

Electrical Noise Techniques to Characterize Resistive Switching of Metal-Oxide-Polymer Memories

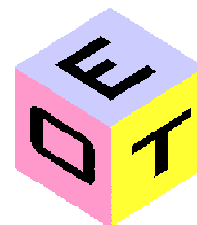
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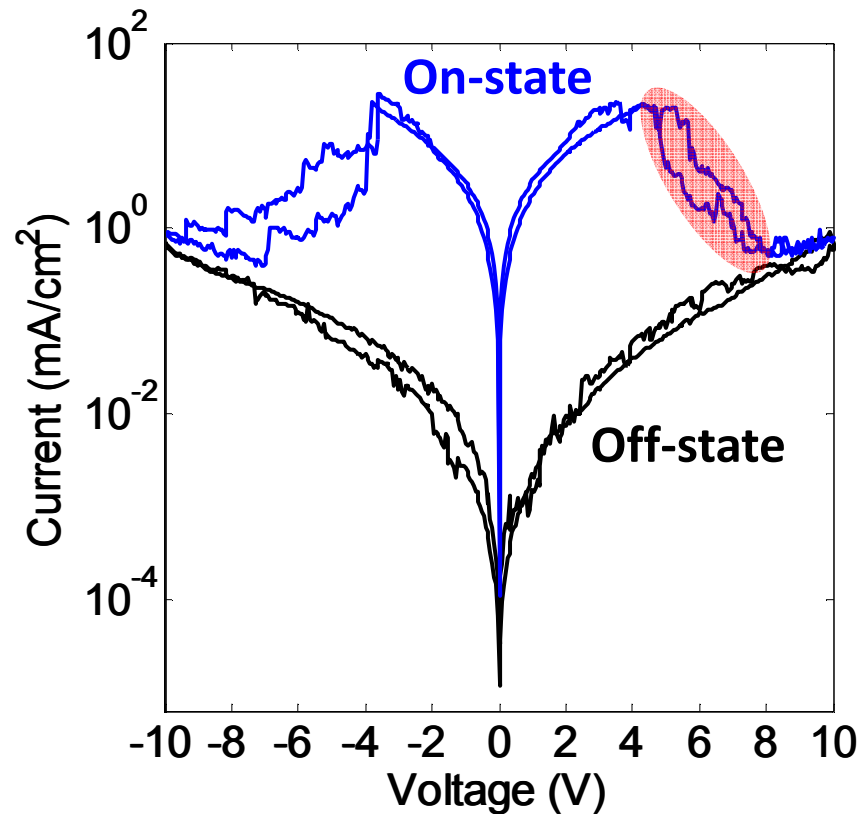
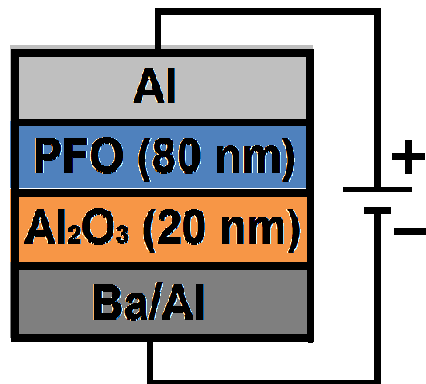
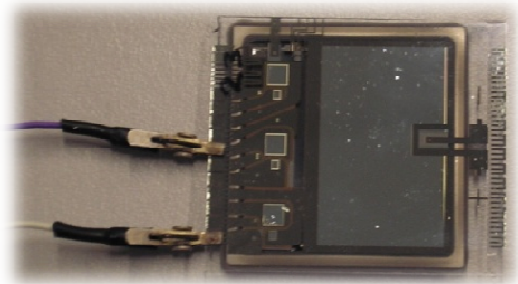
PHILIPS

Outline

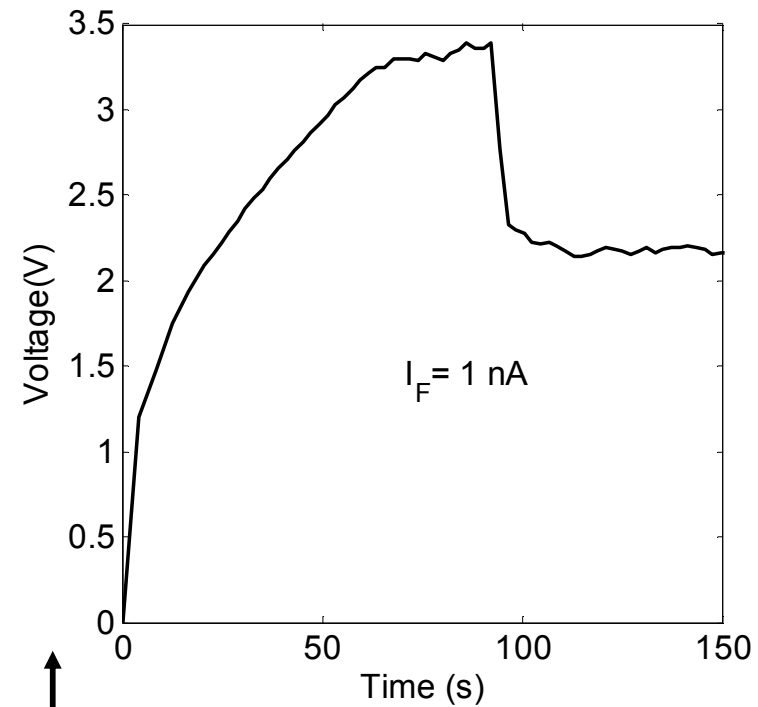
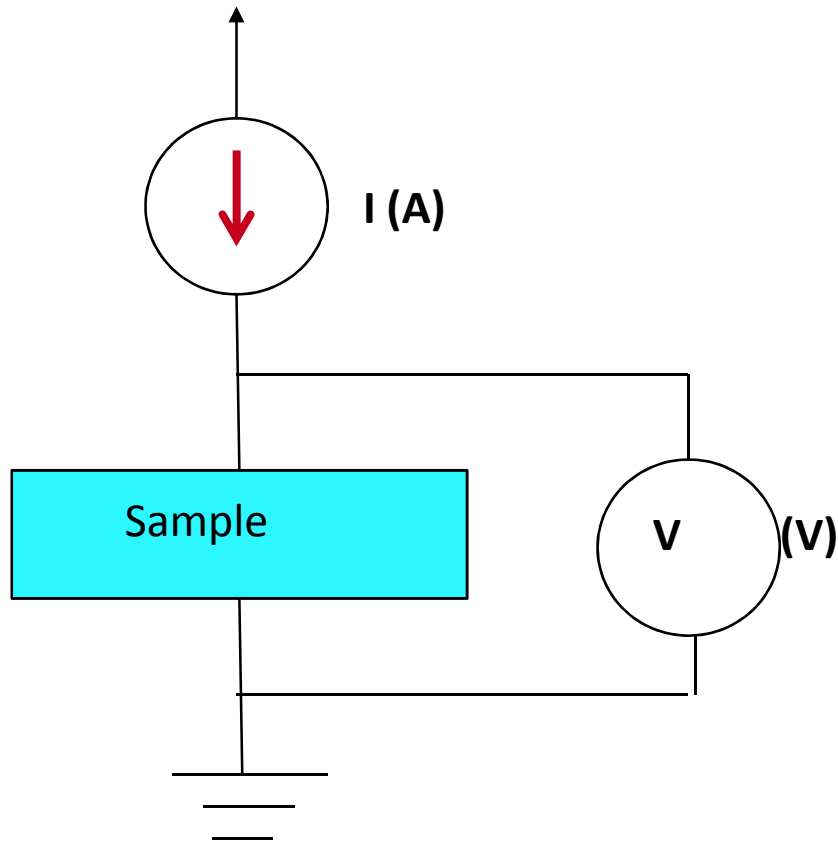
- Introduction to metal/oxide/polymer resistive switching diodes
- Soft-breakdown of oxides (Electroforming)
- Micro-conducting paths and electrical noise
- Random telegraph noise
- $1/f$ noise
- Conclusions



