

WORK PACKAGE 2.2

ELECTRIC

MACHINES

UNIVERSITY OF OXFORD

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14th Jan 2014

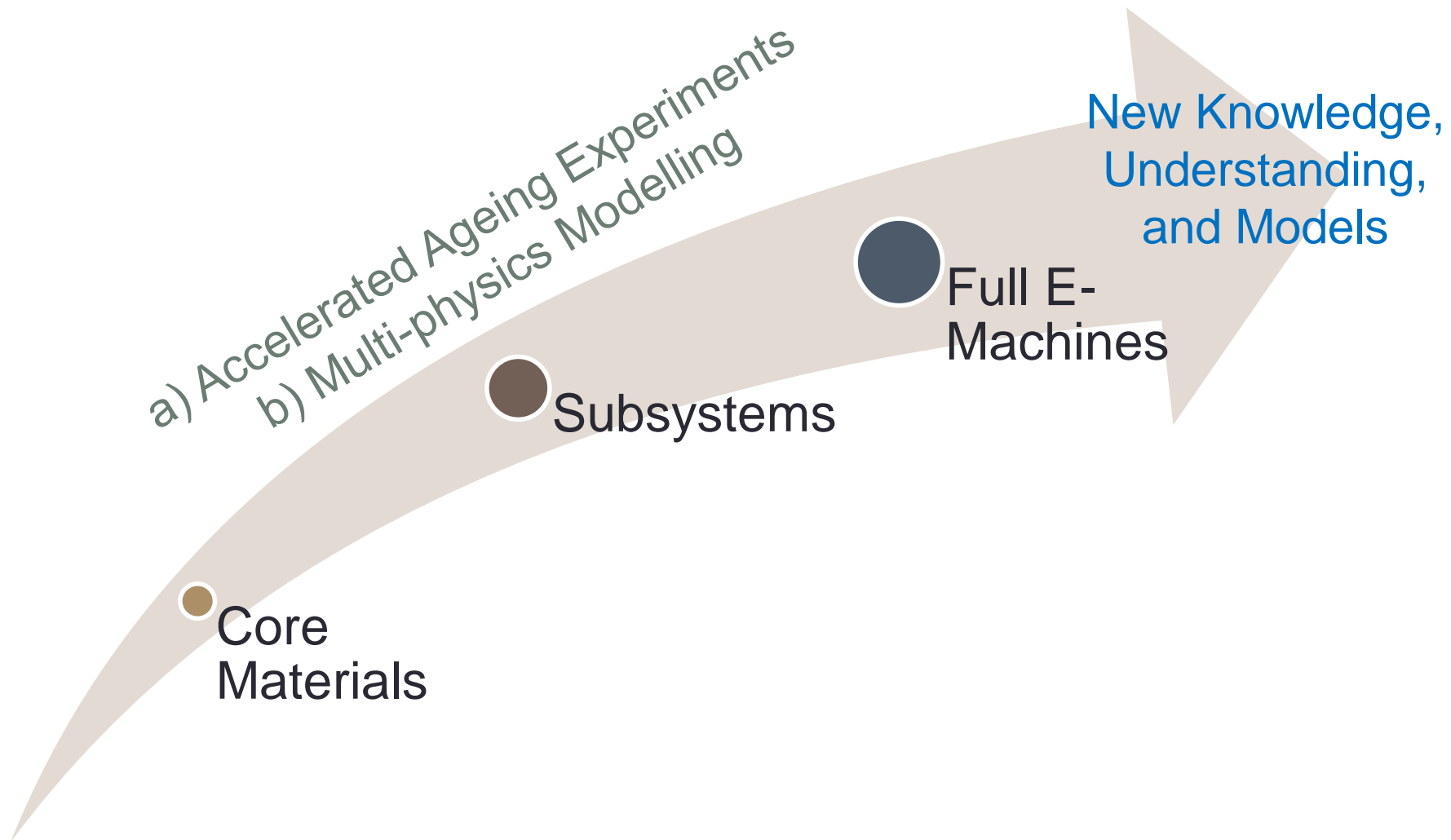
Aims and Objectives

Aim: to develop a greater knowledge of the physical and chemical processes behind electric machine degradation

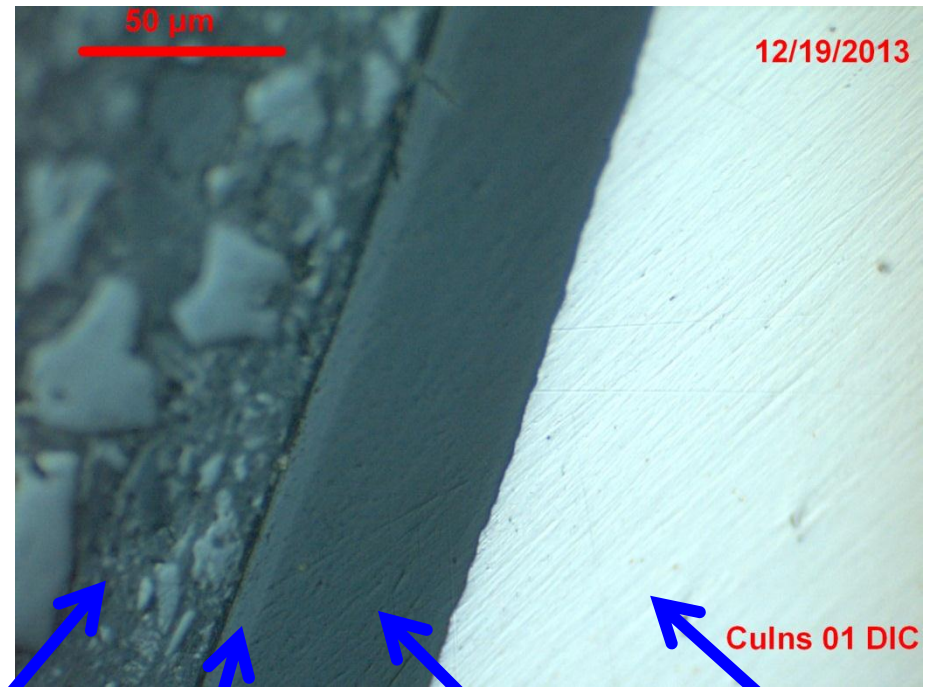
Areas of focus:

