Quantifying the quasi-static dielectric response of nano-objects by imaging electrostatic forces

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Abstract

Understanding long-range interaction forces between small objects is of fundamental importance in materials science and nanotechnology. In particular, electrostatic forces are related to the intrinsic dielectric properties of materials and are essential for assembling molecular electronic devices. However, quantitative detection and interpretation of electrostatic forces remains extremely difficult, particularly for dielectric nano-objects, because they are inherently weak and primary sensitive to geometric effects (shape and size) of the objects. Our group has dedicated all its efforts in recent years to achieving this goal, and succeeded in resolving the dielectric constants on the nanoscale for flat and large insulating films [1-4] using scanning force microscopy techniques. But for small dielectric objects, it is a much more challenging task because the signal is significantly weaker in front of an increased geometrical impact.

Here we present the experimental demonstration that the dielectric constant ε_r - the permittivity in quasi-static regime - of small dielectric objects can be precisely measured from electrostatic forces probed by scanning force microscopy operated in electrostatic mode (EFM). [5] By precisely quantifying the electrostatic forces, we resolved the intrinsic dielectric response of small insulating nano-objects, biomolecular membranes and macromolecular complexes that cannot be measured in bulk due to their complexity or softness. These results open new possibilities for non-destructive, in-situ and quantitative characterization of dielectric proprieties of nano-dielectrics and macromolecules that have so far remained inaccessible. Extension of this approach to measurements in the liquid environment [6,7] will be also discussed.

References

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