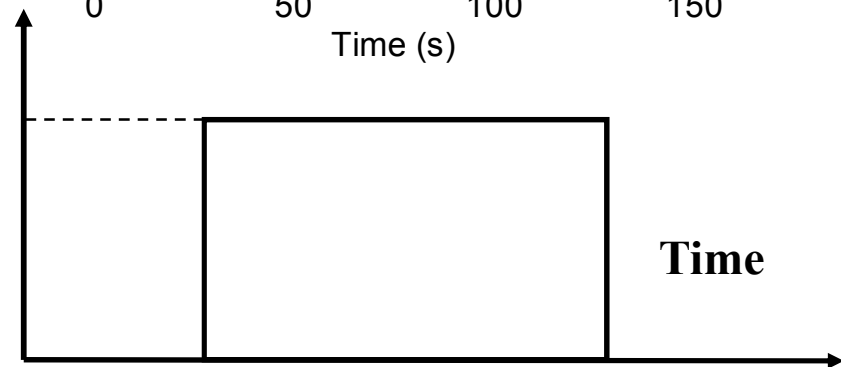
RRAM structure



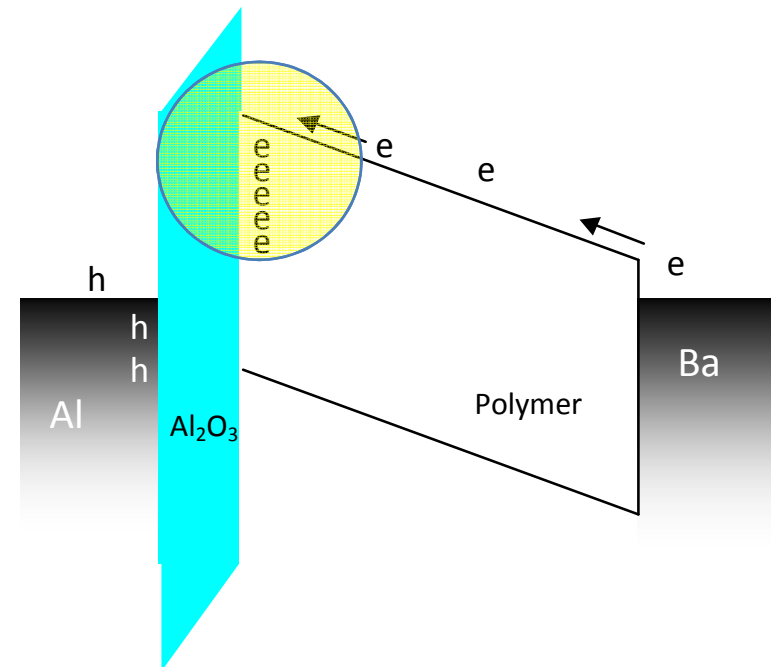
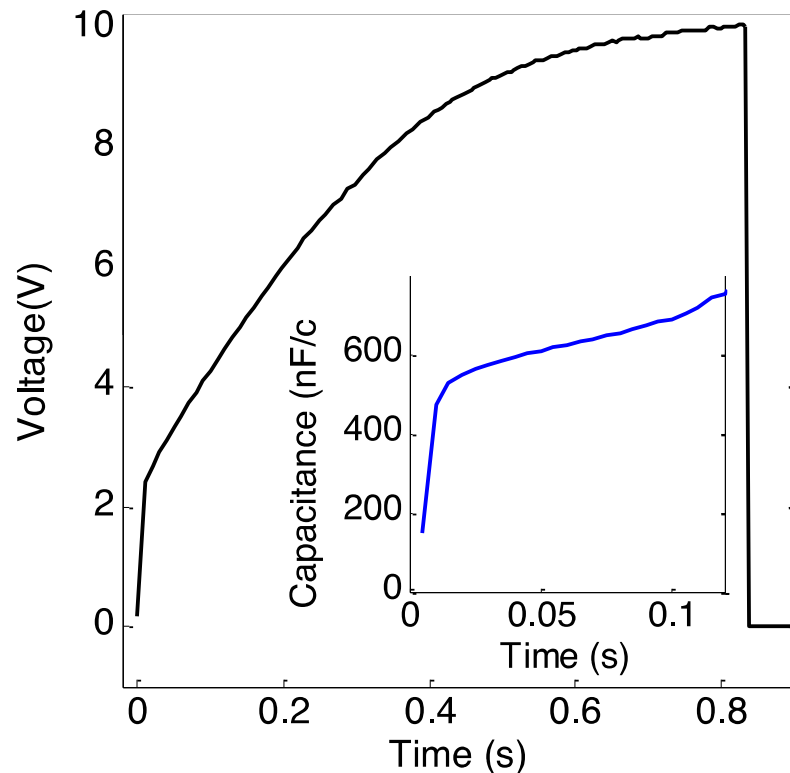
Soft-breakdown induced by a constant current stress (electroforming)