- A. Insulation (**focus of this talk**)
- B. Permanent magnets
- C. Mechanical degradation

Bottom-up Approach



Conductor and Insulation Cross-section



bakelite
encapsulation

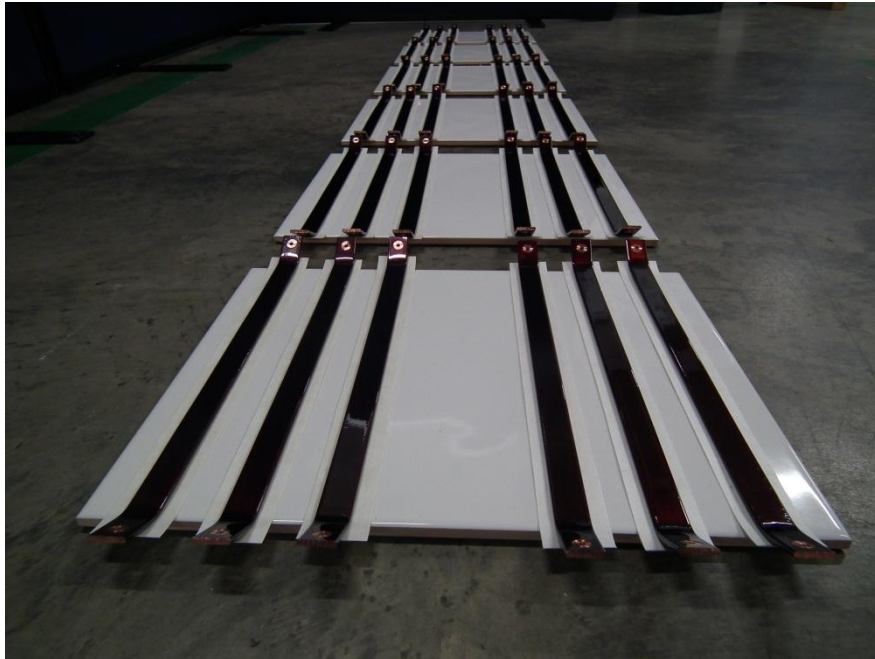
polyamide-
imide

polyester

copper

Thermal Accelerated Aging Experiment

- **Aim:** analyse insulation properties (roughness, FTIR, impedance) over time, at different temperatures
- Samples held at temperature for 100 hours (longer, later)



