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Reliability Assessment Methodologies for RF-MEMS

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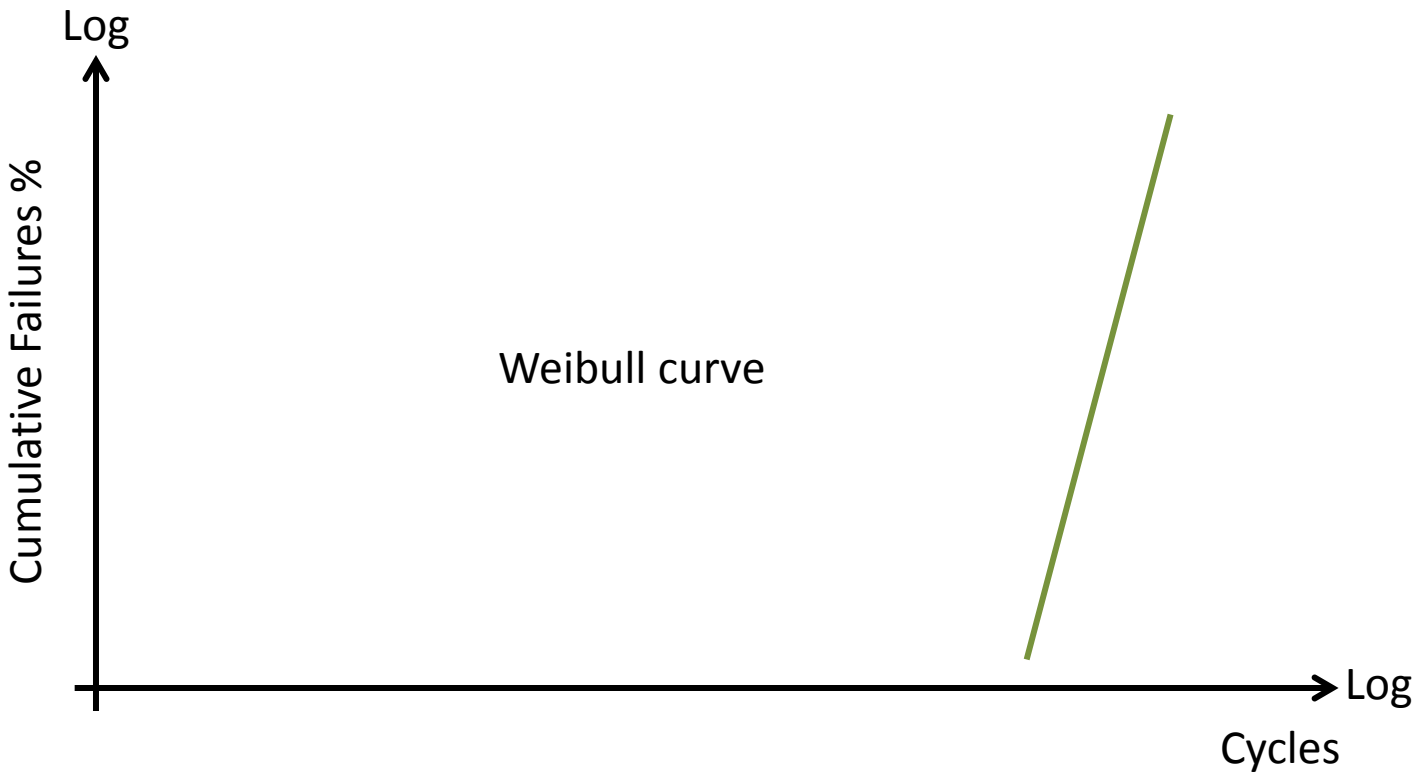
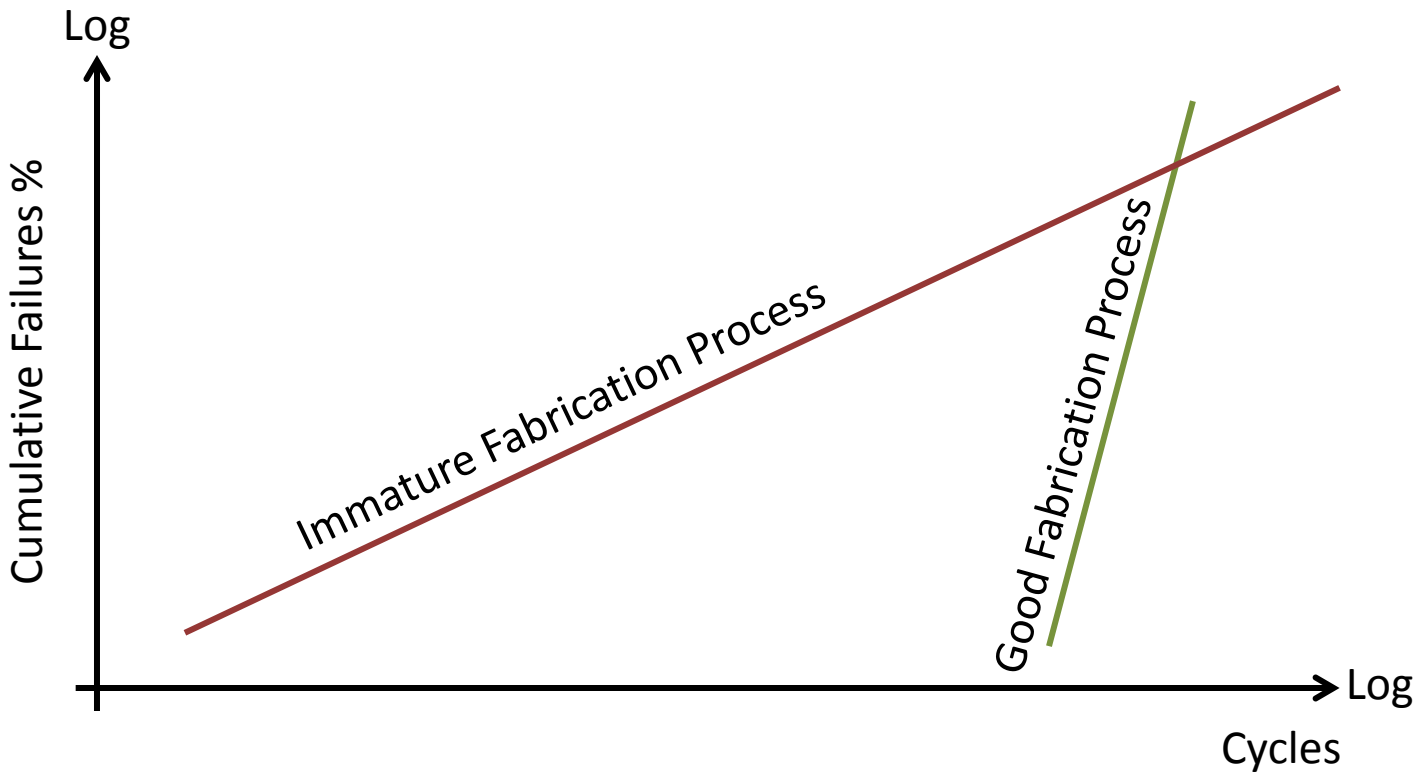
Overview

- Introduction
- Reliability accelerated testing
- Creep measurement
- Conclusions