1 nA

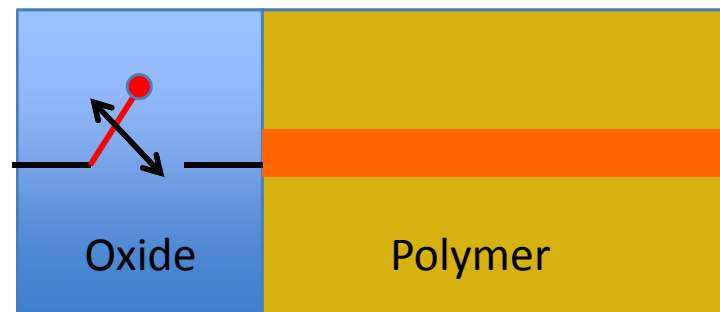
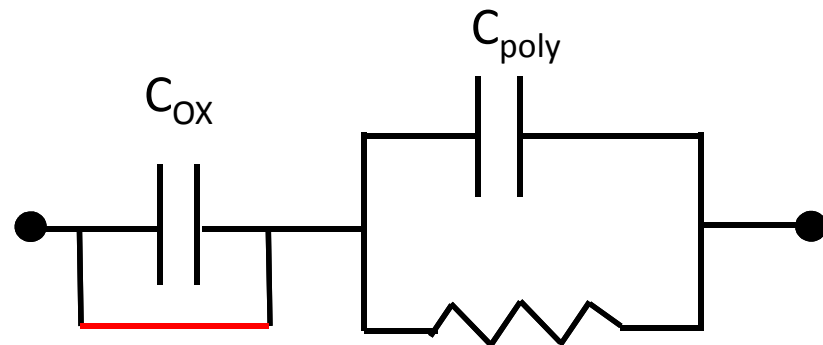
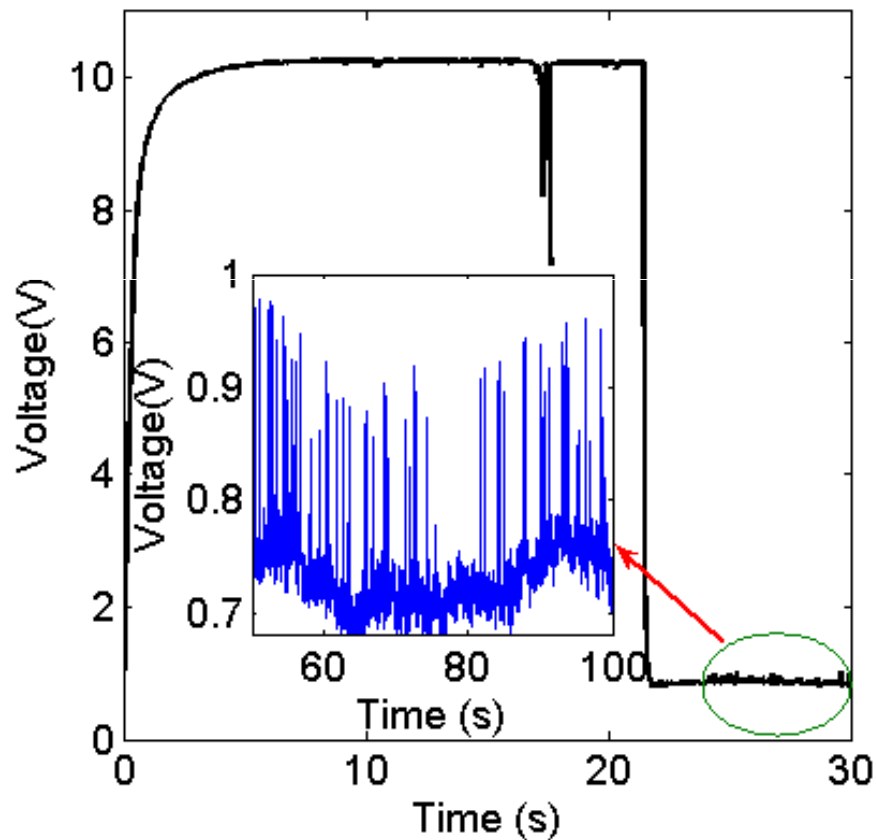


Trapping of electrons at oxide/polymer interface



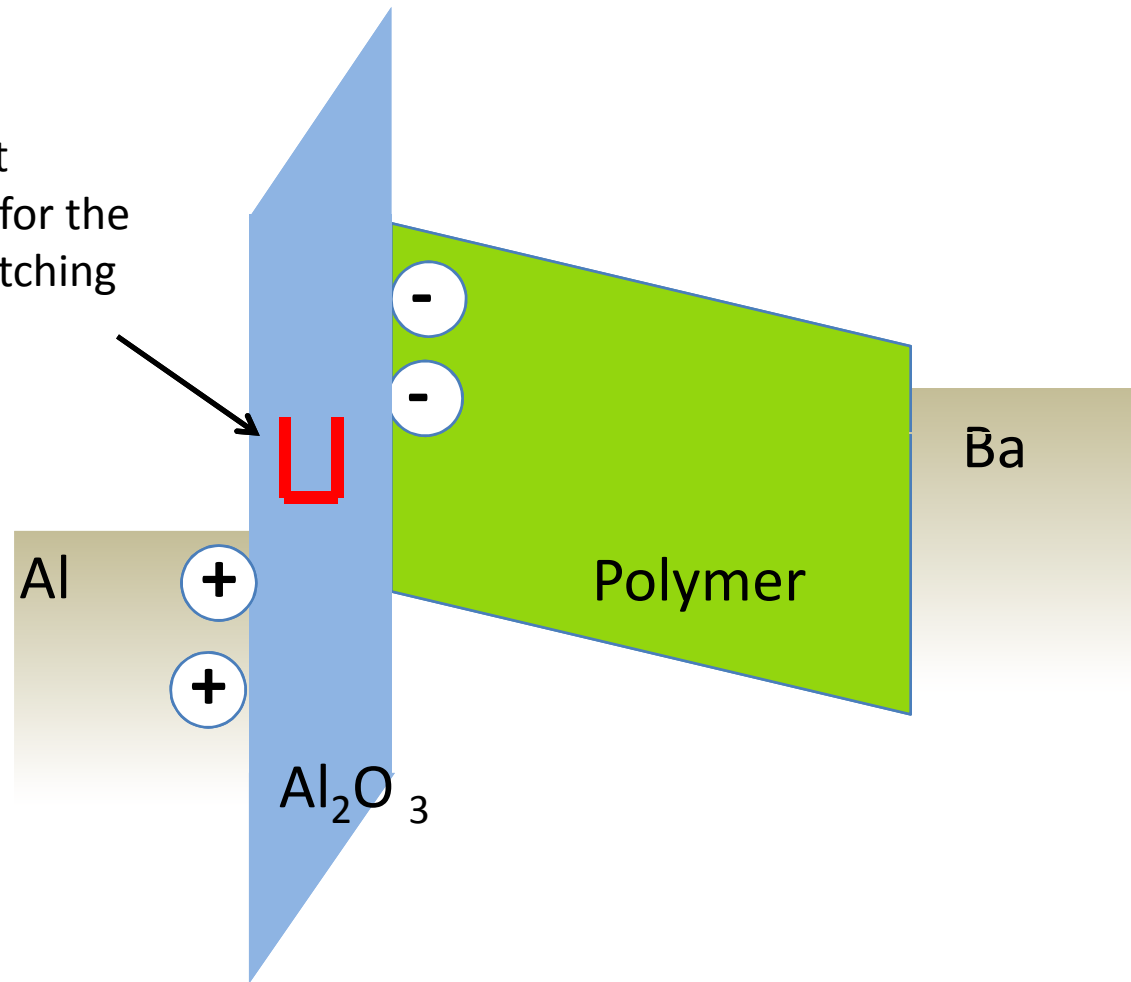
The soft-breakdown is caused by an internal electric field induced by a trapped electron layer at the oxide/polymer interface