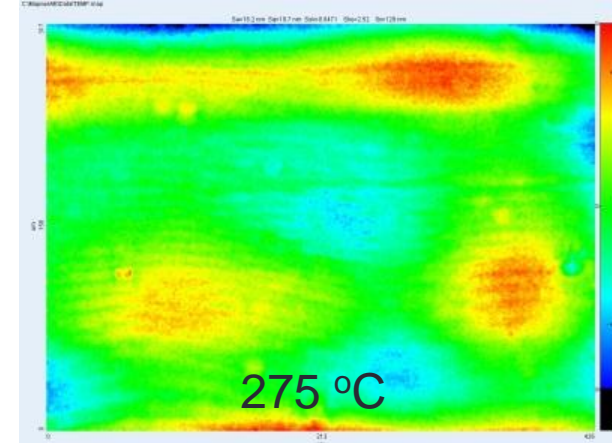
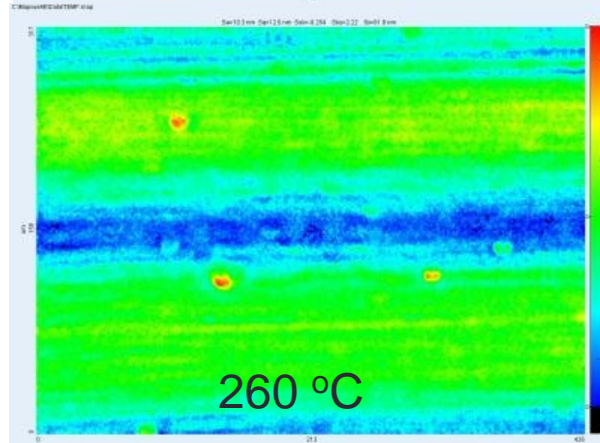
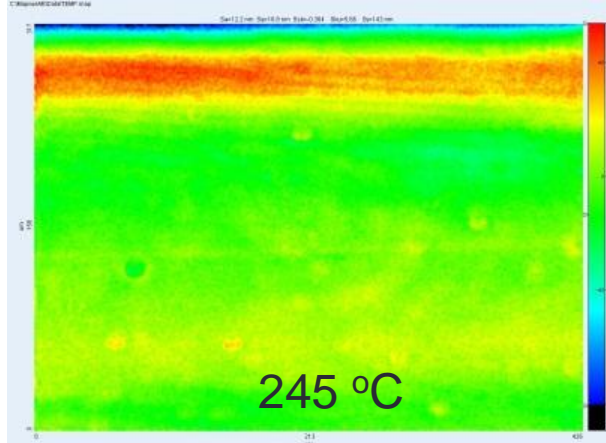
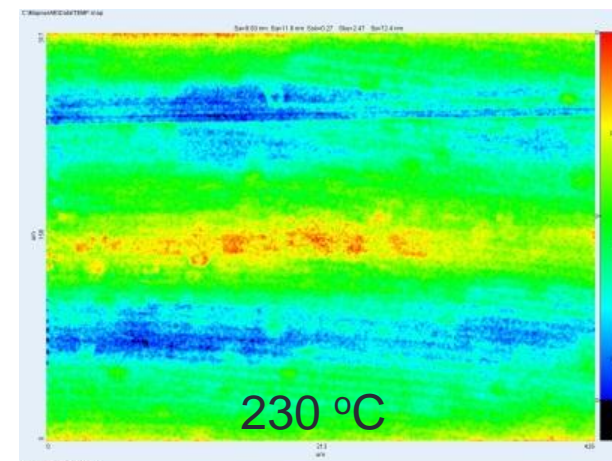
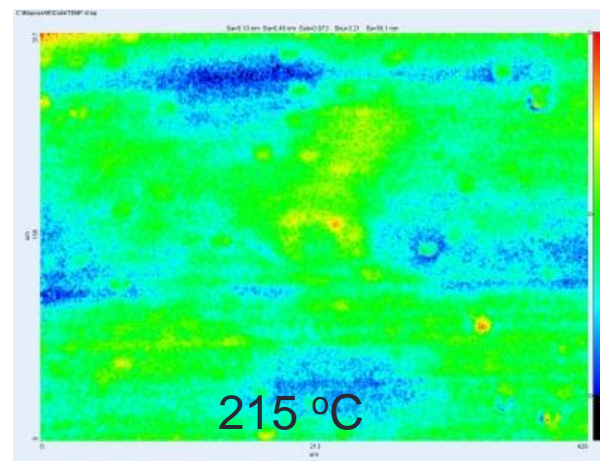
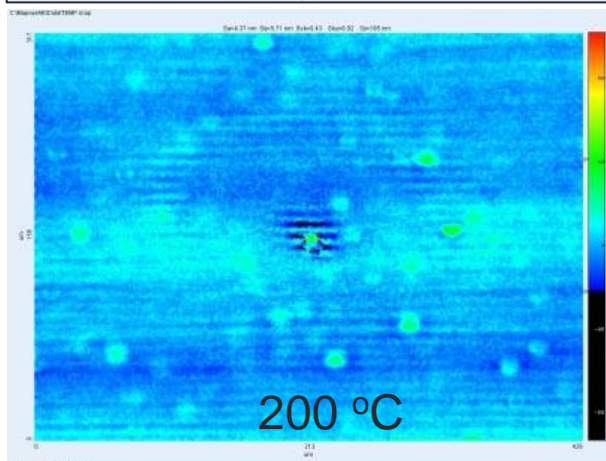
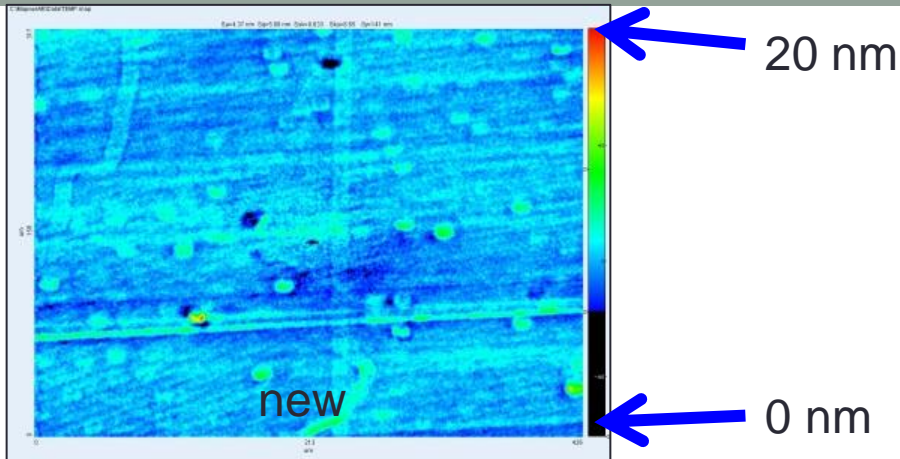
Sample preparation



