IRis

Northeastern University

Center for Nano and Microcontamination Control Proposals

Center for Nano and Microcontamination Control

January 01, 2001

Techniques for finding and characterizing defects and contaminants

Nathan E. Israeloff
Northeastern University

Ahmed A. Busnaina
Northeastern University

Recommended Citation

Israeloff, Nathan E. and Busnaina, Ahmed A., "Techniques for finding and characterizing defects and contaminants" (2001). *Center for Nano and Microcontamination Control Proposals.* Paper 3.

This work is available open access, hosted by Northeastern University.

Proposal #2: Techniques for Finding and Characterizing Defects and Contaminants

Nathan Israeloff, Ahmed Busnaina, Northeastern University

Goals and Objectives

The goal of this work is to develop new techniques for locating and characterizing surface and buried defects and contaminants. We propose to apply recently developed scanning probe microscopy (SPM) techniques toward this goal and to develop these and other techniques into useful imaging and spectroscopic tools. The effect of contamination on nanoscale electrical transport, dielectric properties, and electronic noise will be studied. Will develop SPM techniques into useful tool for locating and characterizing surface and buried defects. Initially we will study insulating layers with well characterized buried defects (insulating, metallic, voids). Use frequency-dependent susceptibility to locate leakage across insulating layers. Study wafers and devices with known and unknown contaminants. Locate noisy traps, correlate with device noise. Study structural relaxation in particles during adhesion.

Project Description

Metallic or insulating contaminants buried in insulating layers or at interfaces can lead to problems such as leakage current and noisy interface traps. Voids in insulating layers may be problematic or useful in lowering dielectric constant. The adhesion of nano-scale particles on surfaces is an important problem that needs to be fully understood. Techniques for measuring local dielectric properties[1], based on scanning probe microscopy, have the potential to locate and identify metallic or dielectric contaminants up to 50 nm beneath the surface of dielectric layers.

We have used an extremely sensitive non-contact technique in which the SPM cantilever is driven at its natural resonance frequency in vacuum[2]. See figure 1. The resonance is detected with a frequency-modulation technique.[3] The sharp SPM tip is biased relative to the wafer, which is coated with a dielectric film (e.g. polymer or oxide). The resonance frequency shifts down when the tip approaches the surface due to attractive electrostatic forces. The shift is proportional to the local dielectric constant, ε, beneath the tip. We have used this technique to study local dielectric relaxation in glassy polymer films[4]. We have also developed SPM techniques for studying the complex frequency-dependent dielectric susceptibility, $\varepsilon(\omega) = \varepsilon'(\omega) + i\varepsilon''(\omega)$, which can reveal dissipation mechanisms. We propose to use the magnitude and frequency-dependence of the dielectric loss tangent $\tan\delta = \varepsilon''/\varepsilon'$, to locate current leakage and regions susceptible to dielectric breakdown.

We have recently been able to observe the dynamics of individual buried defects in polymer films with SPM[5]. These dipolar defects produced spontaneous noise in the form of random telegraph signals, which indicated these defects had a small number of discrete polarization states. We propose to use this technique to monitor structural rearrangements in nanometer sized PSL beads as they undergo aging and deformation during adhesion[6], in order to gain a better understanding of adhesion mechanisms. In addition we propose to use this technique to find and characterize noisy traps at conductor-insulator interfaces, and to correlate the observed traps to noise in the underlying conducting layers.

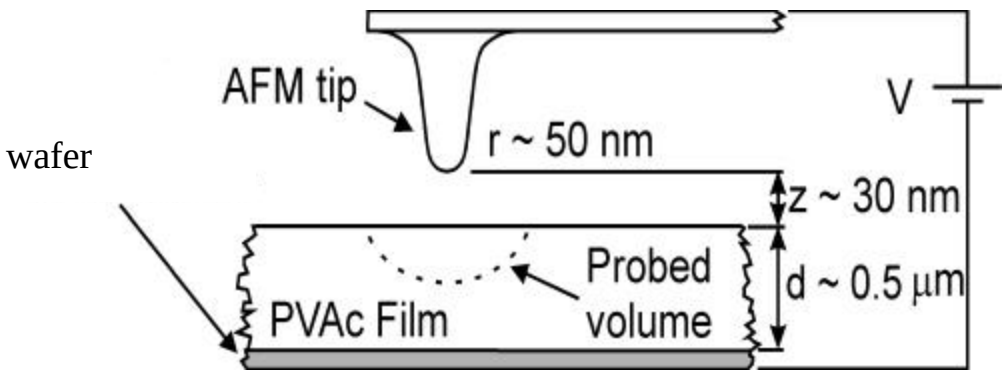

Figure 1. The atomic force microscope tip and wafer form a capacitor with polymer dielectric film inside. The cantilever resonance frequency is influenced by electrostatic forces.

1. Y. Martin, D.W. Abraham, and H.K. Wickramasinghe, Appl. Phys. Lett. **52** 1103 (1988).
2. T. R. Albrecht, P. Grütter, D.Horne, and D. Rugar, J. Appl. Phys. **69**, 668 (1991).
3. L. E. Walther, N. E. Israeloff, E. Vidal Russell, and H. Alvarez Gomariz, Appl. Phy. Lett. **72**, 3223 (1998).
4. L. E. Walther, N. E. Israeloff, E. Vidal Russell, and H. Alvarez Gomariz, Phys. Rev. **B57** (Rap. Comm.), R15112 (1998).
5. E. Vidal Russell, N. E. Israeloff, *Nature* 408, 695 (2000).
6. J. Tang and A. Busnaina, J. Adhesion, Vol. 74, pp. 411-419, (2000)