Breakdown and low-frequency current (voltage) fluctuations

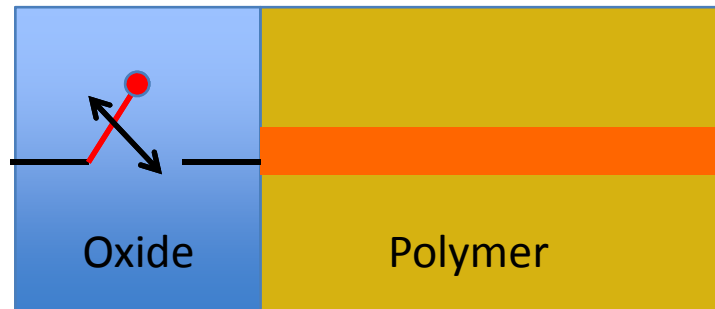


Motivation

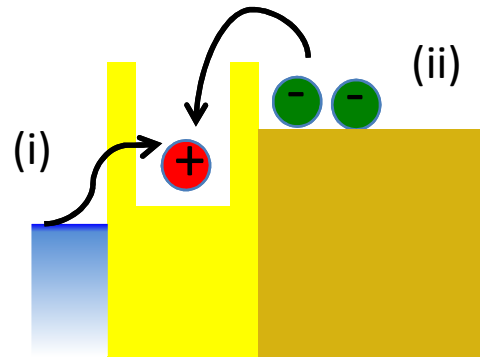
Oxide defect
responsible for the
resistive switching



Why noise based techniques?



(i) Hole Injection
controlled by the
applied bias.



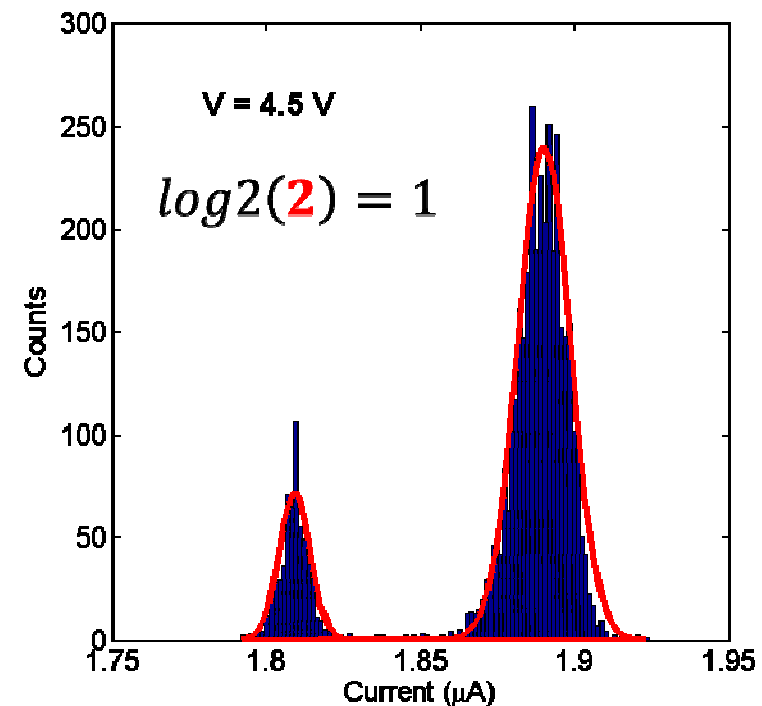
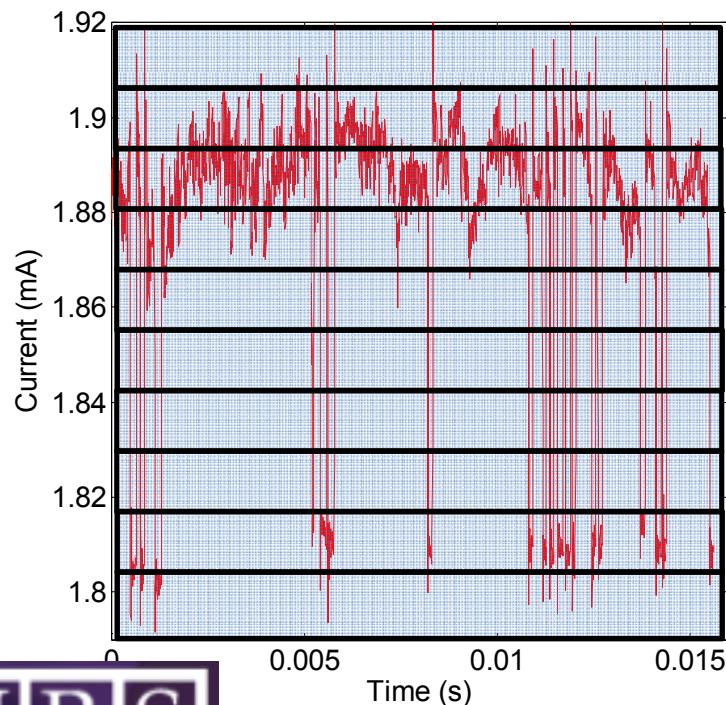
(ii) Recombination
(controlled by the electron
trap density)

These traps cannot be probed by
small signal impedance, DLTS or TSC.