Samples in oven

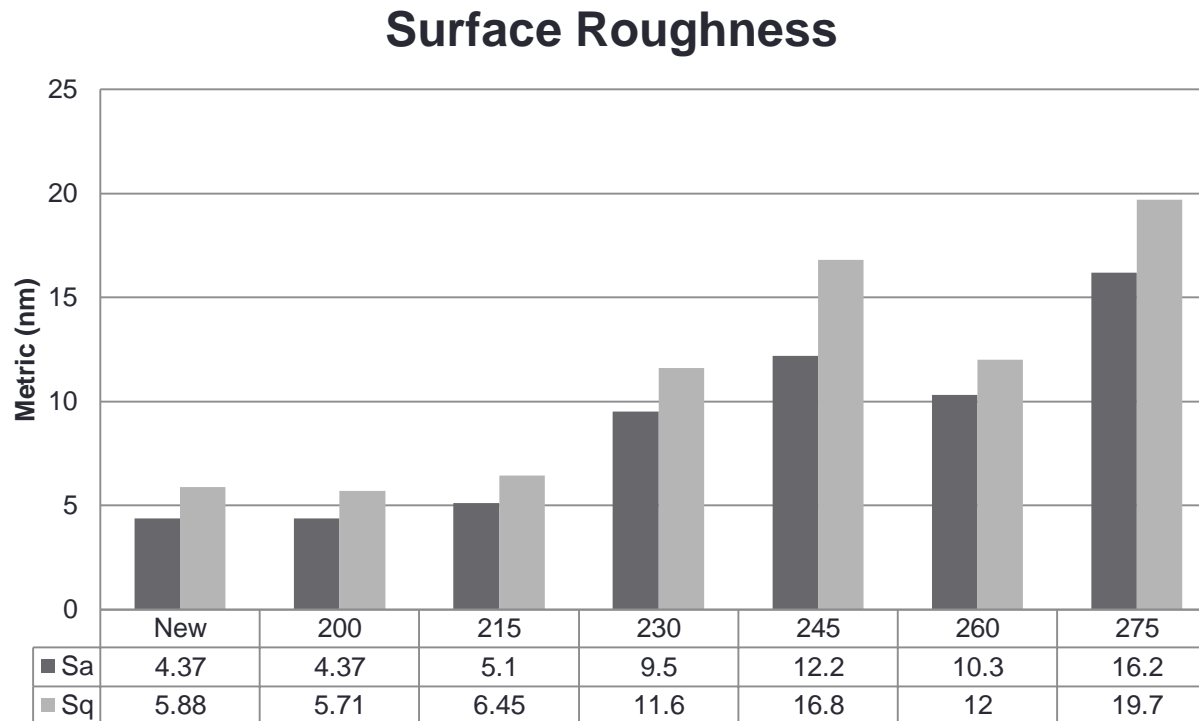
Surface roughness using MicroXAM

Samples are 317 x 421 μm




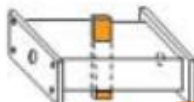
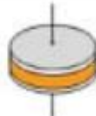



Surface roughness profiles

- The Roughness Average Sa
- The Root Mean Square (RMS) roughness Sq
- *→ conclusion: (irreversible?) changes to material properties with temperature*

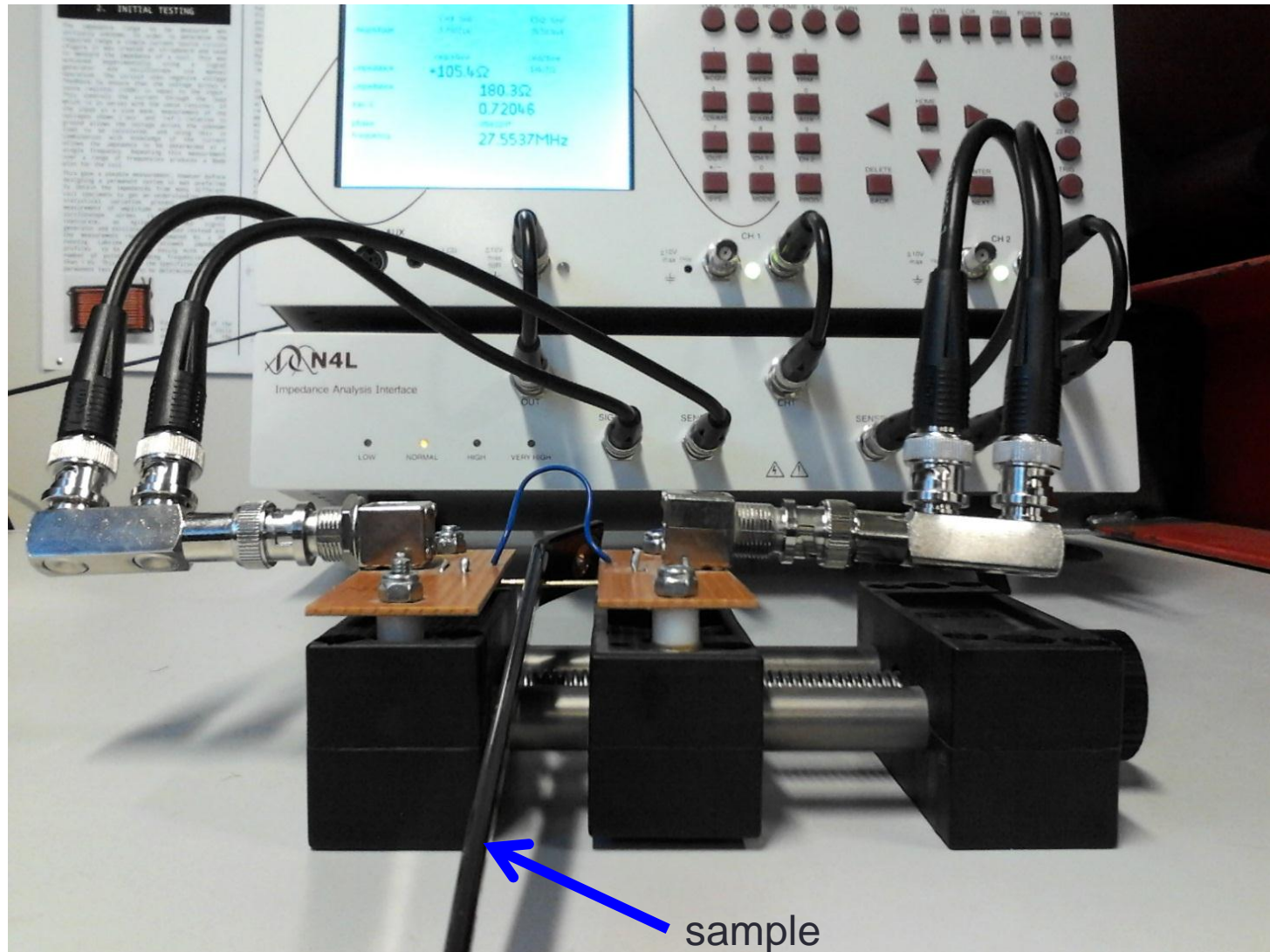


Dielectric Properties

Coaxial Probe ϵ_r		Broadband, convenient, non-destructive Best for lossy MUTs; liquids and semi-solids
Transmission Line ϵ_r and μ_r		Broadband Best for lossy to low loss MUTs; machineable solids
Free Space ϵ_r and μ_r		Broadband; Non-contacting Best for flat sheets, powders, high temperatures
Resonant Cavity ϵ_r		Single frequency; Accurate Best for low loss MUTs; small samples
Parallel Plate ϵ_r		Accurate Best for low frequencies; thin, flat sheets
Inductance measurement μ_r		Accurate, simple measurement, a toroidal core structure is required