Introduction Statistical Study of Reliability

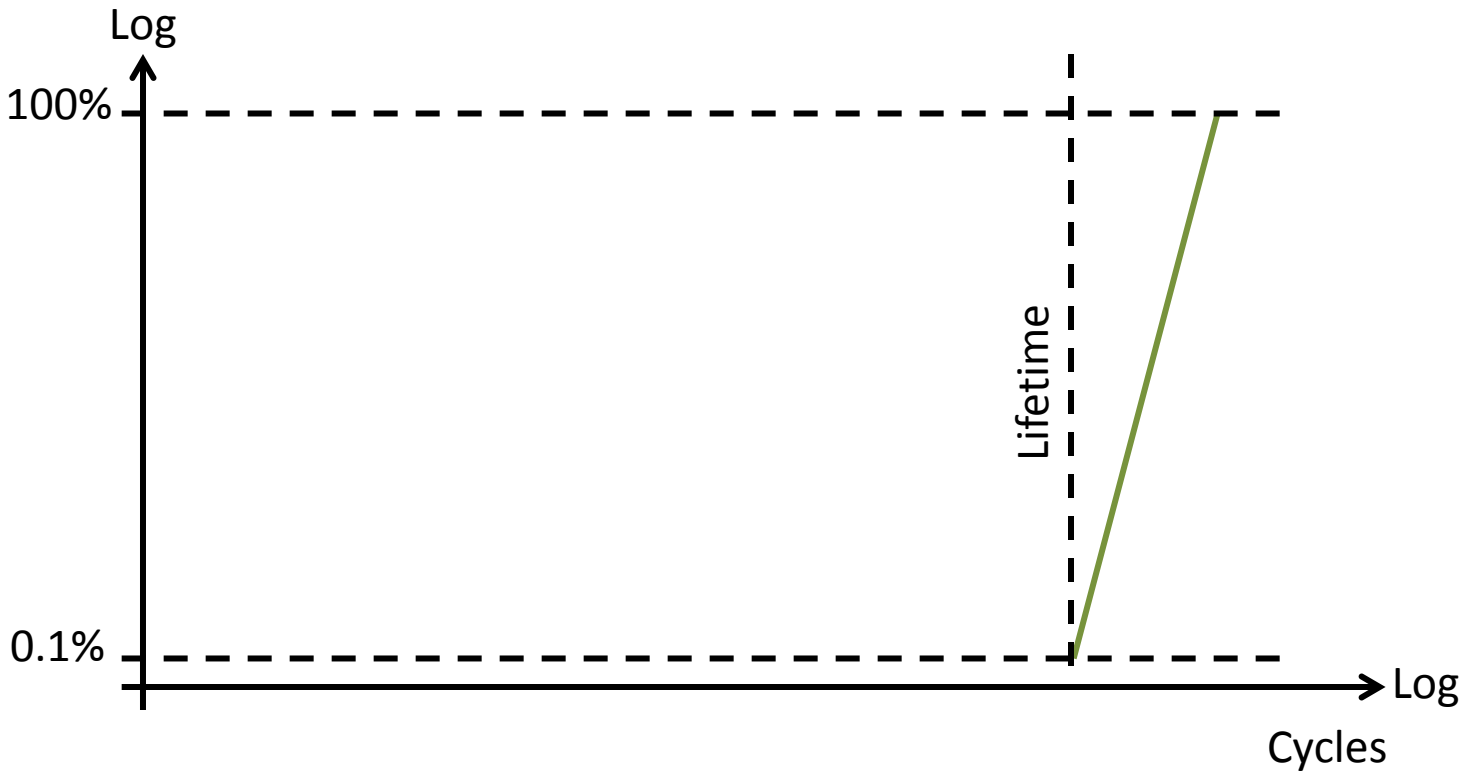


Statistical Study of Reliability



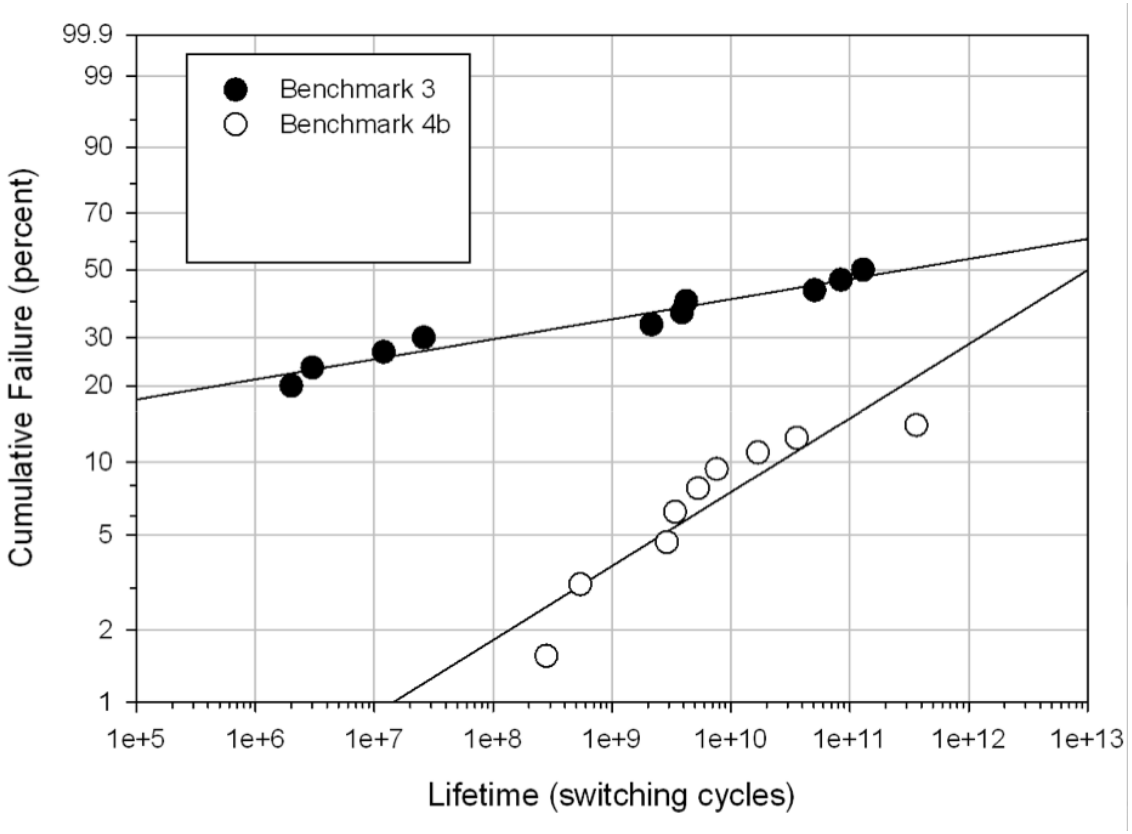
Statistical Study of Reliability

- Definition of lifetime



Statistical Study of Reliability

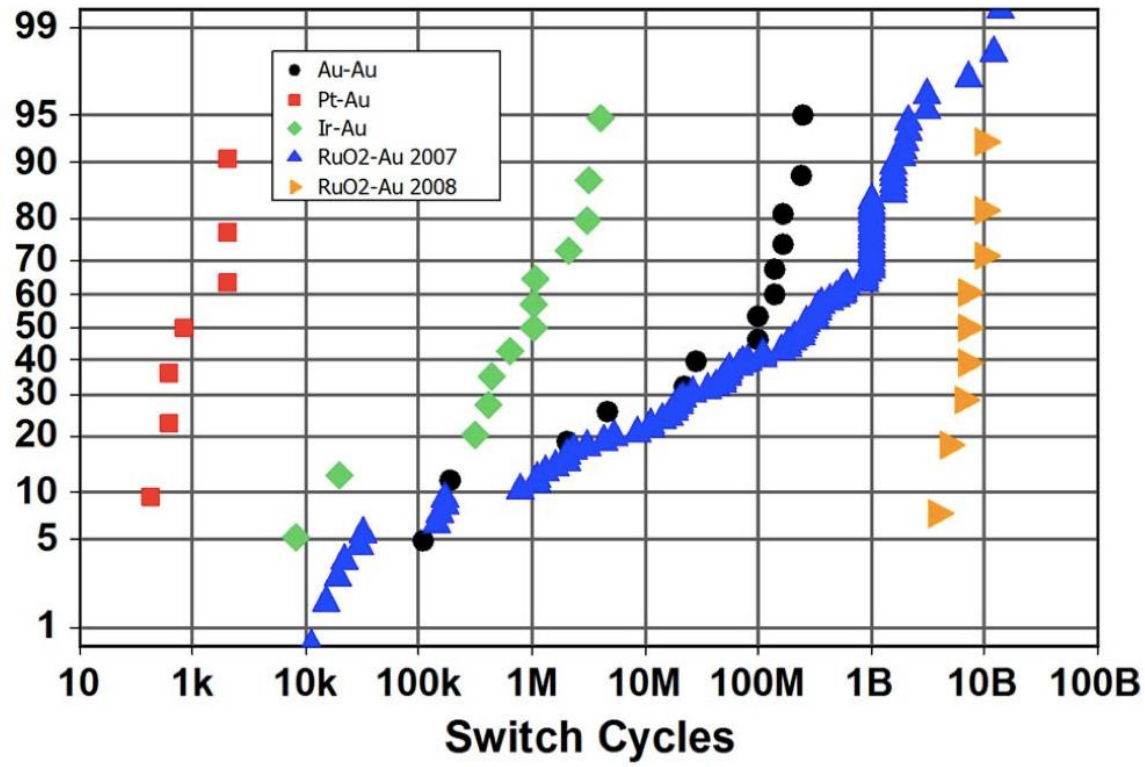
- Examples in the litterature



"Rugged and Reliable Ohmic MEMS Switches "
John Maciel, Sumit Majumder, James Lampen and Charles Guthy
Radant MEMS, Inc., Stow, MA 01775
IMS 2012 Montreal

