597-5603

Figures

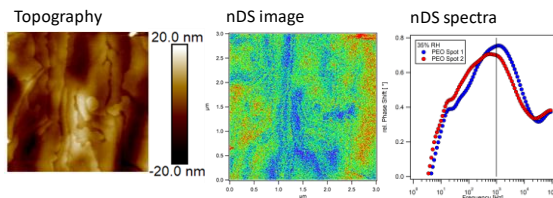


Figure 1: AFM topography image of a PEO film (left) and nanoDielectric Spectroscopy measurement (right).