- Permittivity measurements using the parallel plate method

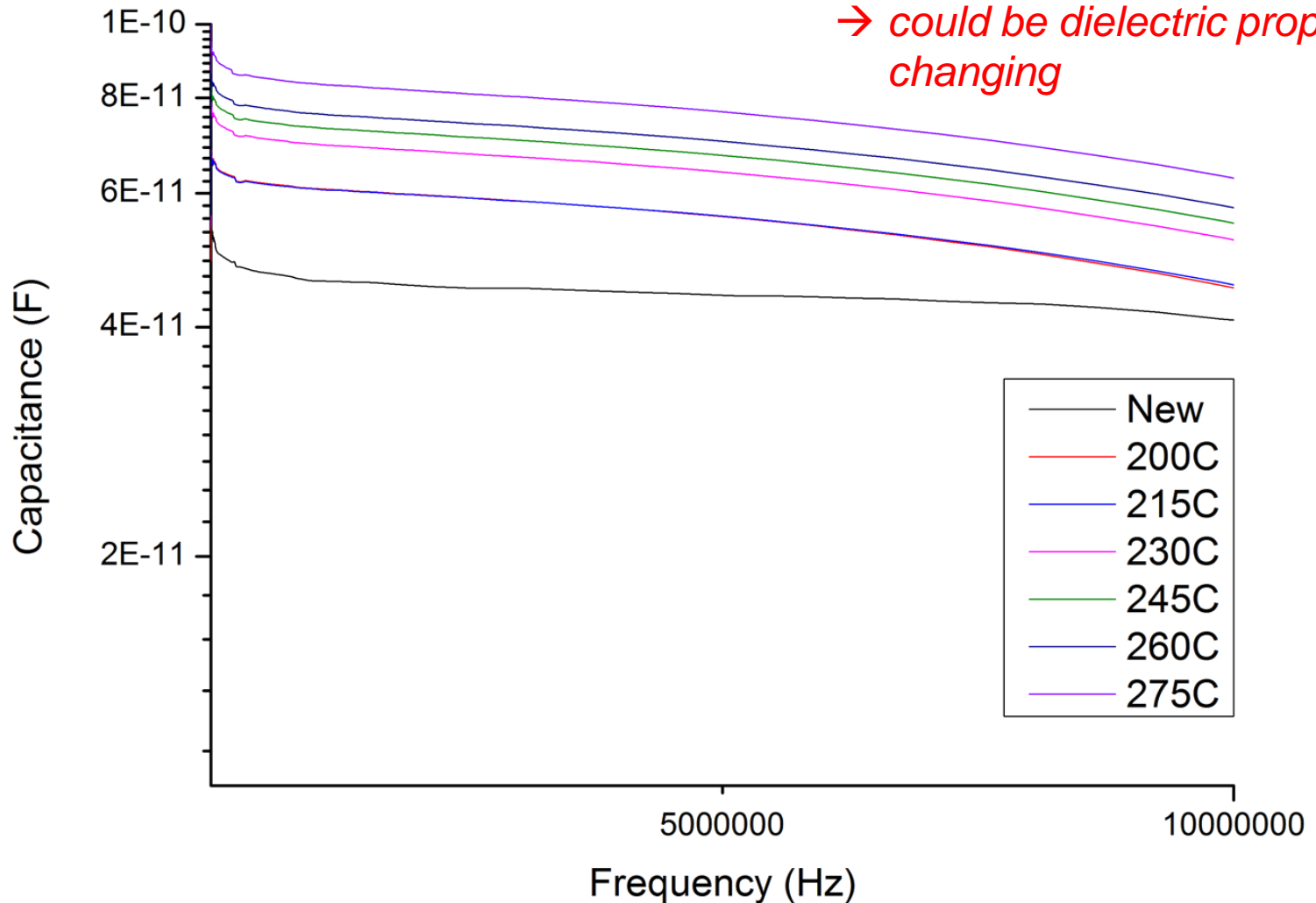
Capacitance Measurement Set-up



Capacitance

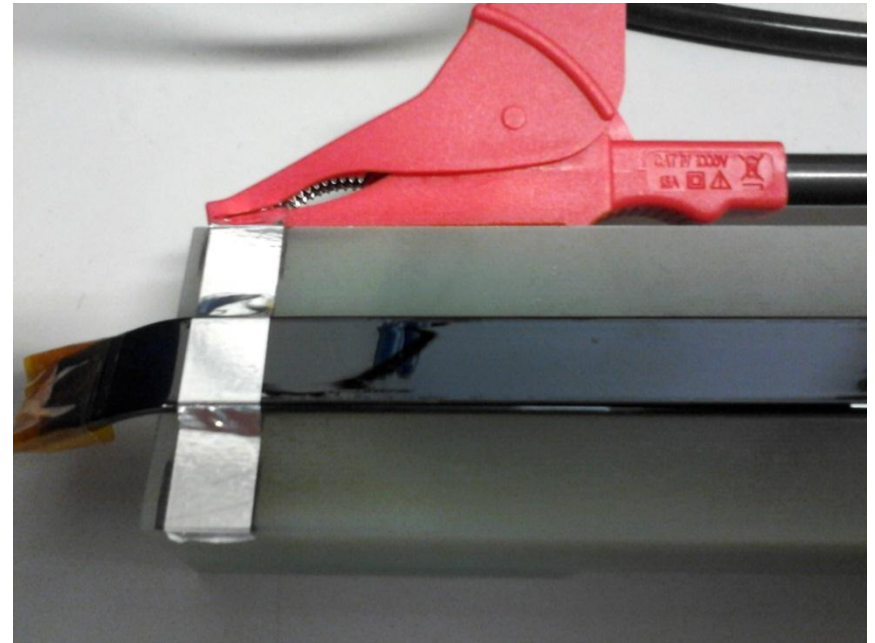
→ capacitance is a strong indicator of temperature history?