Basics about random telegraph noise

How can I estimate the number (N) of detectable trap levels in my diode?

Histogram \rightarrow Gaussian \rightarrow $\log_2(N)$

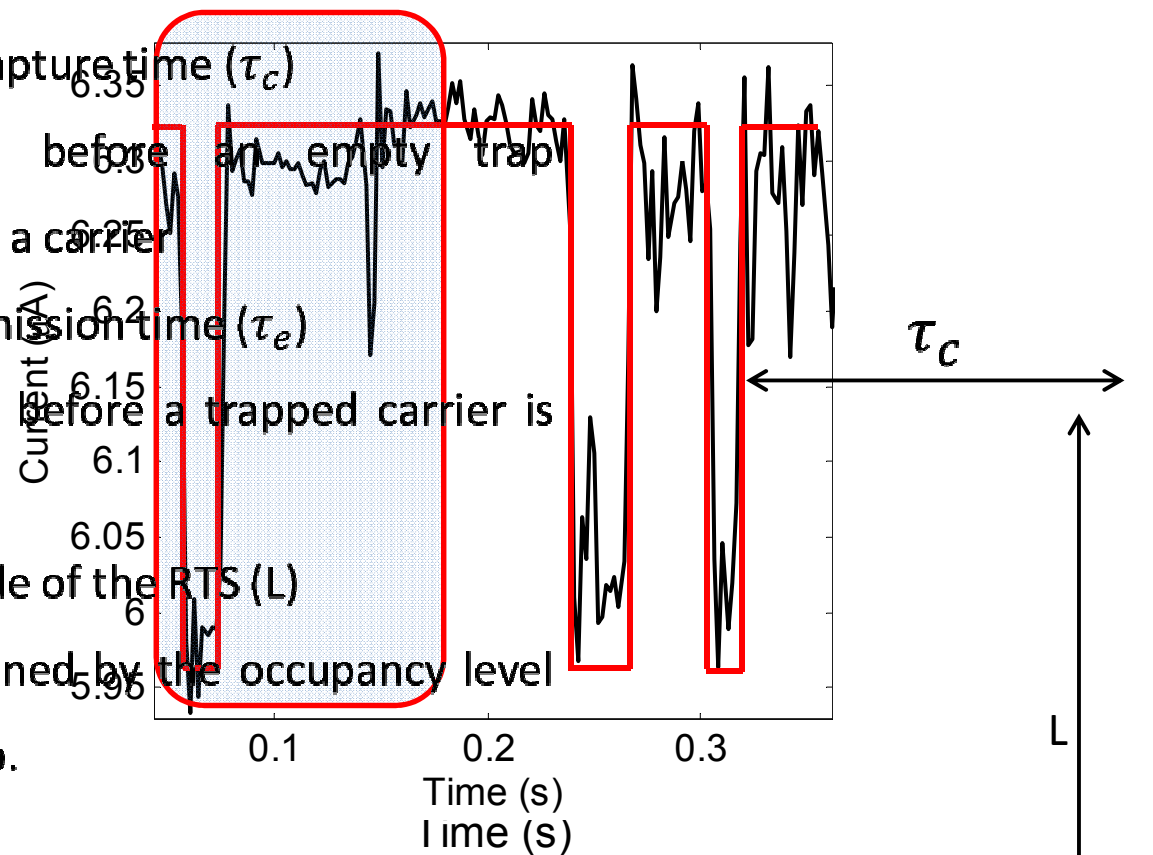


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Random Telegraph Signal analysis

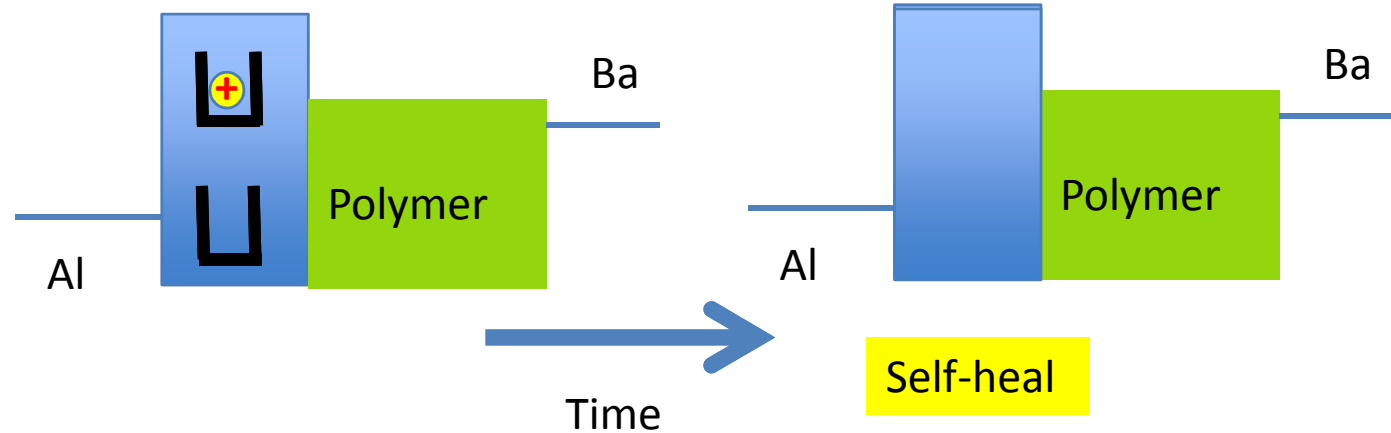
Three key parameters that define RTS noise:

1. The mean capture time (τ_c)
 - duration before an empty trap captures a carrier
2. The mean emission time (τ_e)
 - duration before a trapped carrier is released
3. The amplitude of the RTS (L)
 - Determined by the occupancy level of a trap.

