Modeling Temperature Mediated Metal-Insulator Transitions With Dielectric – Breakdown Networks

Ashivni Shekhawat, Stefanos Papanikolaou, Stefano Zapperi, James Sethna
Dielectric Breakdown:
Change from resistor to conductor under effect of applied voltage and temperature

\[ X(T) = X(0) - AT \]

A resistor ‘Breaks Down’ to become a conductor under influence of applied voltage and temperature
Dielectric – Breakdown Model

Field at the $i^{th}$ bond:

$$h_i(X_i, \Delta V_i, T, A, C, J, V) = X_i(0) - AT + J \sum_k S_k - \Delta V_i$$

- $X_i$: Strength of $i^{th}$ bond, random
- $T$: Temperature
- $V$: Voltage bias per site
- $A$: Constant
- $J$: Ising Coupling
- $\Delta V_i$: Voltage drop across $i^{th}$ bond
- $S_k$: 1 before breakdown, -1 afterwards
- $C$: Contrast Ratio
- $k$: Summation index runs over six neighboring bonds

Breakdown Criteria: $h_i \leq 0$

Ising coupling models local interaction and contrast ratio models ‘real’ insulators and conductors
A Realistic Lightning Bolt
An Idealized Lightning Bolt

Is Dielectric – Breakdown a realistic model for lightning bolts?
Metal – Insulator Transition Experiments on VO$_2$

Setup
- Resistance of VO2 device measured with changing temperature (2-3 K/min)
- Domains mapped by electronic and optical measurements

Observations
- Resistance changes in jumps indicating avalanches
- Resistance jumps power law distributed
Conducting-Insulating Clusters

Experiment
VO2 based material

Simulations
Size of the largest resistance jump increases with increasing applied voltage.
Power Law Distributed Jumps

Experiment

Simulations

Scaling exponent from simulations is compatible with the experiments
Avalanches

- High J, Low V
- High J, High V
- Low J, Low V
- Low J, High V
Acknowledgements and References


- [http://en.wikipedia.org](http://en.wikipedia.org) for some images and animations
Thank You!!

Questions...?
Finite Contrast Ratio

How does the contrast ratio effect the clusters and scaling exponents?