Statistical Study of Reliability

- Examples in the litterature



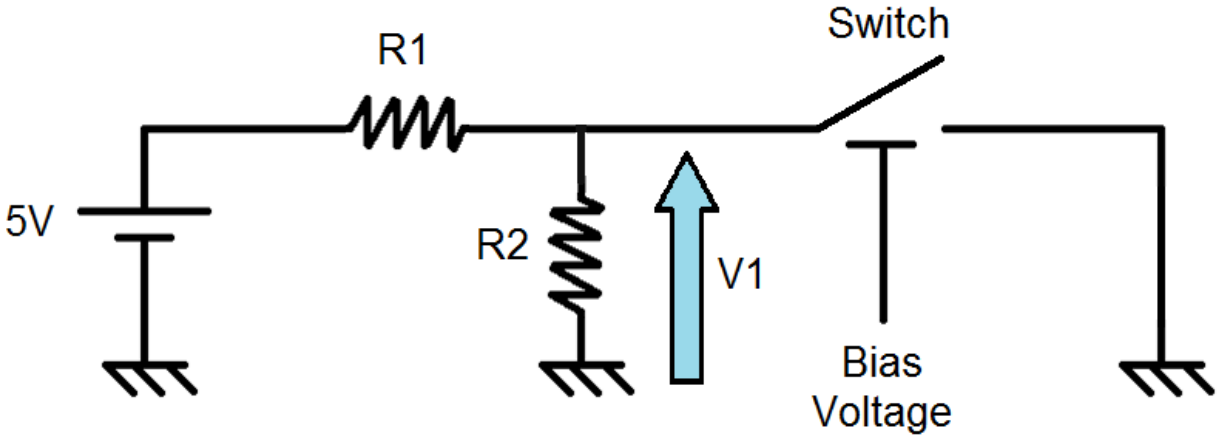
D. A. Czaplewski, C. D. Nordquist,
G. A. Patrizi, Garth M. Kraus, W. D. Cowan,
RF MEMS Switches With RuO2–Au Contacts
Cycled to 10 Billion Cycles
JOURNAL OF MICROELECTROMECHANICAL
SYSTEMS, VOL. 22, NO. 3, JUNE 2013

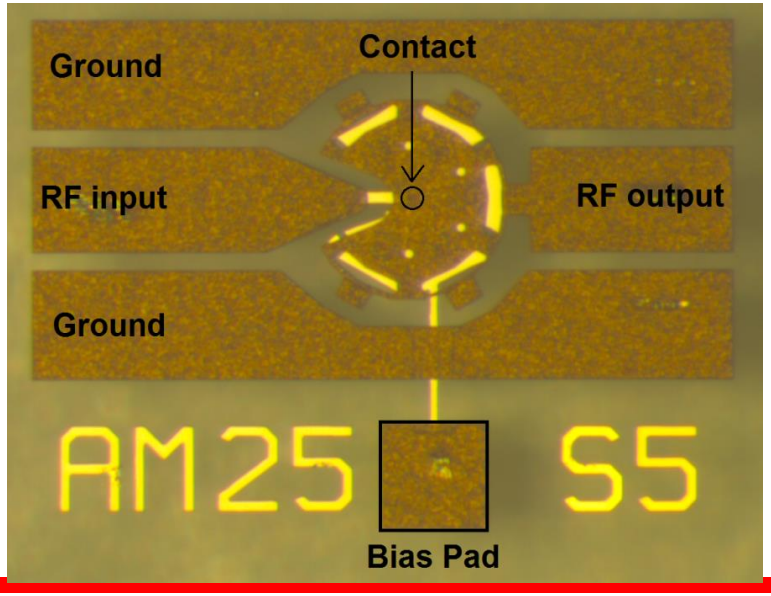
Reliability of RF-MEMS switches

- Reliability must be studied on a population of devices to obtain a statistical distribution of lifetime
- Acceleration methods are necessary to obtain this distribution as fast as possible
- RF-MEMS are slow!

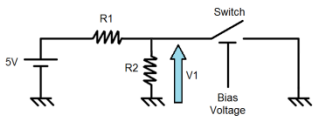
Performances of RF-MEMS in cold switching

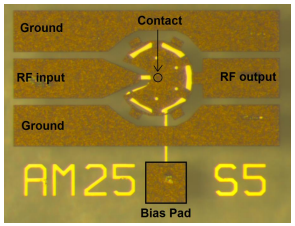
R1=10kOhm
R2=40kOhm

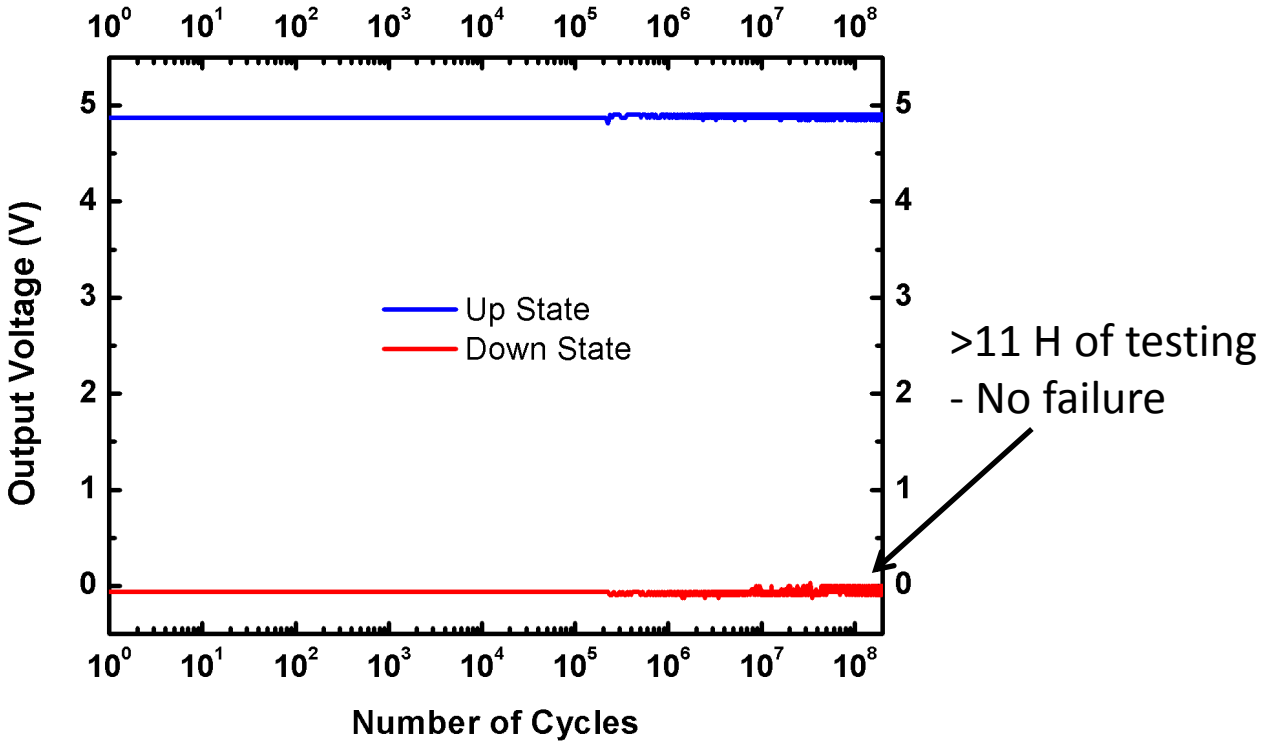




Example of testing – cold switching

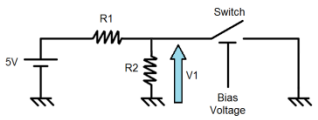


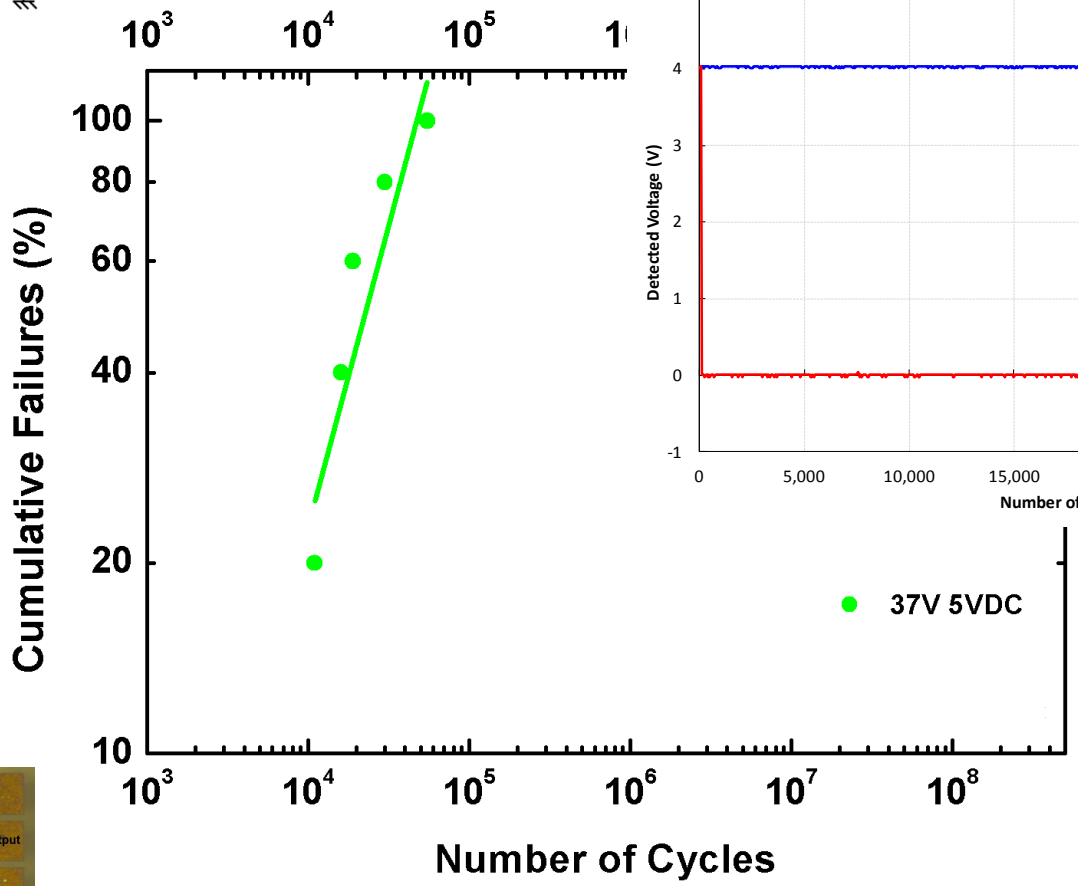


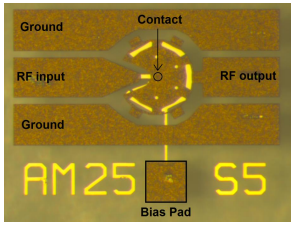


Not suited for accelerated testing !

