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Electrical Property Measurements of Dielectric Films Using a Nanoindentation Platform

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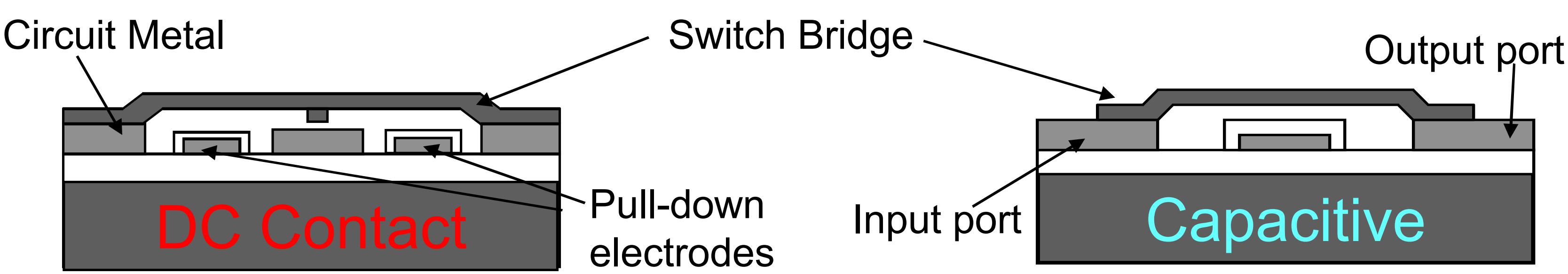
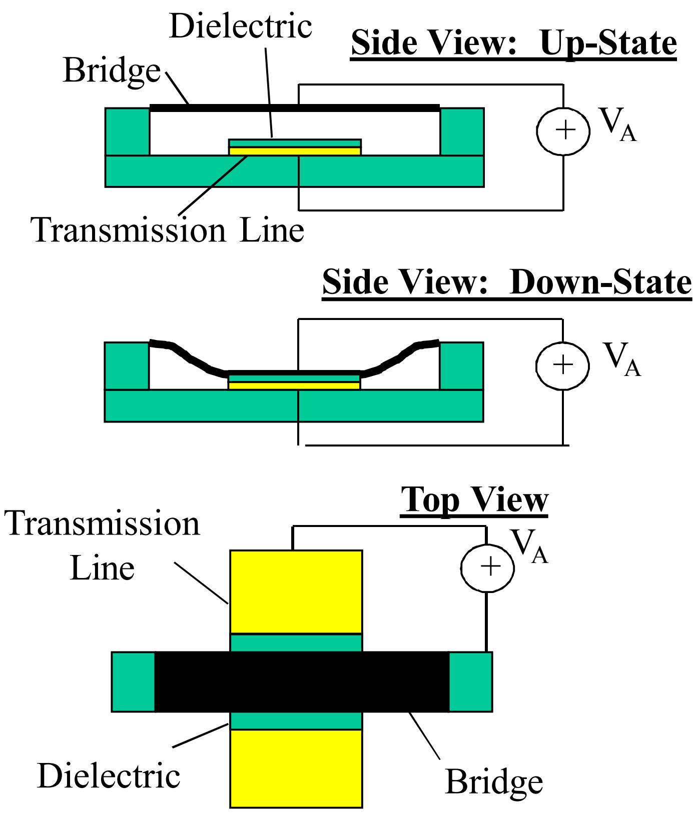
RF MEMS Switches

- 2 Types of switch contact mechanisms
- Mechanical action of the switch "shorts" the circuit
  - DC switch
    - Ohmic contact across the switch
  - Capacitive switch
    - Capacitive susceptance of dielectric sandwich



Why use MEMS switches?

- **MEMS switches show superior performance compared to solid-state devices (PIN or FET) in virtually every aspect**
  - **Low Insertion Loss (~0.1 dB)**
  - **Very High Isolation (~20 to 60 dB)**
  - **Low Power Consumption**
  - **Wide Frequency Band (DC to 40 GHz, Capacitive to 100 GHz)**



MEMS switches pair the performance of electromechanical switches with low cost and size of solid state switches.

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Issues with MEMS switches?