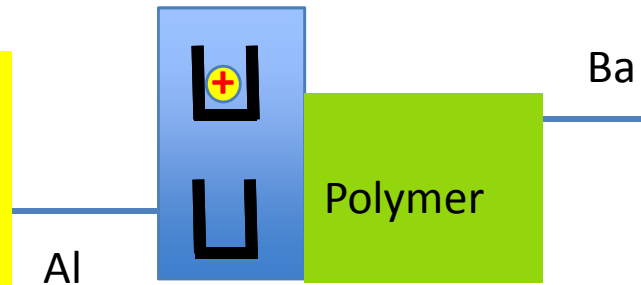


What we can learn from the RTS noise?

Soft-breakdown under
low power conditions
(Metastable-memory)
($P=1 \text{ mW/cm}^2$)

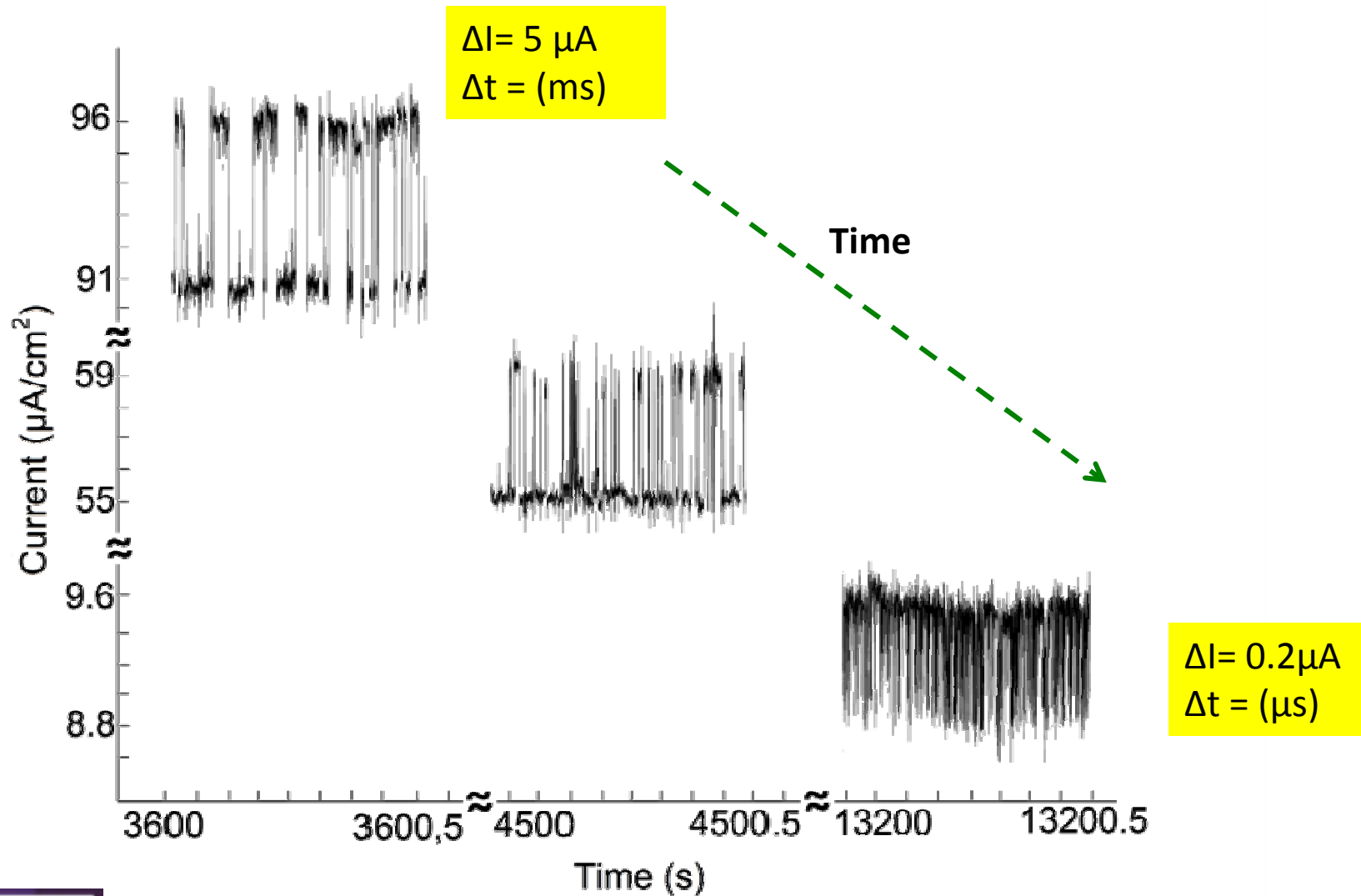


Soft-breakdown under
high power conditions
(Permanent memory)
($P=100 \text{ mW/cm}^2$)