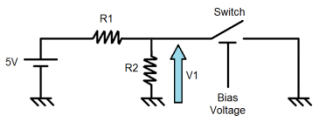
Reliability acceleration testing hot switching

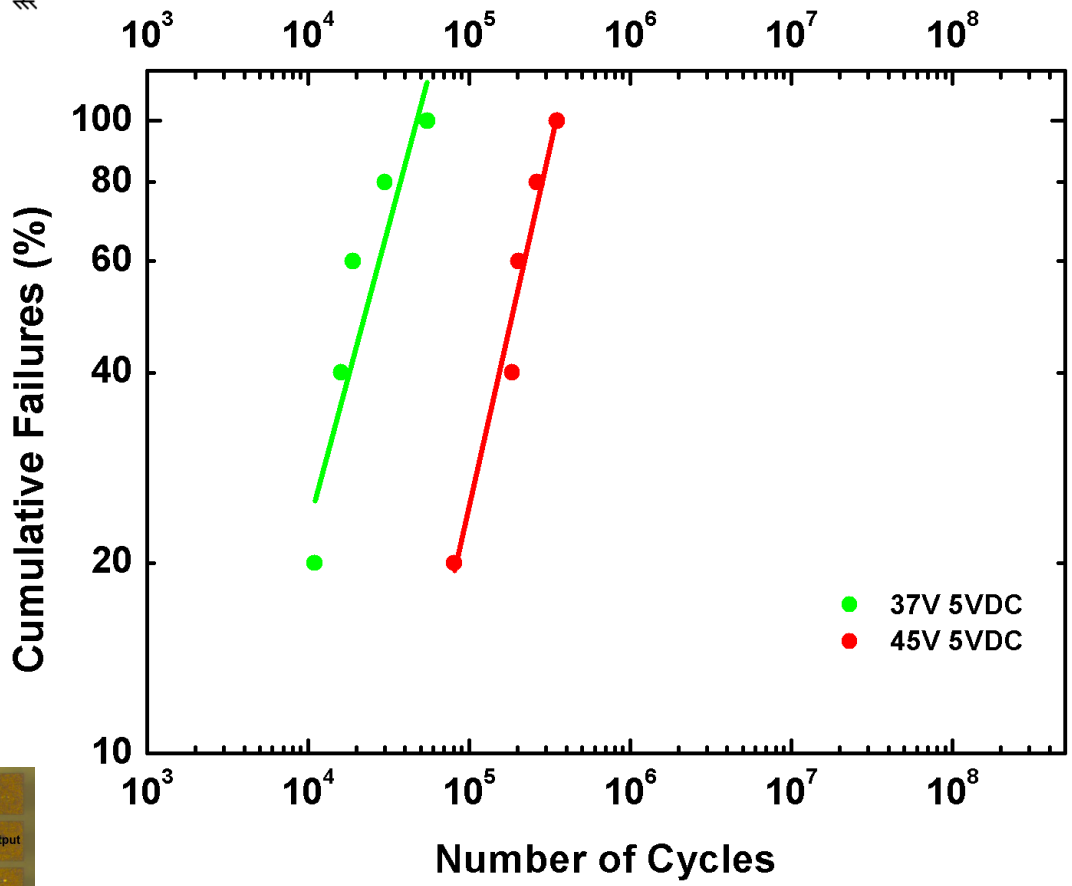


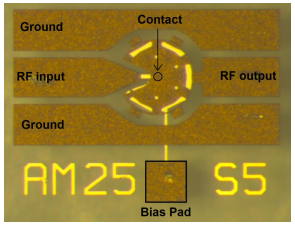




Reliability acceleration testing







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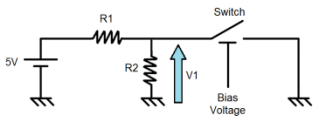