- Primary disadvantages are
  - Voltage requirements (electrostatic actuation)
  - Switching time
    - Microseconds compared with nano- to picoseconds
  - Low power handling capability
    - Less than 1 W
  - Issues with reliability
    - Mechanical fatigue
    - Stiction of components
    - Trapped charge

Origins of trapped charge

- **Trapped charge arises from:**
  - **Device actuation**
    - **High pull-down fields**
  - **Tribocharging**
    - **Transfer of electrons from one surface to another during contact**
  - **Dielectric processing**
    - **Bulk charges**
    - **Surface (interface) charges**
    - **Plasma processing**

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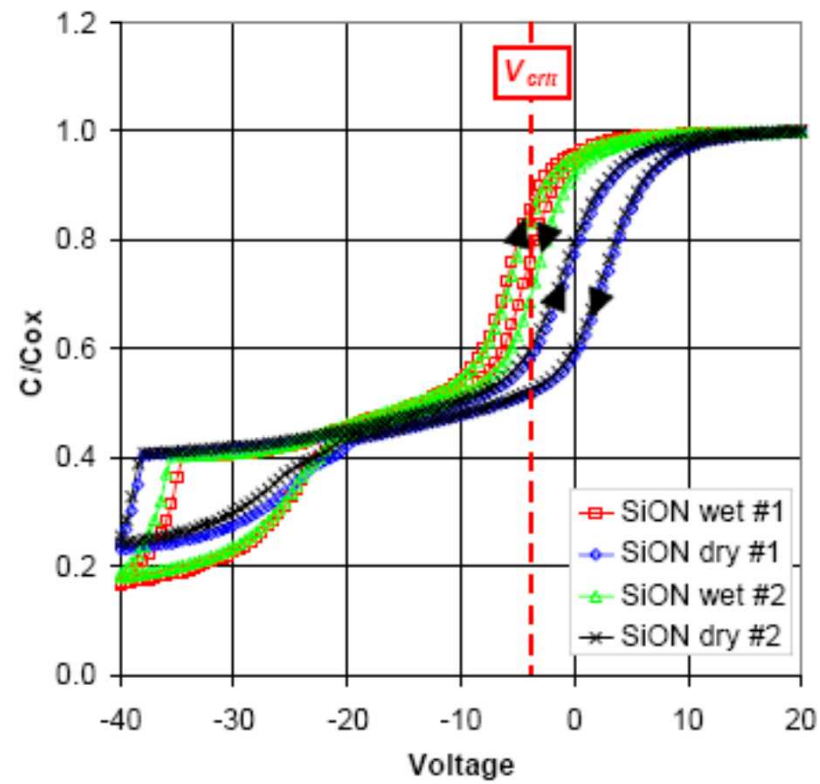
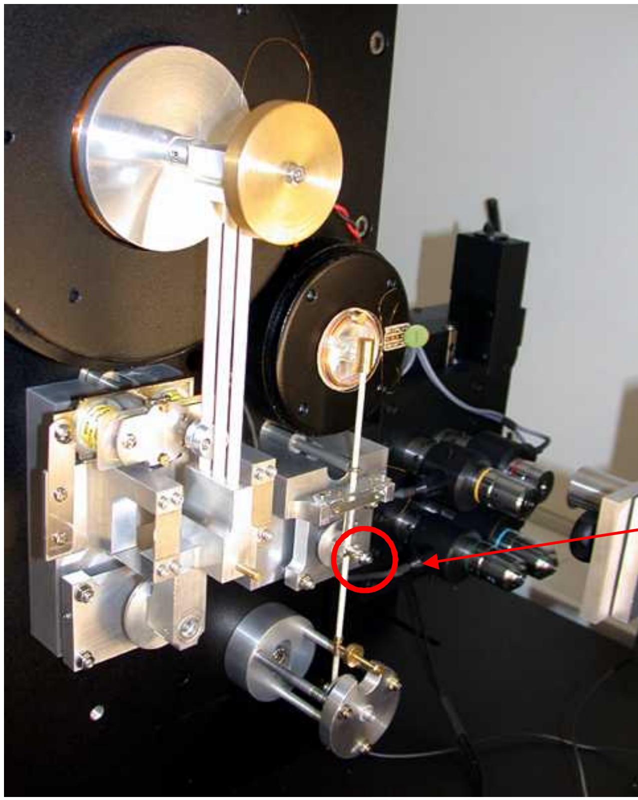
MEMS C-V curves – Previous Work

