Scanning Probe Microscopy For Nanoelectronics

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ABSTRACT

Recent focus of Scanning Probe Microscopy (SPM) developments has been to further push the technology closer to its physical limits. We will present a few aspects of these developments relevant to nanoelectronics. This includes: high resolution structural imaging at lower forces or higher throughput, quantitative nanomechanical characterization, and advances in electrical and chemical property measurements.

High resolution structural imaging at lower forces & higher throughput:

Compared to more conventional imaging modes (for example: contact mode and Tapping mode), Peak Force Tapping provides improved tip-sample force control and the possibility to operate at lower forces (down to tens of pN). This enables longer tip lifetime, improved resolution, and more accurate imaging of delicate sample structures. The Peak Force Tapping method is explained and illustrated with various examples, including deep trench structures as well as soft, fragile materials. Imaging speed is the second aspect of structural imaging addressed here. SPM throughput increase is illustrated by both automated parameter optimization techniques as well as improved scanning hardware.

Nanomechanical characterization:

The lack of quantitative measurements of mechanical properties at the nanoscale has been identified as a bottleneck for the development of new materials. To achieve reliable mechanical measurements with temporal resolution of nanoseconds and spatial resolution of nanometers, we have explored and optimized several approaches, namely, tapping harmonics, contact resonance and Peak Force Tapping. These methods now allow us to achieve highly consistent modulus, adhesion, deformation & dissipation measurements that are scalable for materials from a few MPa to tens of GPa. Examples are shown of simultaneous mapping of these mechanical properties with morphology at the nanometer scale.

Advances in electrical & chemical property characterization:

Today, a wide range of SPM-based electrical characterization methods is routinely applied in the study of nanoelectronics materials and devices. This application range has been further expanded with the availability of new methods. An example is the combination of Peak Force Tapping with Conductive (or Tunneling) AFM, allowing one to measure soft or fragile samples, previously not accessible with contact-based methods. Other improvements focus on environmental control (higher repeatability & reliability) and the elimination of the effect of the AFM laser light (eliminate light-induced artifacts).

The combination of a Raman spectrometer with SPM methods allows one to correlate chemical information with SPM-generated nanoscale information. Two approaches are rapidly gaining interest and application ranges: (i) Co-localized measurements in which SPM and Raman measurements are sequentially performed at the exact same sample location, providing correlated material information, and (ii) Tip-Enhanced Raman Scattering (TERS): By holding a specially-prepared SPM tip a few nanometer from the sample's surface, highly-localised enhanced Raman signals can be generated by increasing the strength of the electromagnetic field through surface plasmons supported at the apex of the tip. This can result in Raman maps with resolution beyond the diffraction limit, again correlated with other SPM-generated material information.