→ could be dielectric properties changing

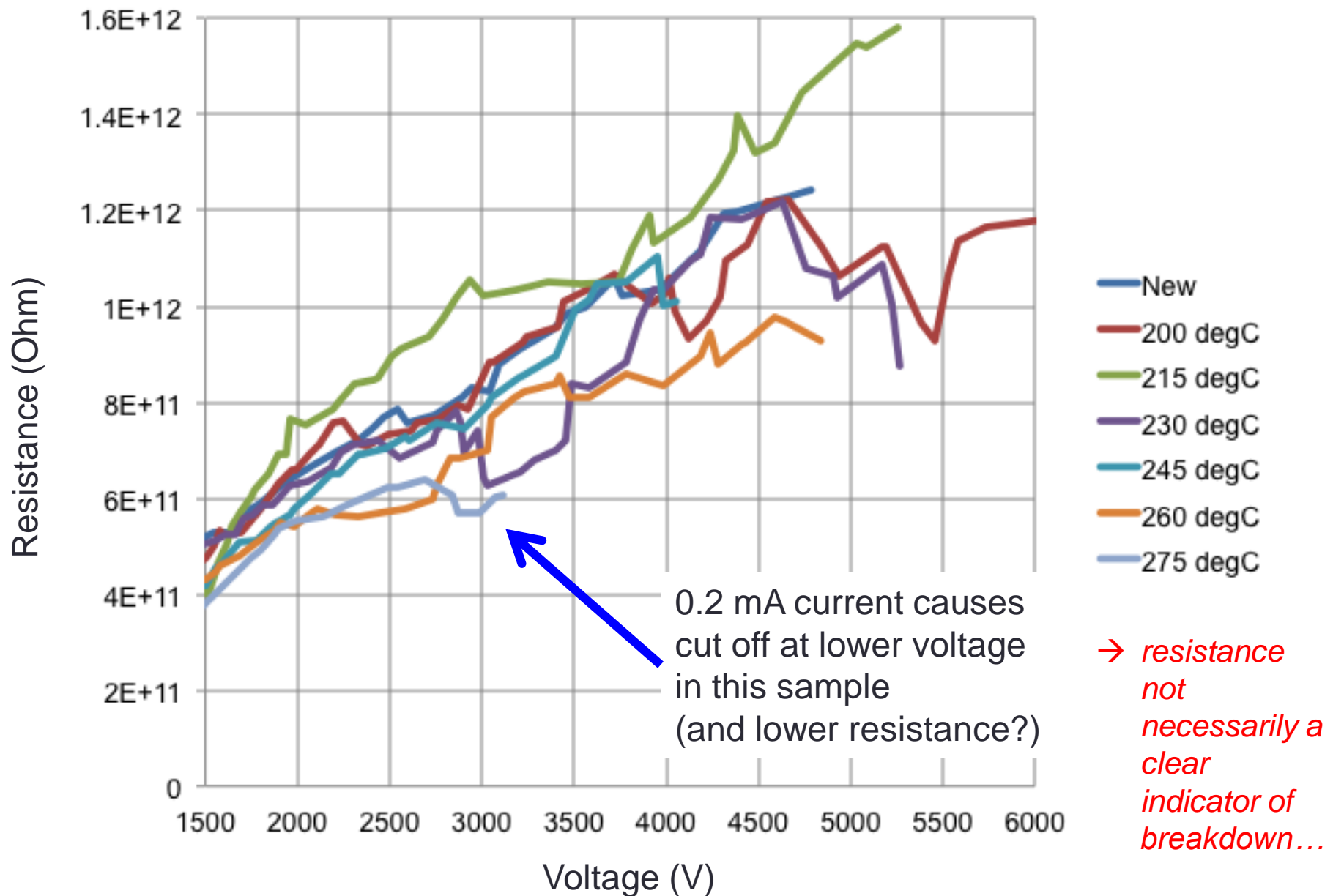


High Voltage Breakdown Measurements

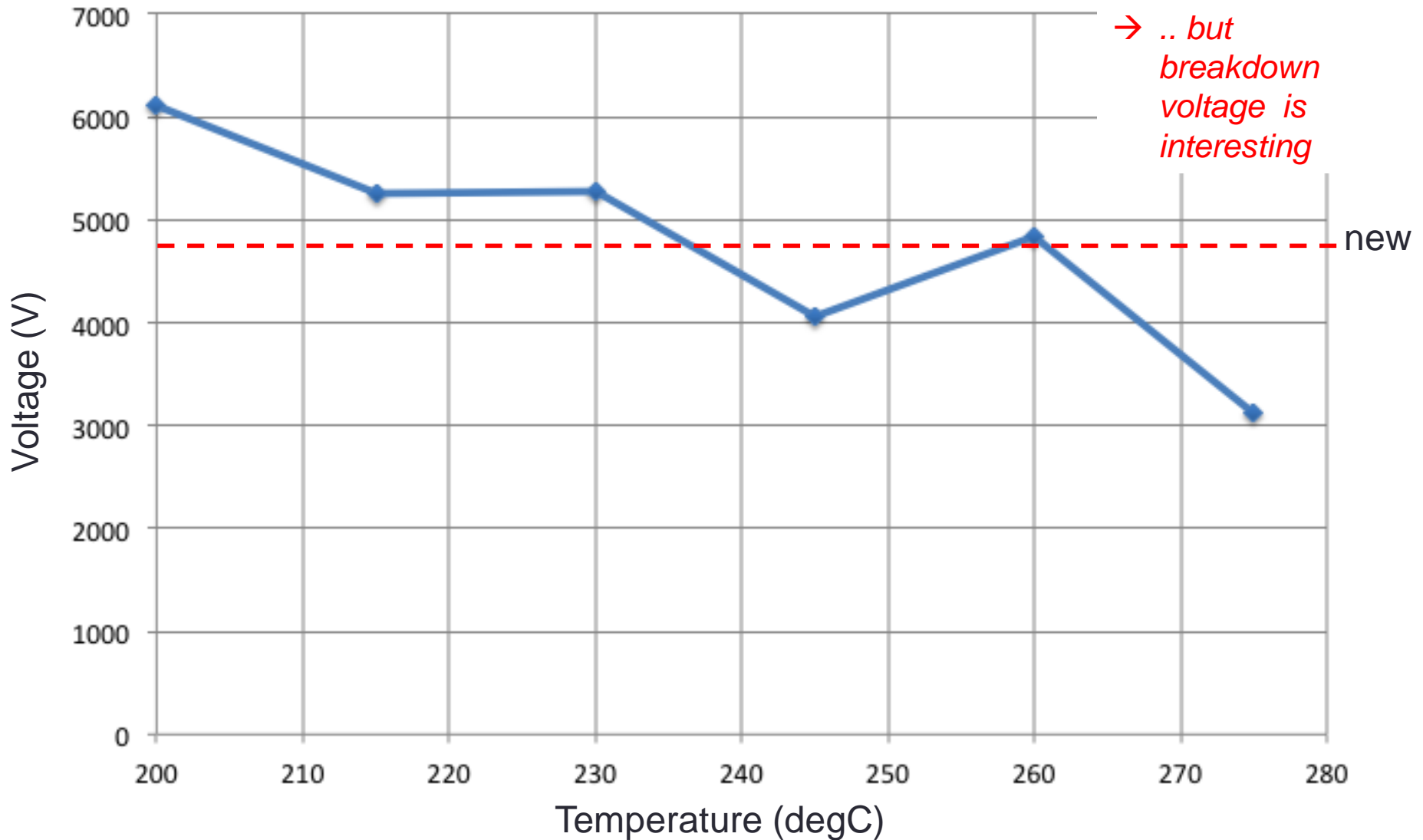
CA6555 15kV Test Set-up



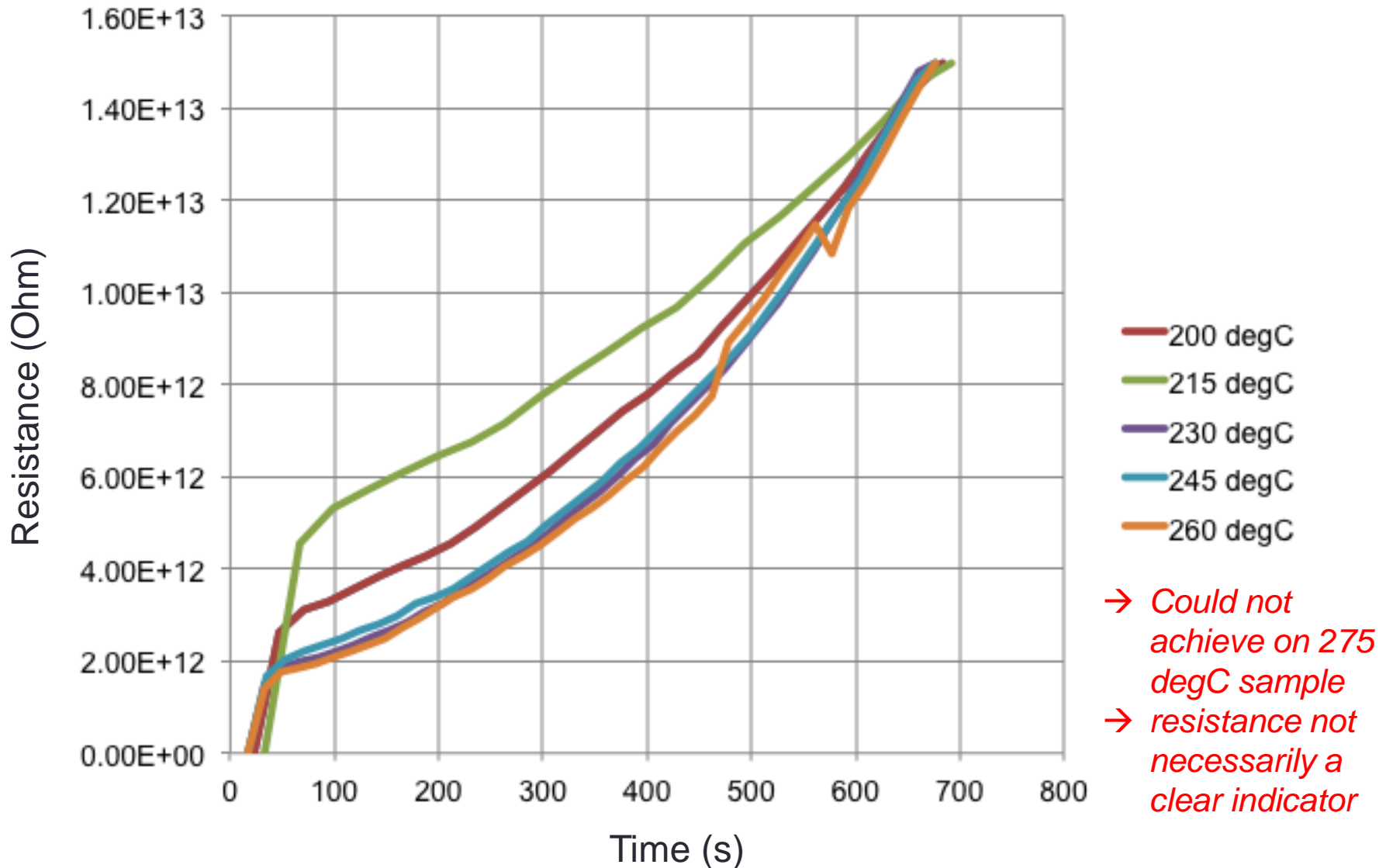
Voltage Ramp 1100V to Early Breakdown



Early breakdown cut off voltage



