

**Probing dielectric constant on the nanoscale:
from thin films to DNA and two-dimensionally confined water**

Laura Fumagalli

*School of Physics and Astronomy - Condensed Matter Physics group and National Graphene Institute
University of Manchester, Oxford Road, Manchester, M13 9PL, UK*

Contact: laura.fumagalli@manchester.ac.uk

Electric polarizability (or dielectric constant) is a fundamental physical property that plays a crucial role in a variety of phenomena and disciplines, from physics and materials science to chemistry and molecular biology. It is inherently linked to charge storage and transport in energy and electronic devices. It modulates various forces (Coulomb, van der Waals, solvation and hydration) between macromolecules and, therefore, is crucial in macromolecular assembly and interactions. For many decades, dielectric spectroscopy has been one of the main methods used for sample characterization. Yet, despite a massive amount of literature, the dielectric polarization properties at molecular level have essentially remained unknown for great difficulties in measuring an electric response on such a small scale.

In this talk, I will review our work in which we developed Scanning Dielectric Microscopy, a scanning probe technique able to probe the dielectric constant on the nanoscale based on current [1,2] and electrostatic force [3,4] sensing. We determined the local dielectric constants of a variety of nanostructures and biological samples for the first time: from thin oxides and biological membranes [1,2,6] to single nanoparticles [3], viruses [3,4] and bacteria [5]. We demonstrated that measurements can be done in electrolytic environment [7] and extended up to the microwave regime (GHz frequencies) [8]. Noteworthy, we resolved the dielectric constant of DNA [4], a critical parameter for understanding DNA-protein interactions, and recently, the dielectric constant of few water layers confined between atomically thin crystals [9]. For many decades, it has been speculated that the dielectric constant of water near surfaces should be different from that of bulk water. Our experiments revealed the presence of an interfacial layer with vanishingly small polarization. The electrically dead layer was found to be two to three molecules thick, in agreement with the thickness predicted by molecular dynamics calculations. Our results provide much needed feedback for theories describing water-mediated surface interactions and behaviour of interfacial water.

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