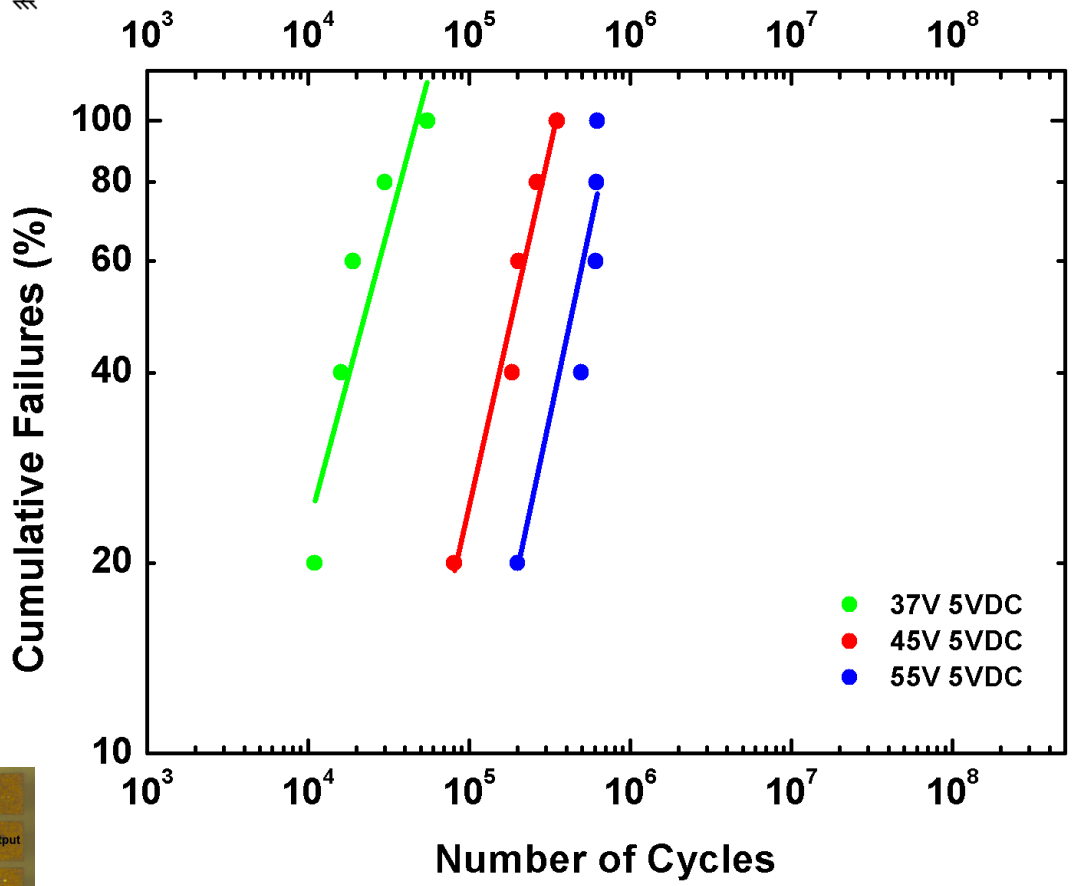

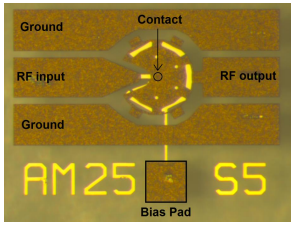

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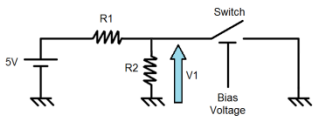
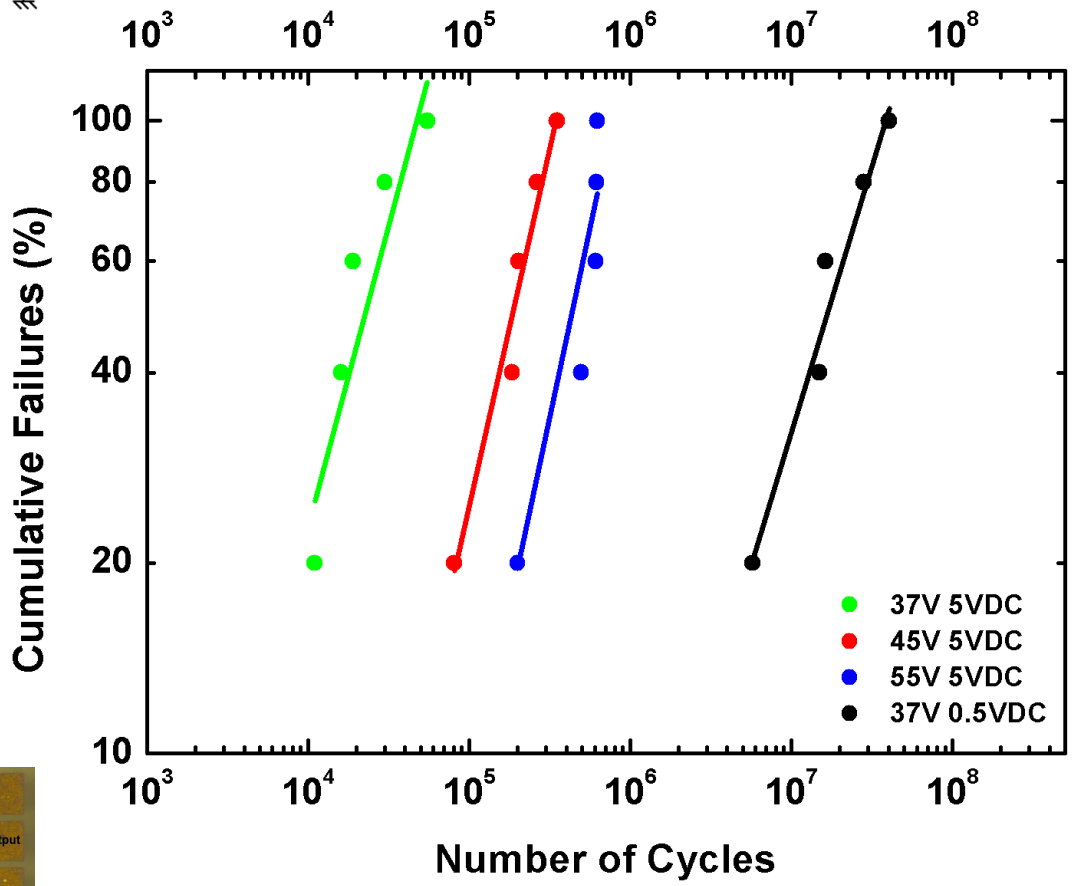
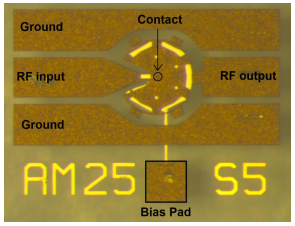






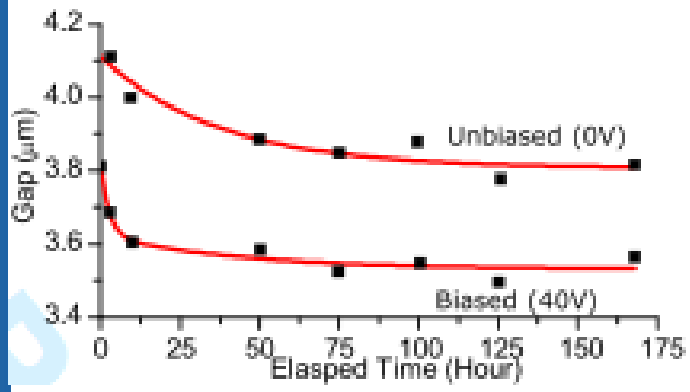
Conclusion – Weibull analysis

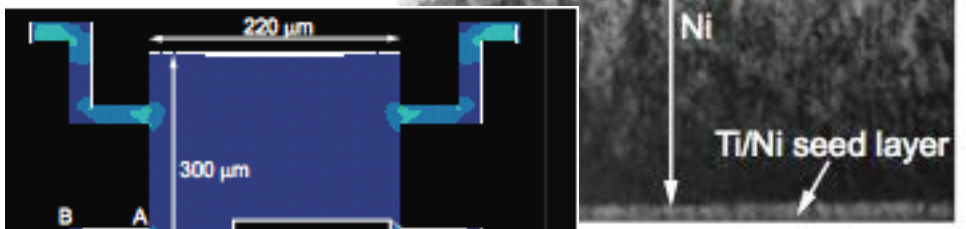
- Failure in RF-MEMS switches is accelerated with hot switching
- Input-output voltage permits dramatic acceleration of failure
- Bias voltage has a large influence on final reliability

Creep measurement

Creep

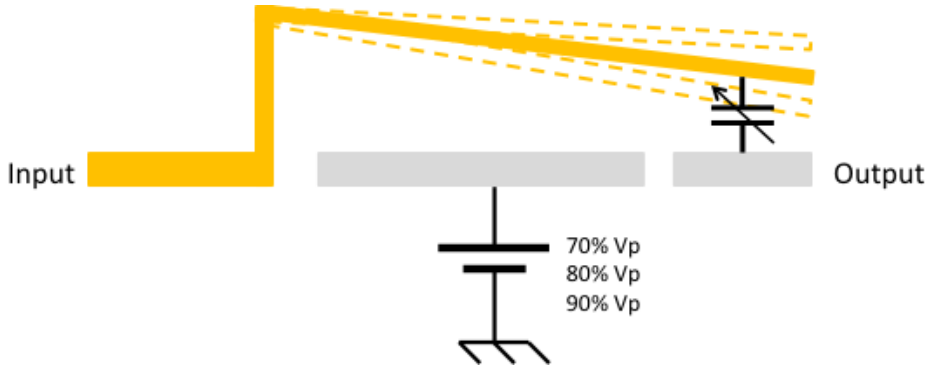
- Semi-permanent mechanical deformation, present in metals, especially in gold
- Accelerated with temperature
- Partly reversible if bias is removed
- Slow process (Hours)

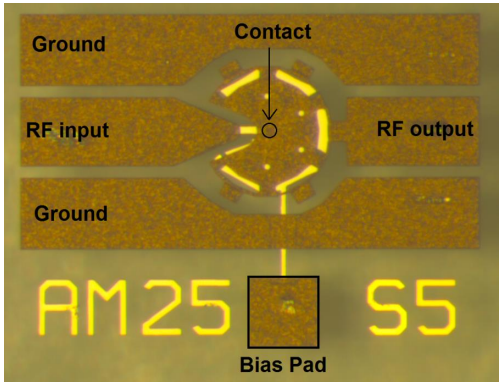




RF Characterisation

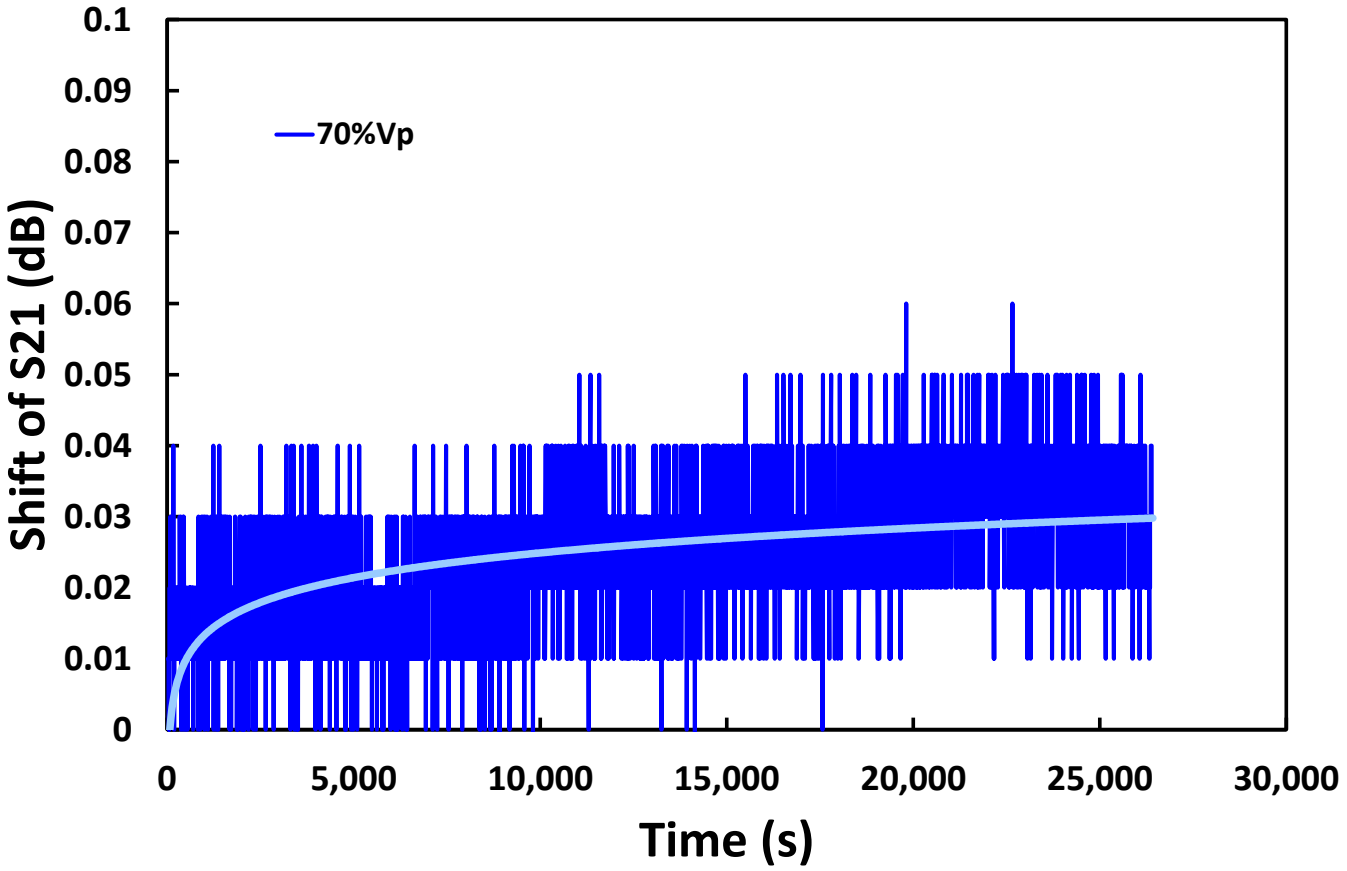
Measurement of RF-transmission parameter (S_{21}) over time -> Proportionnal to the input to output capacitance -> proportionnal to the mechanical separation between input and output