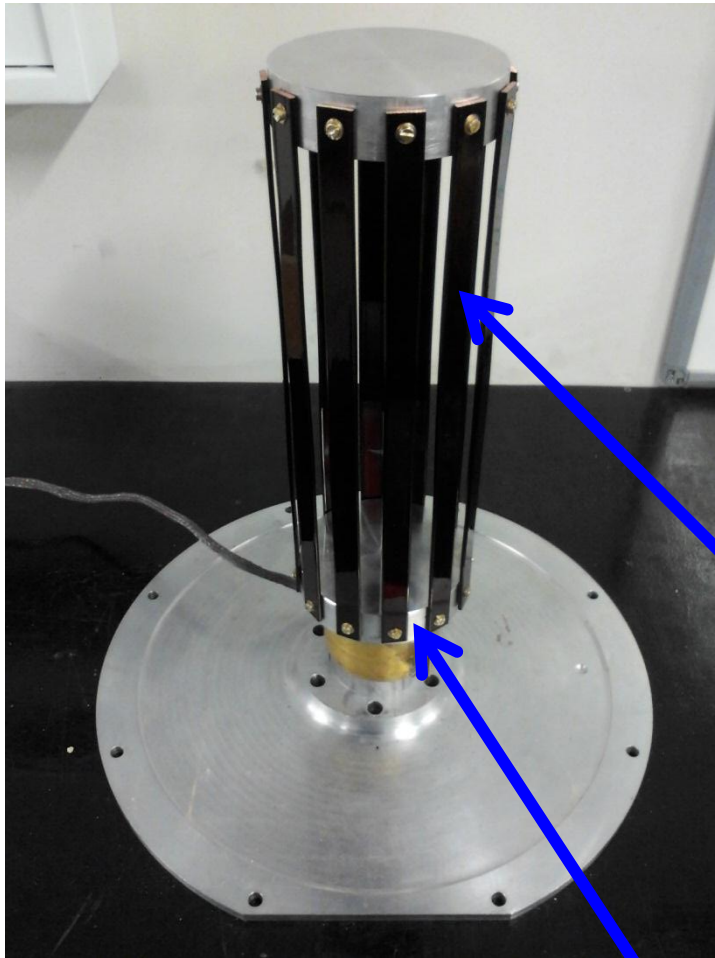
Resistance Trend for Fixed Voltage 5kV



Conclusions

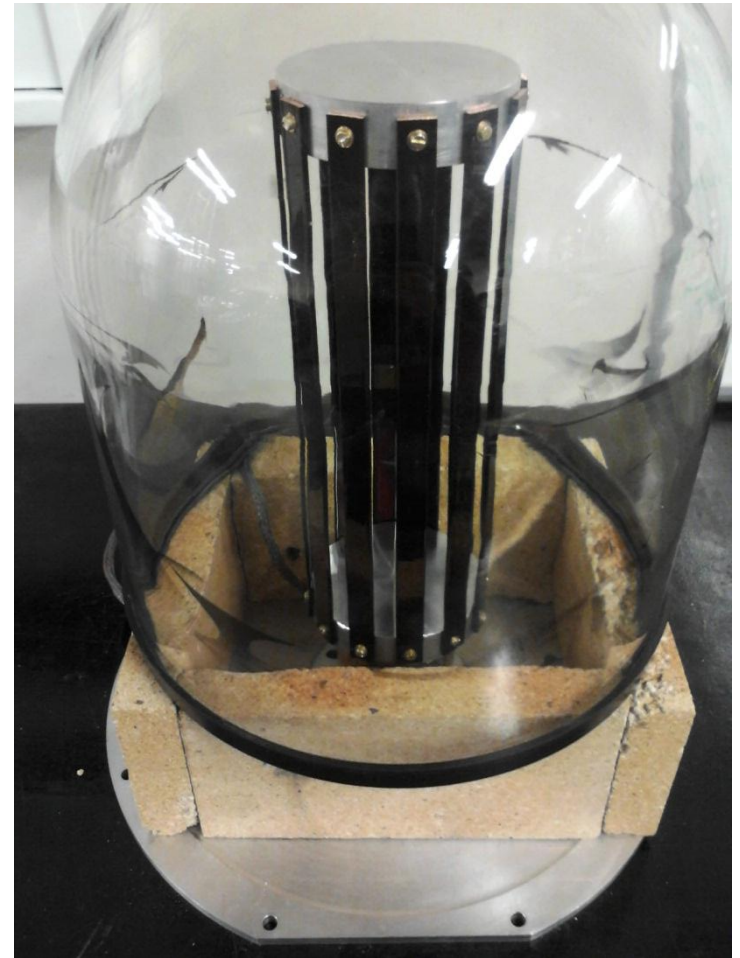
- Insulation material changes after **high temperature exposure**
- Early breakdown voltage decreases at 275 degC
- Complex effect – includes drying out etc. (awaiting analysis of FTIR data)
- **Capacitance** – good indicator of temperature exposure history?
- Resistance – not necessarily?

Thermal Gradient Experiment



Vertical
thermal
gradient
280-180
°C

band heater



Thank you for your time!



Extra Slides

Dissipation Factor