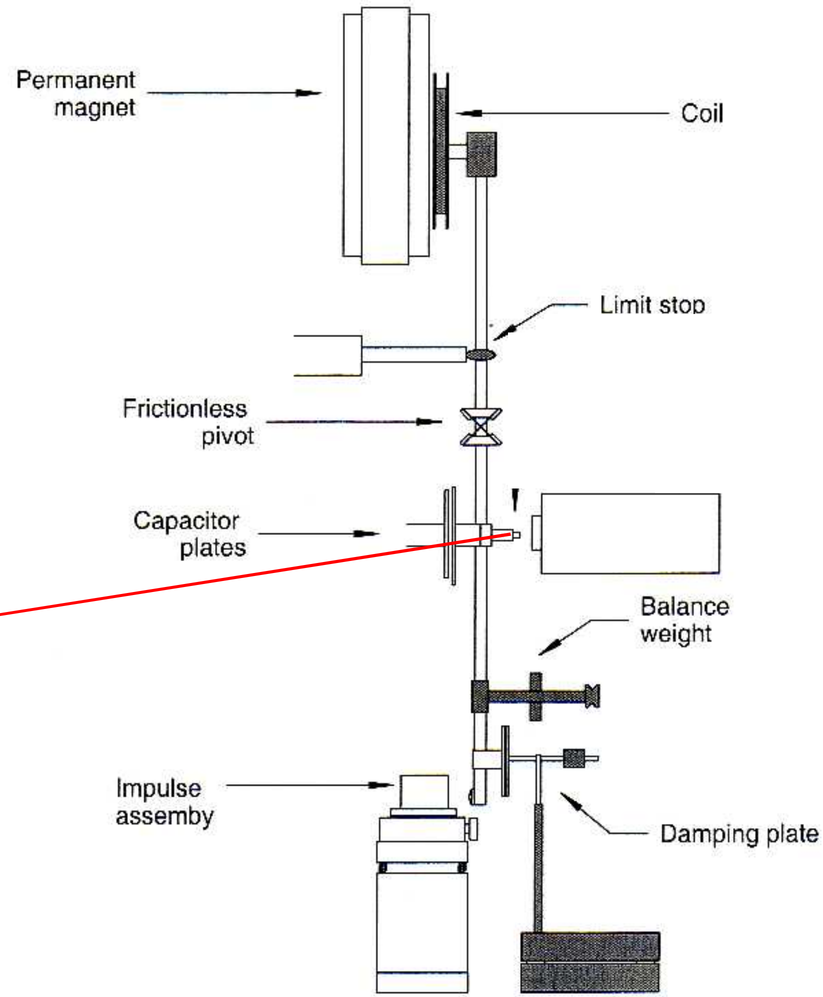
- **Shallow slope indicates interface states**
- **Shift of curves due to dielectric damage**
  - **Plasma-induced damage**



C/V data courtesy of J. Webster

Nanoindentation Setup





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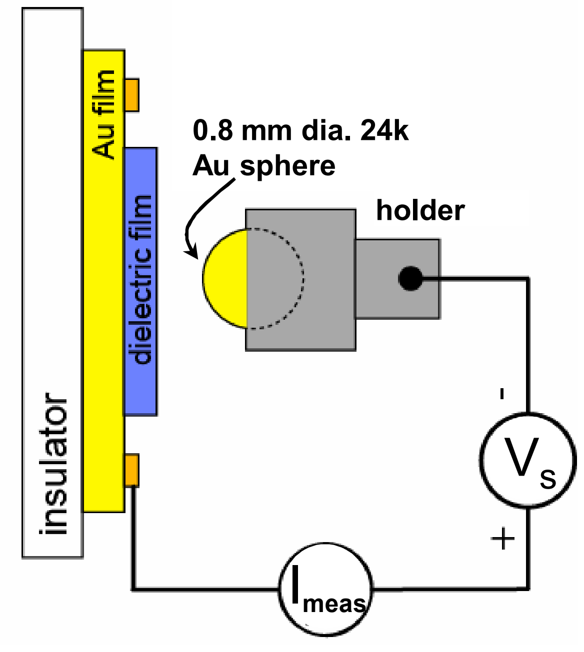
Schematic of I-V setup