Creep - > Small deformation over time with a permanent bias voltage applied

- Measured results 70% of pull-in voltage applied



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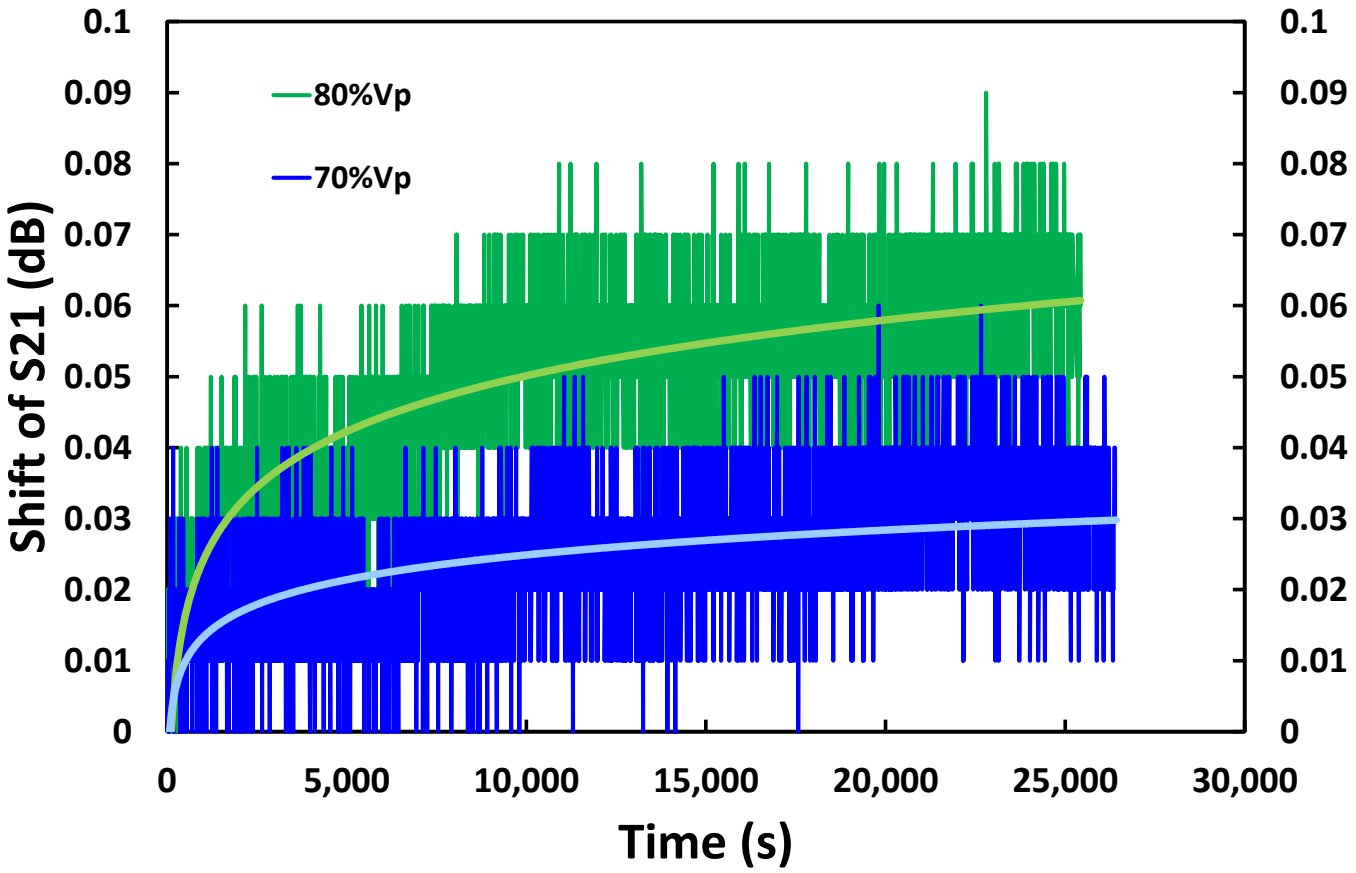

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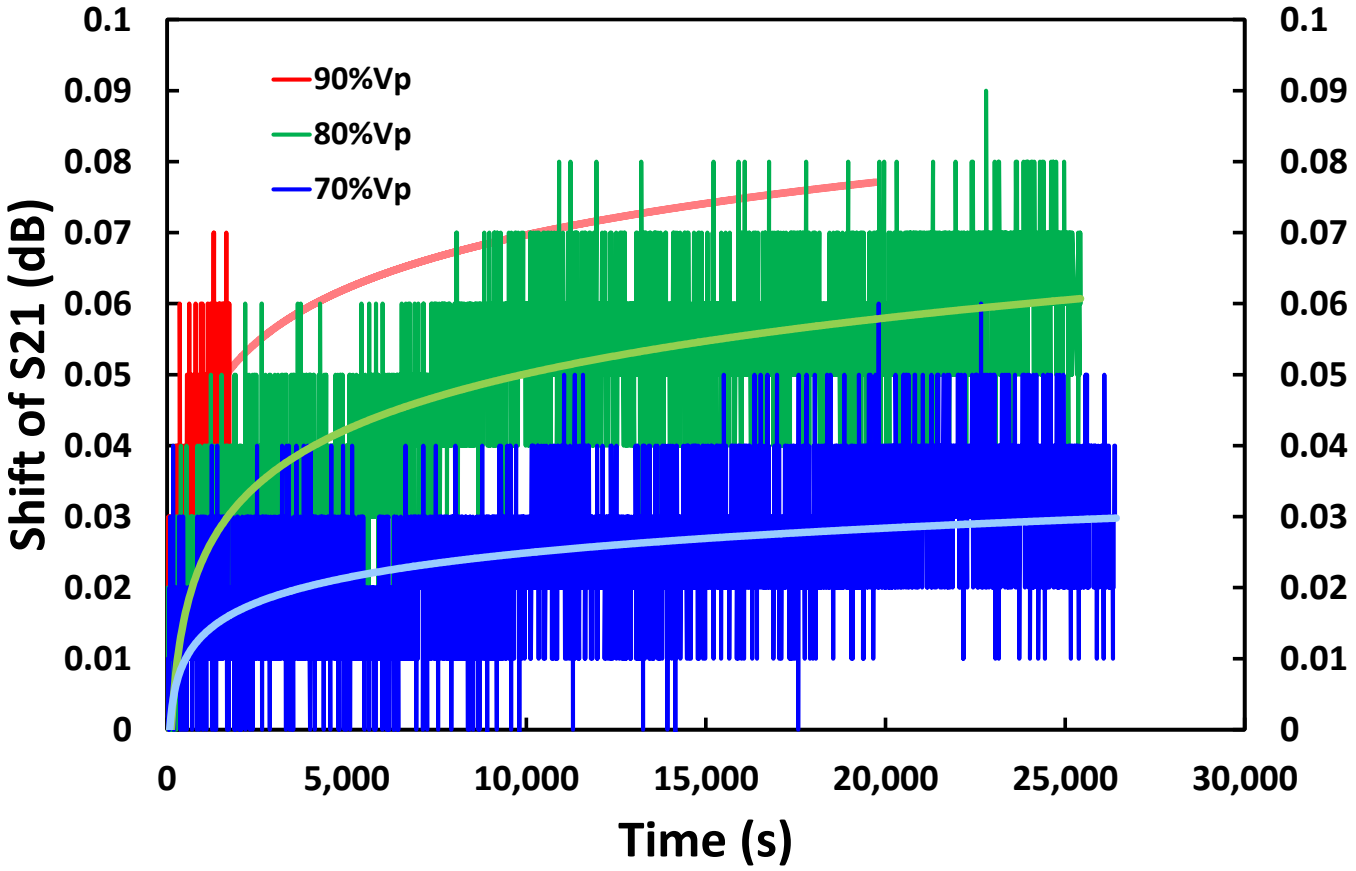
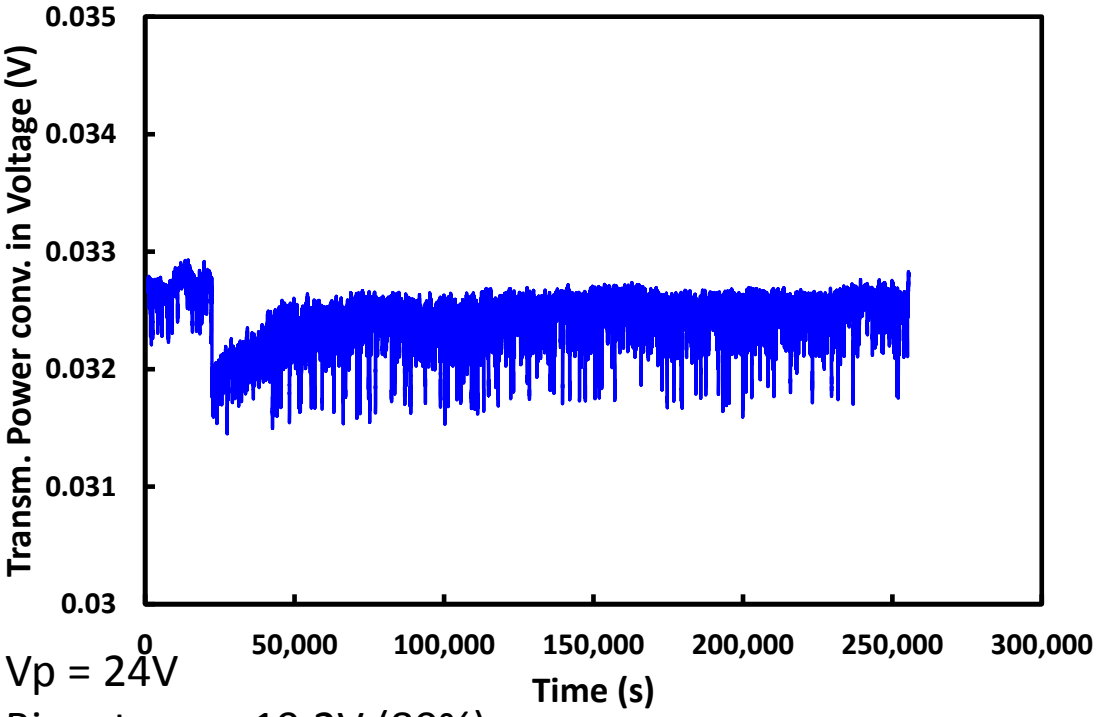
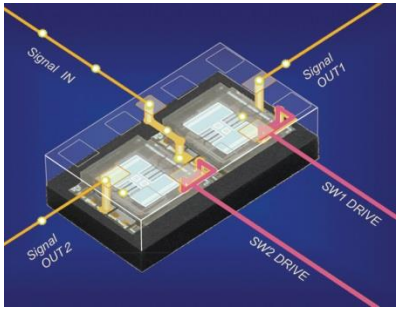