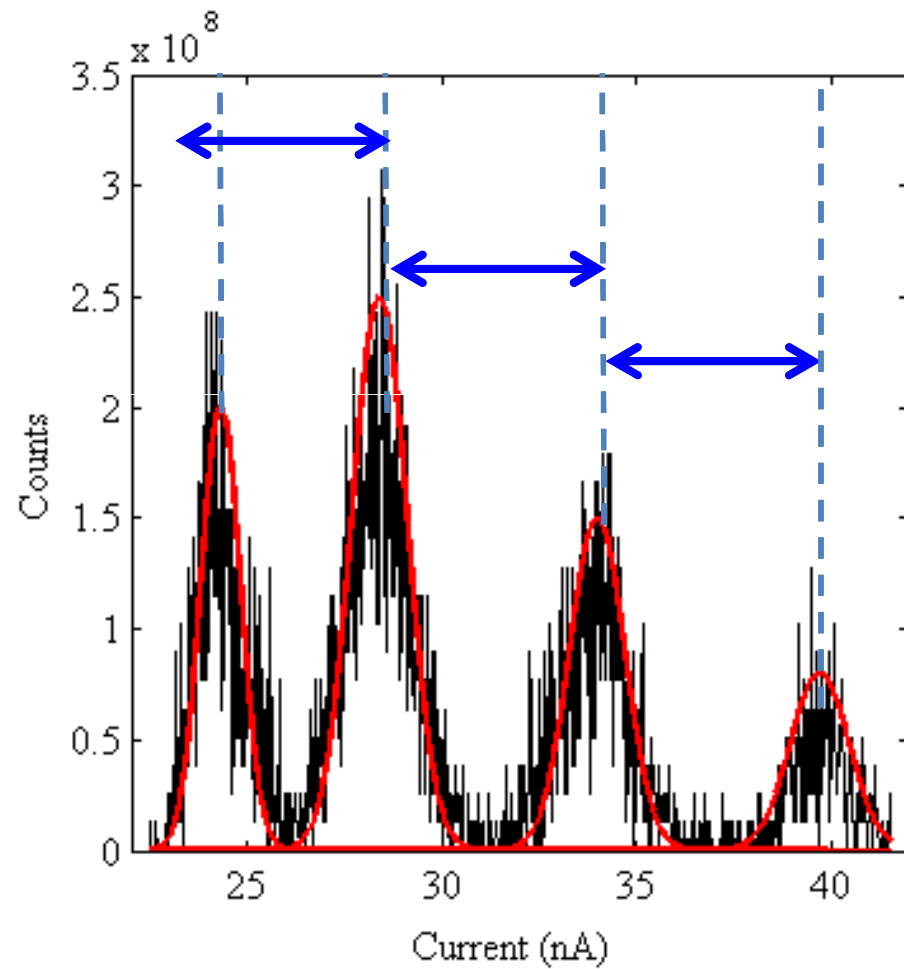
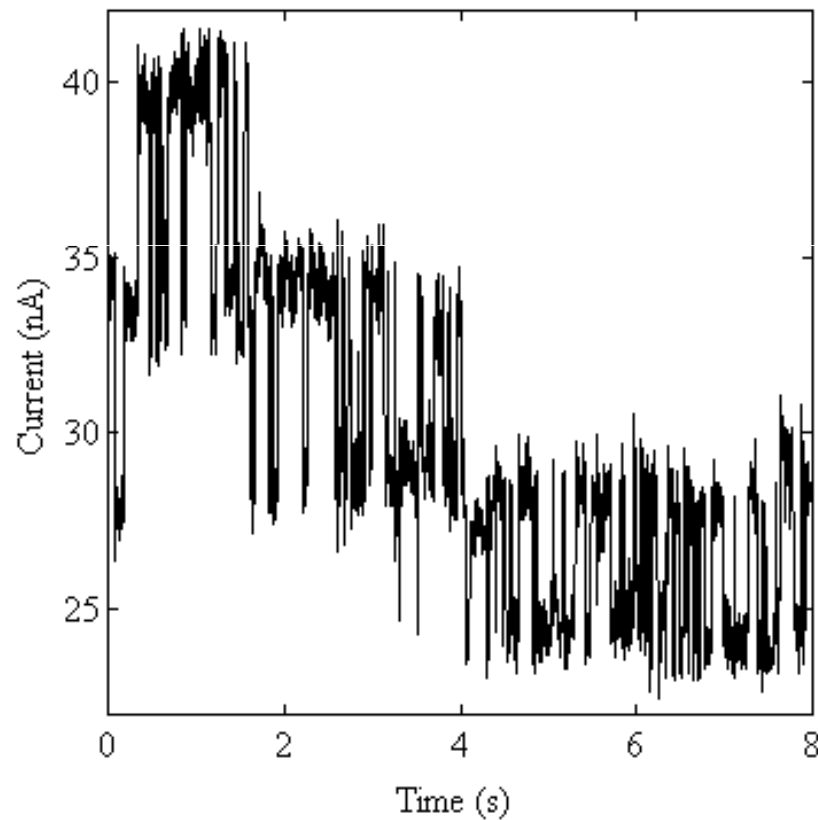


We studied the number of
defects created and their
occupancy

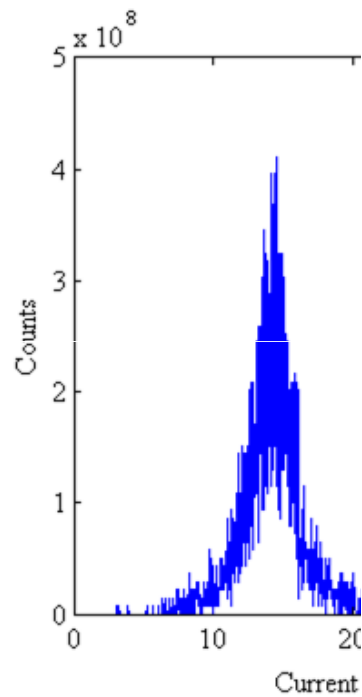
Time dependence of the noise characteristics