- Experiments performed in dry N2
  - Relative humidity below 0.1% (Dew point of ~ -40°C)
- Applied load of 1 mN
  - Contact area ~ 13 μm^2
- Use Keithley 6517A
  - High resistance sourcemeter



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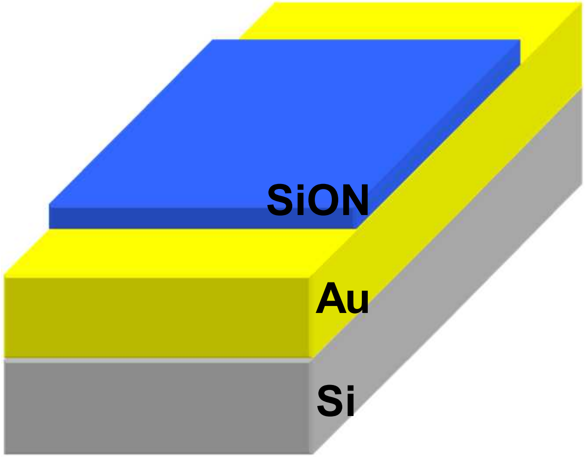
SiON sample coupons

- (100) Si substrate
- 2 µm electroplated Au
- SiON deposited with 13MHz glow-discharge
  - ~300 nm thick

- “Wet” release (Solvent)
  - 80°C NMP, Methanol, supercritical CO_2

- “Dry” release (Plasma)
  - Same as “wet”
  - 90 min, 250W ashing plasma



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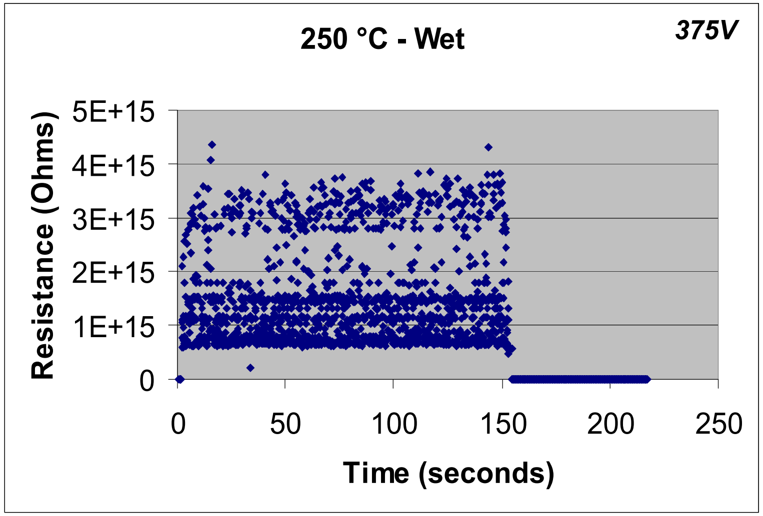
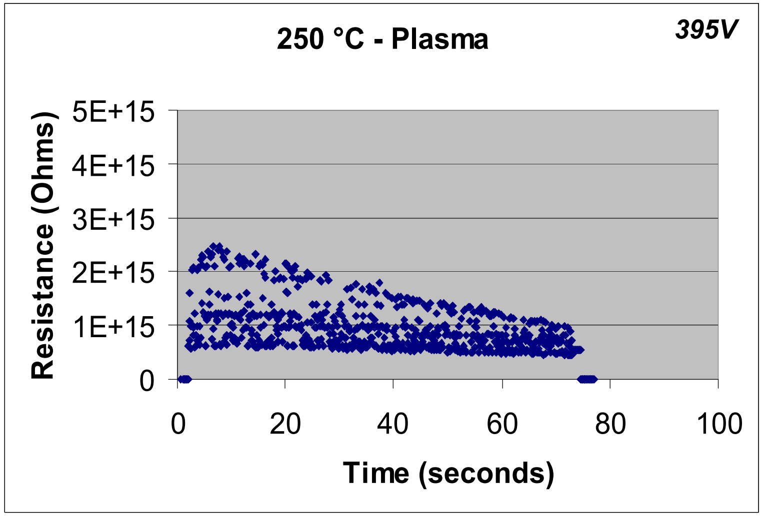
Wet SiON Breakdown Behavior