RF Characterisation

- Testing on Omron devices (Single cristal mechanical structure – no Creep)





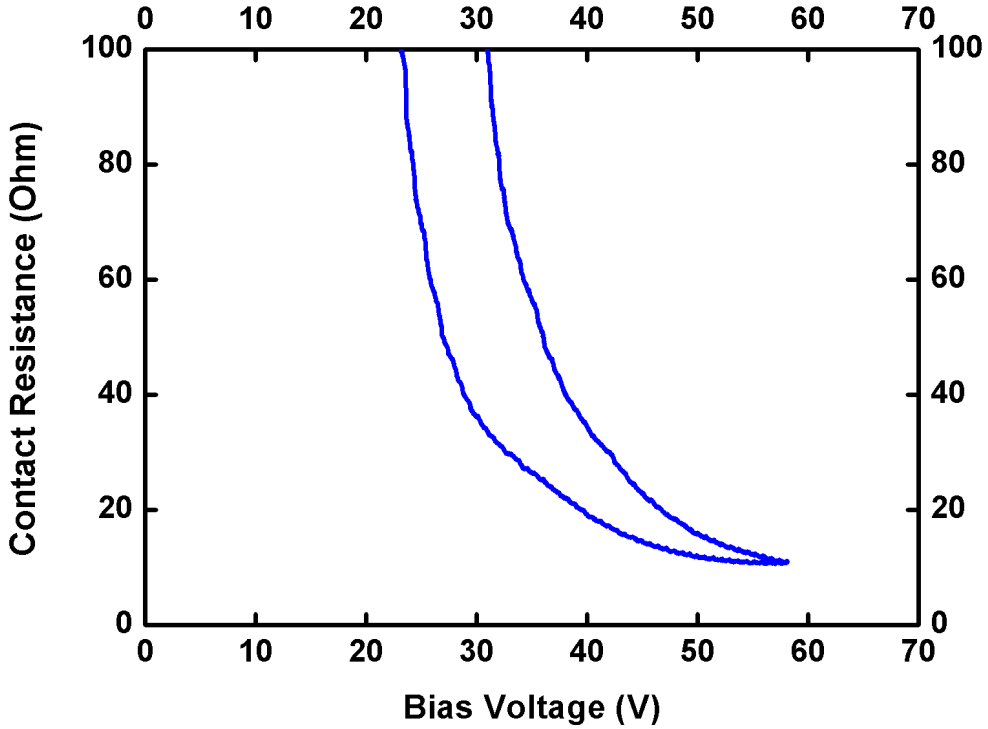
Vp = 24V

Bias stress = 19.2V (80%)

Constant R_{on} servo monitoring of bias voltage

Constant R_{on} servo monitoring of bias voltage

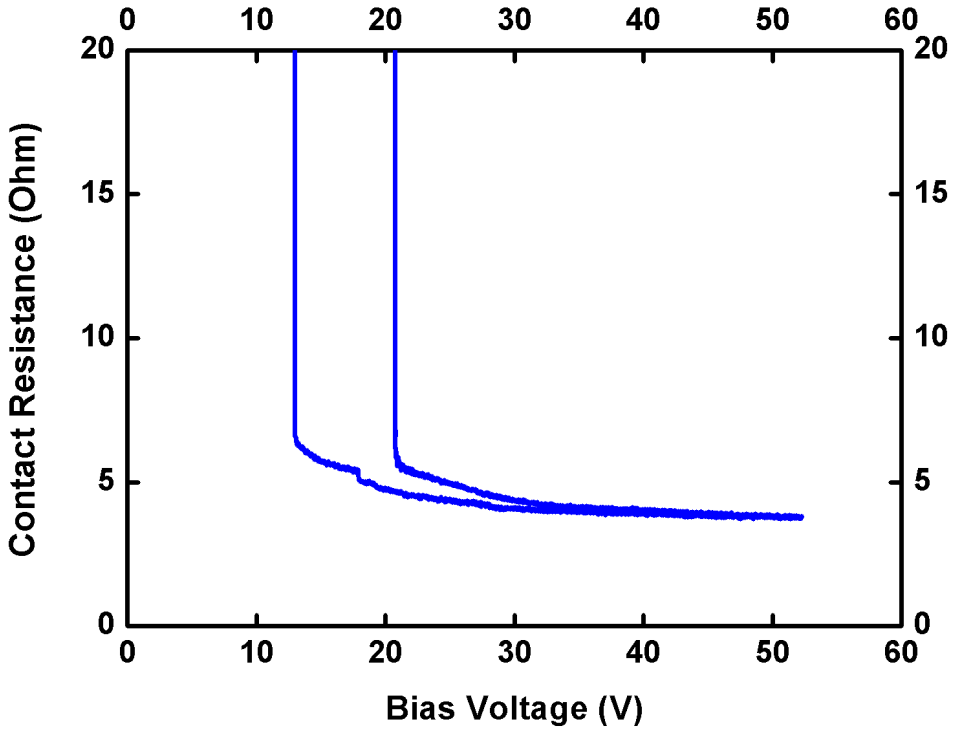
- Contact resistance vs applied bias measurement