Mapping current levels

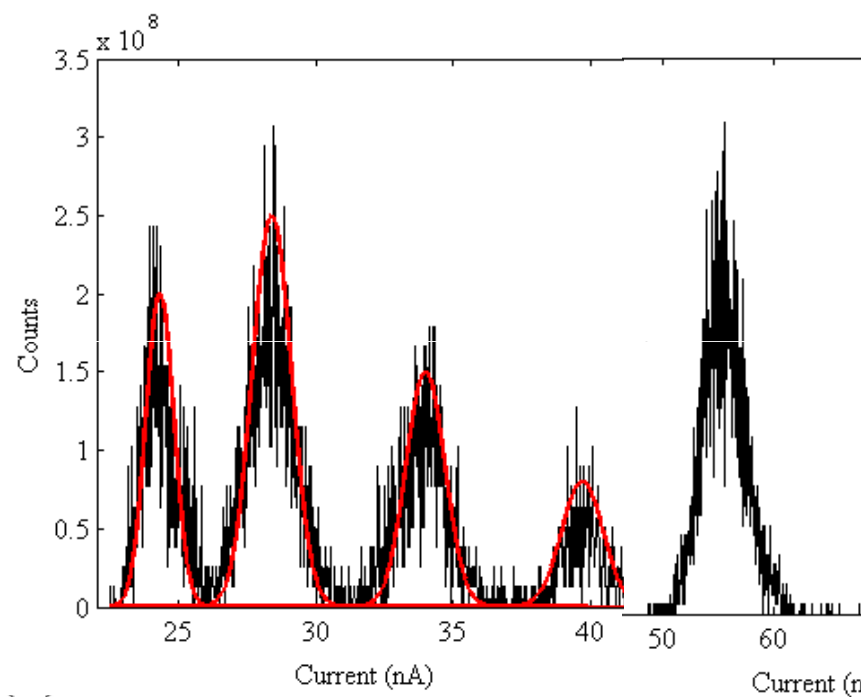


Mapping current levels



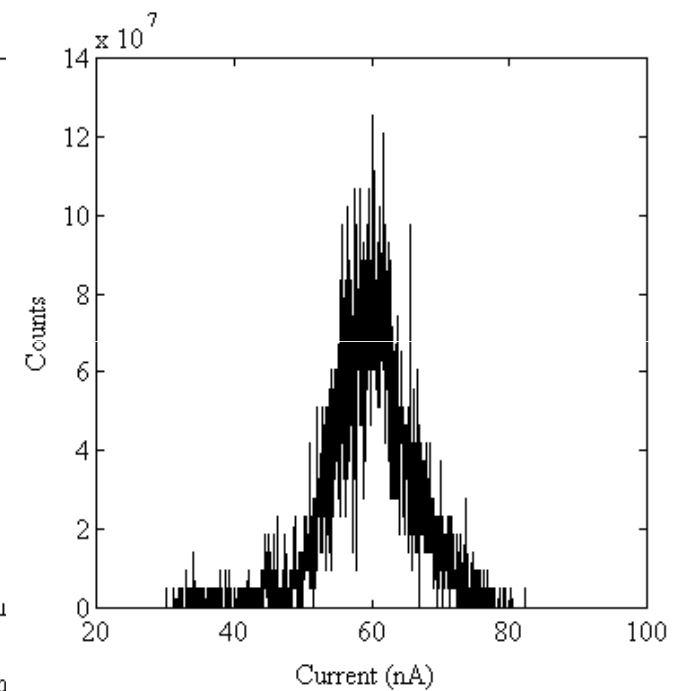
$T=218$ K

$\tau_c = 234$ ms



$T=235$ K

$\tau_c = 131$ ms



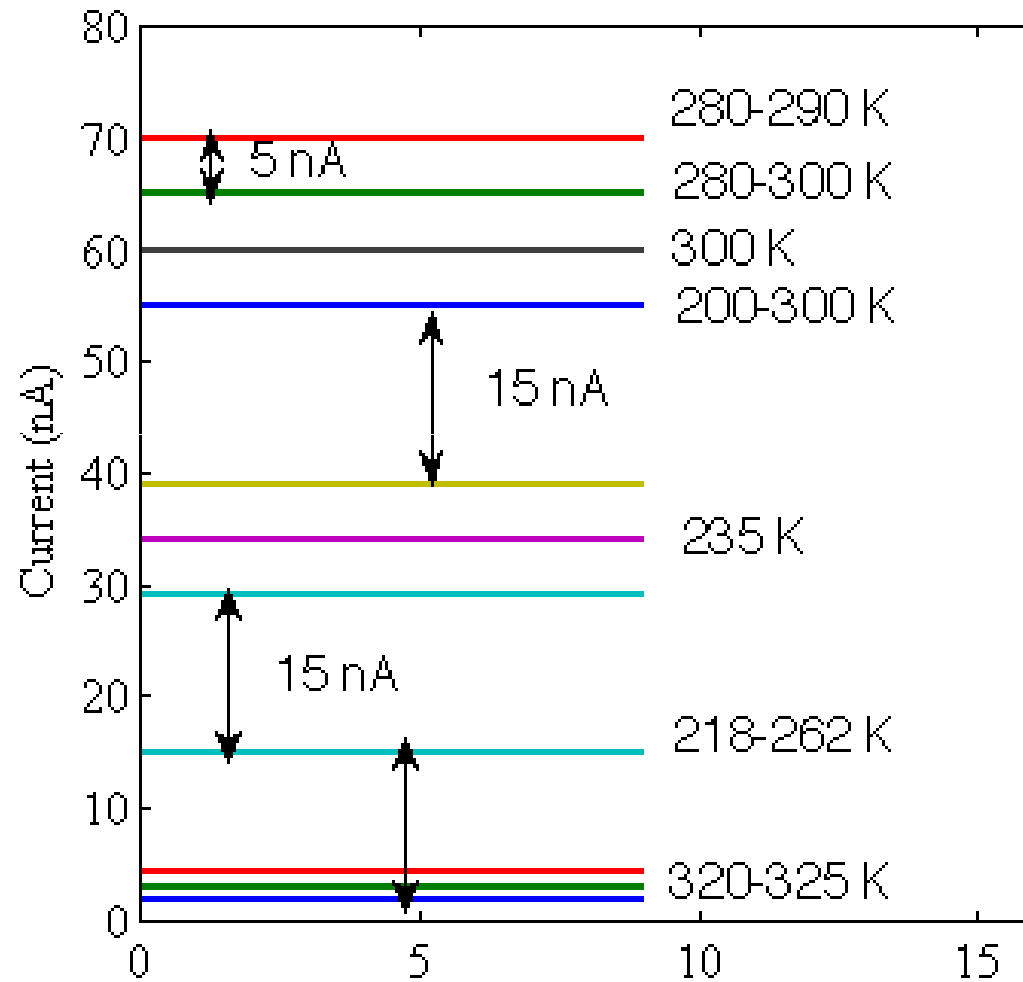
$T=312$ K

$\tau_c = 1.3$ ms

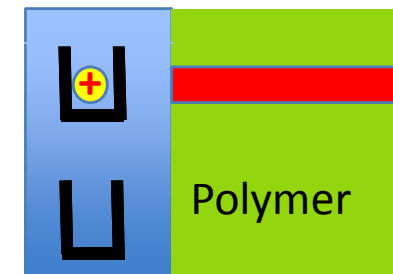


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Mapping current levels



A typical filament carries 5 nA of current



Acknowledgments

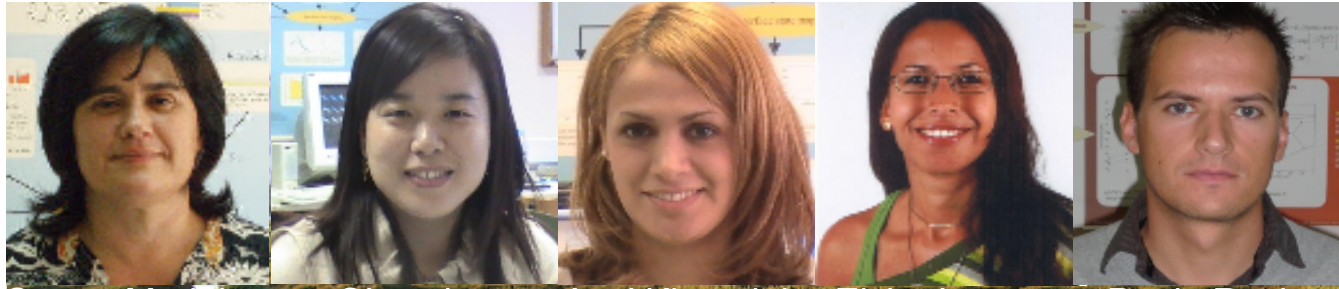
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Thank you for your attention

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