Development of New Methods for Locating and Characterizing Defects and Contaminants

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INTRODUCTION

• Where are defects and contaminants?
  – Surface
  – Buried in insulating layers
  – Interfaces

• What type?
  – Voids
  – Insulating or metal particles

• What do they cause?
  – Shorts across insulators
  – Noisy traps
  – Built-in voids for low \( \varepsilon \)
Can we develop methods based on scanning probe microscopy (SPM)?

- buried particle
- particle
- void
- current leakage
- electron trap
- insulating layer
- metal
- wafer

Israeloff and Busnaina
Local dielectric properties can be probed with SPM

- Spatial variations in dielectric constant.
  - Buried particle detection
- Defect characterization with dielectric susceptibility.
  - Insulator or metal contaminants
  - Leakage across insulators
- Time-dependent changes in dielectric constant.
  - Buried noisy defects and electron traps
  - Study particle adhesion process

Acquiring new state-of-the-art high-sensitivity variable temperature SPM
Local dielectric relaxation

- Dielectric relaxation measured in 50 nm region of polymer film via cantilever resonance.

- Discrete steps in relaxation observed.

Dielectric Susceptibility with SPM

- Frequency dependent dielectric susceptibility
- \( \tan \delta = \varepsilon''/\varepsilon' \) measured locally in polymer film
- reveals presence of dissipation
- can distinguish resistive loss (e.g. leakage) from dielectric loss in insulators.
Individual buried defects in insulating layers observed and characterized with SPM

- Spontaneous time-dependent variations in dielectric constant observed in polymer films.
- Buried individual noisy defects produce random-telegraph-noise.
- Sensitive to depths of 50 nm.


Structural relaxation in PSL spheres during adhesion not well understood
Deformation of PSL Spheres (0.99 micron) with Time

FIGURE 8. Contact area versus time for submicrometer polystyrene particles on silicon.
Time Effect on Removal Effectiveness for Different Particle Diameters

![Graph showing the effect of time on removal efficiency for different particle diameters. The graph plots deposition time in hours against removal efficiency as a percentage.]
Scanning electron micrographs of glass particles of different sizes on a highly compliant polyurethane substrate.
SPM study of adhesion
Summary and Outlook

• Will develop SPM techniques into useful tool for locating and characterizing surface and buried defects.
• Initially 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.