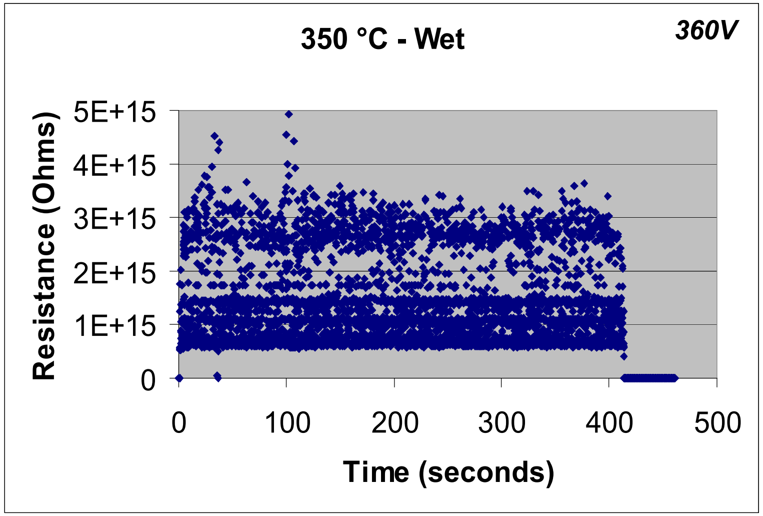
- **Wet etch shows no degradation before breakdown**
- **Plasma treated film shows drop in resistance with time**
  - **Increase in charge conduction**
  - **Likely arising from chemical or physical modification of the dielectric**

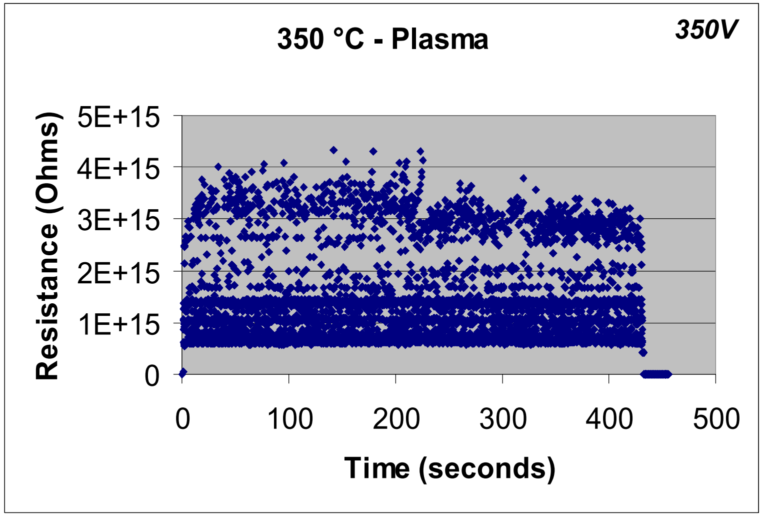




Plasma SiON Breakdown Behavior

- Wet etch shows no-minimal drop in resistance
- Plasma treated film shows slight apparent drop in resistance with time
  - Much less pronounced than with 250 °C SiON





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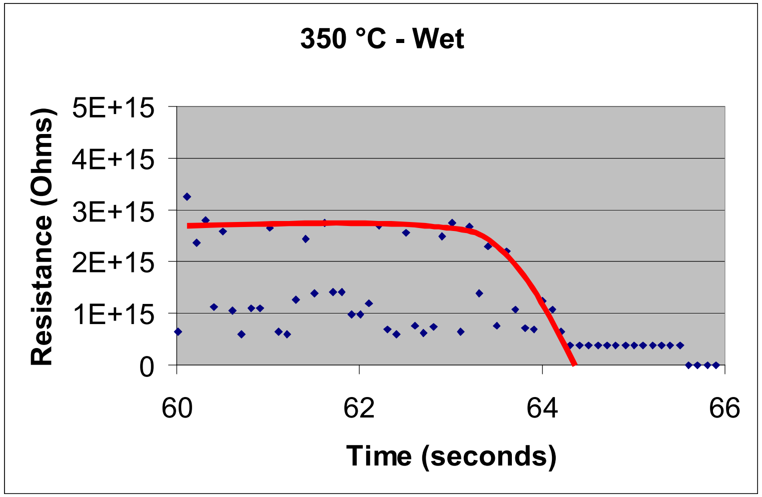
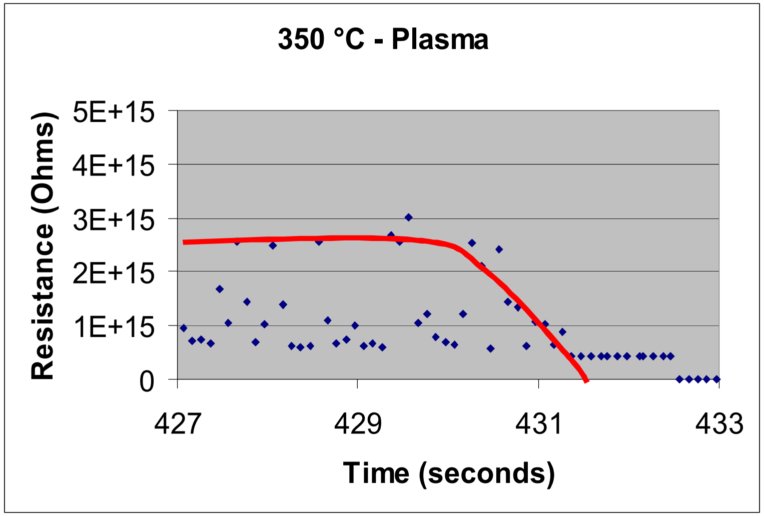
SiON breakdown

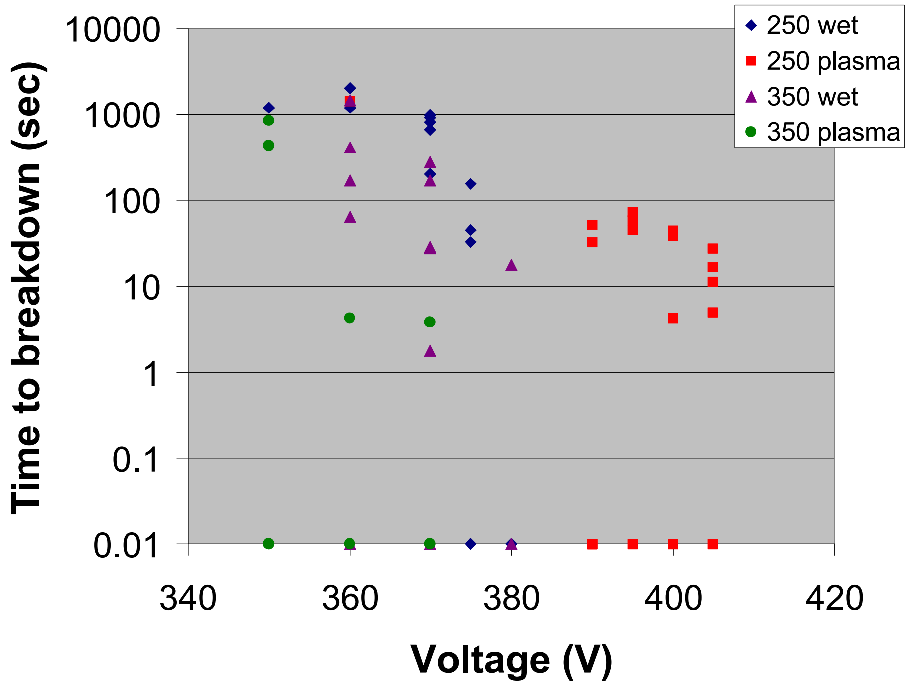
- All films show a decrease in the measured resistance immediately before breakdown
  - Formation of a conducting path?



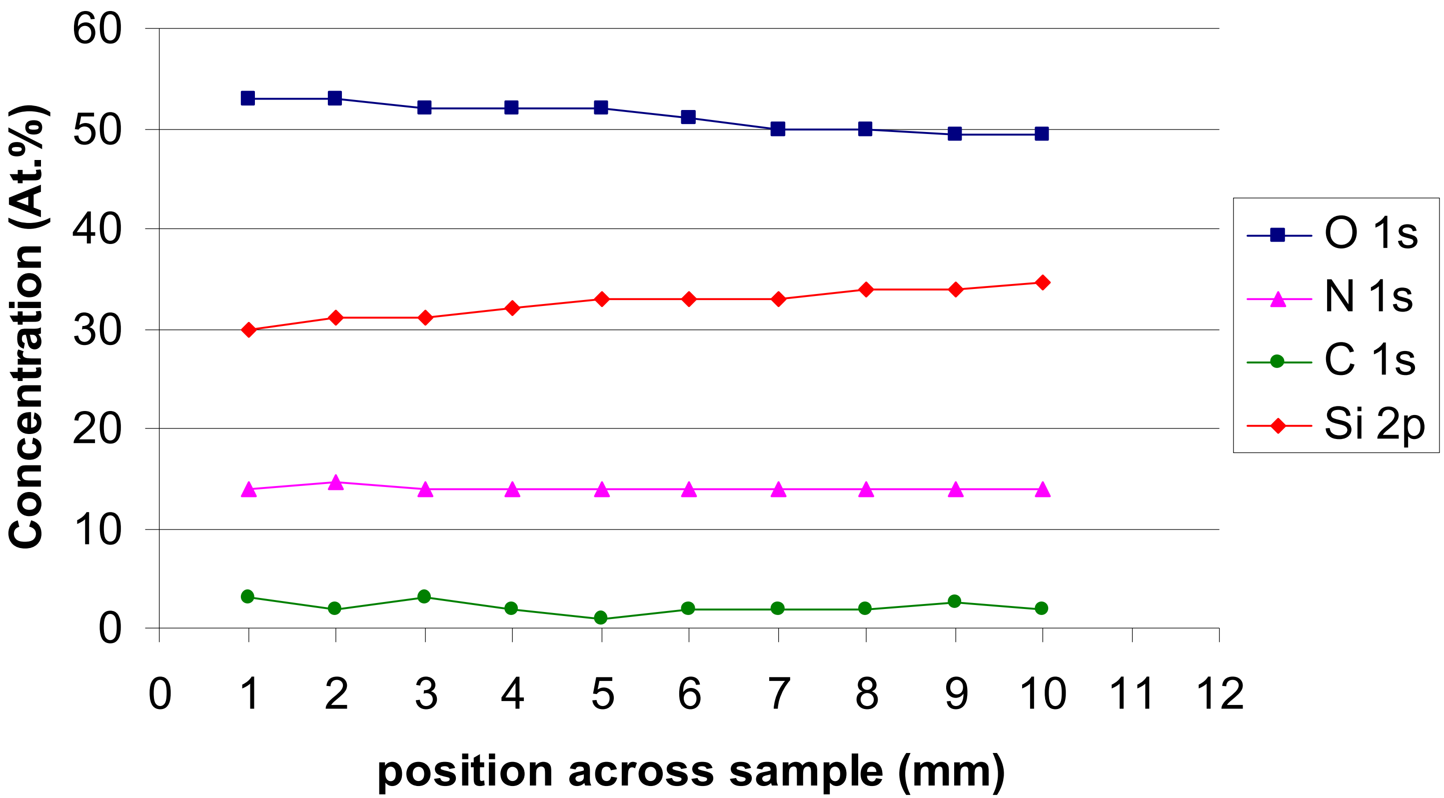


SiON Breakdown Fields

- **Electrical inhomogeneities**
  - **Dielectric breakdown over a range of voltages**
- **Processing temperature and method**
  - **Unexpected behavior of plasma treatment on breakdown field**



Chemical Analysis (XPS)



Variation in oxygen and silicon across sample

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Summary and Conclusions

- Changes in behavior from plasma processing consistent with previous MEMS-scale work
  - Plasma-treated films show increase in leakage current with time
  - Leakage current in wet-etched films is stable
- Electrical inhomogeneity across all samples
  - Possibly due to chemical variation across film
- Breakdown of SiON immediately proceeded by drop in resistance
- Variation of chemistry across the sample
  - Possibly due to impurities (SiO_x)

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Acknowledgements

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