Xlim S7
Au/Au contact

Constant R_{on} servo monitoring of bias voltage

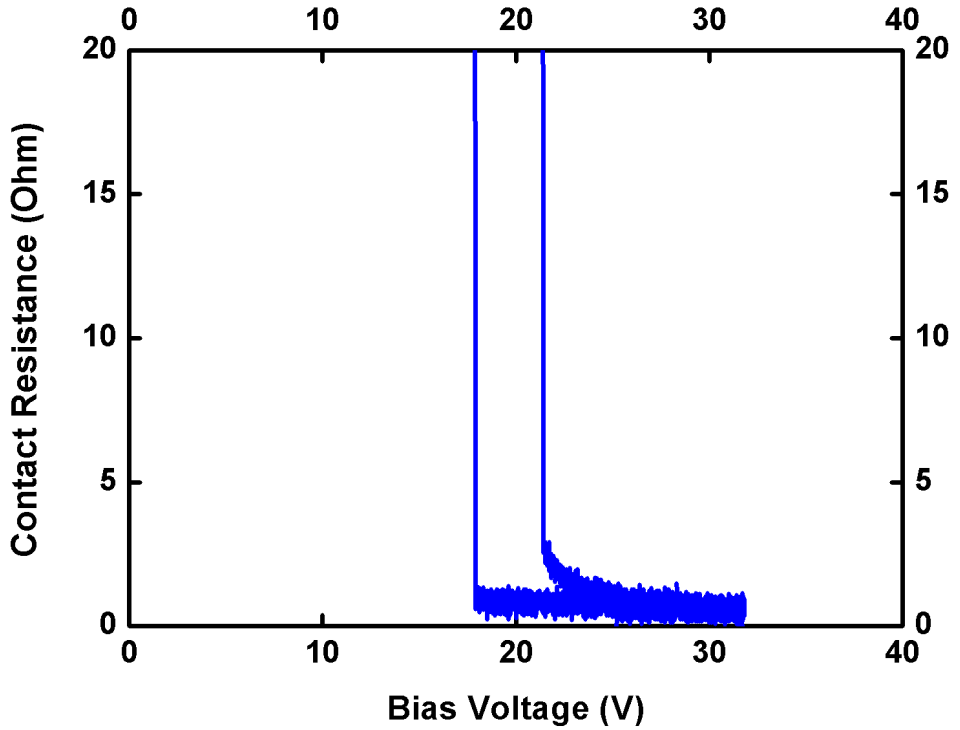
- Contact resistance vs applied bias measurement



Xlim S3
Ru/Au contact

Constant R_{on} servo monitoring of bias voltage

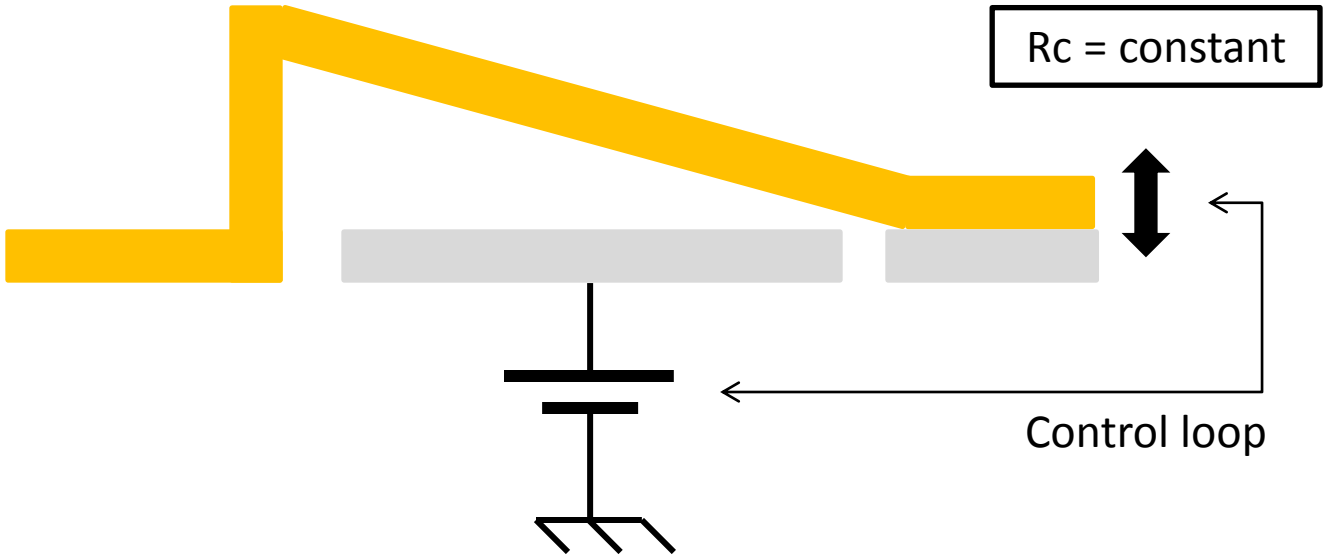
- Contact resistance vs applied bias measurement



Omron
Ru/Ru contact

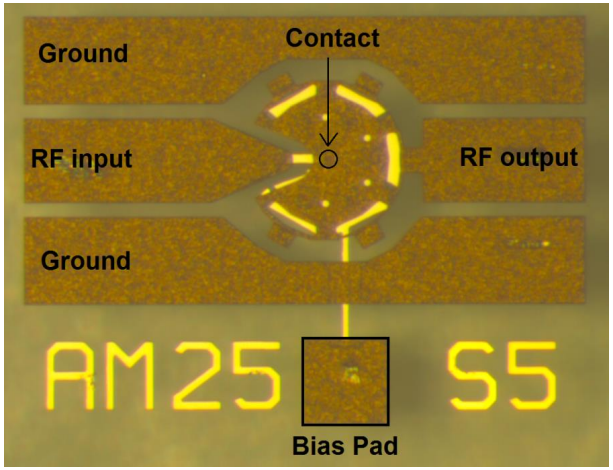
Constant R_{on} servo monitoring of bias voltage

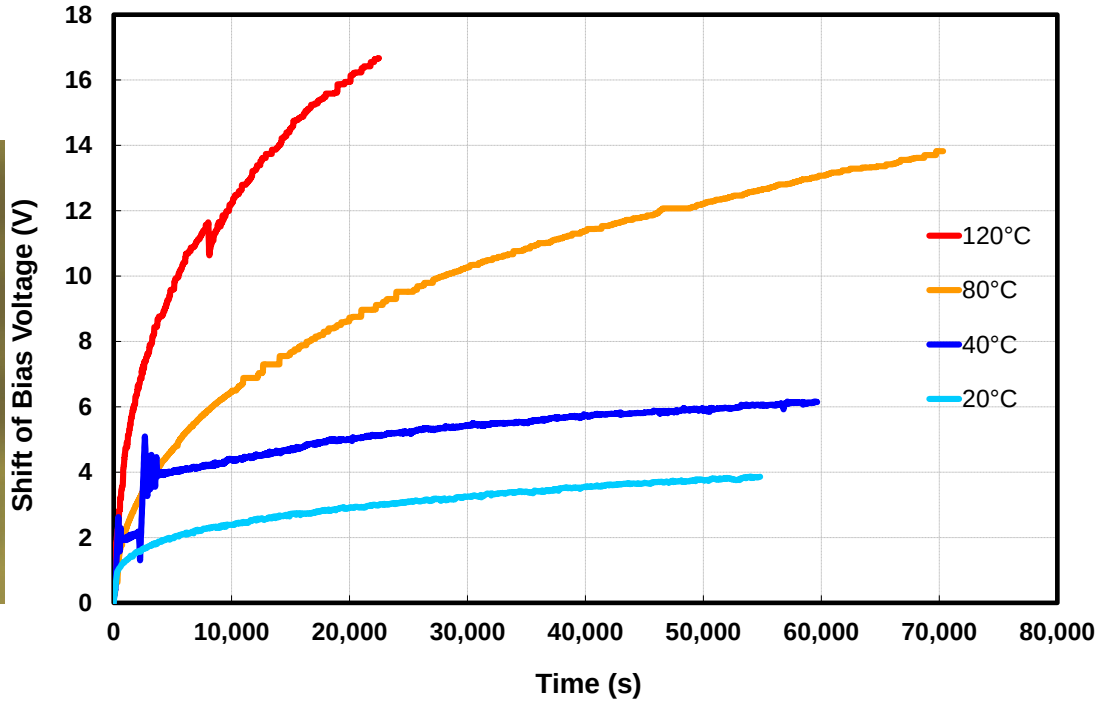
- Constant Resistance measurement



Constant R_{on} servo monitoring of bias voltage

- Voltage drift versus time for various temperature
- Start voltage is 35 V





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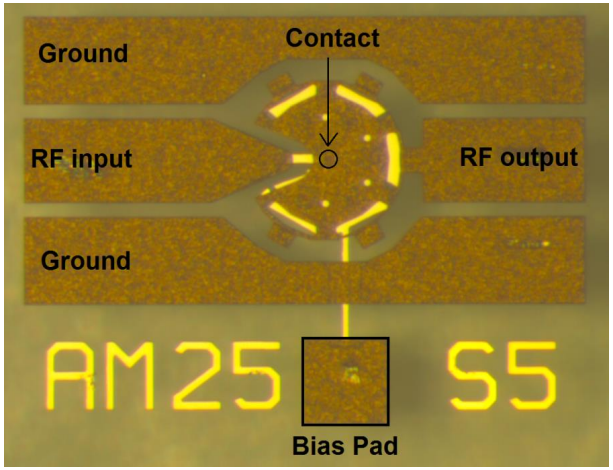
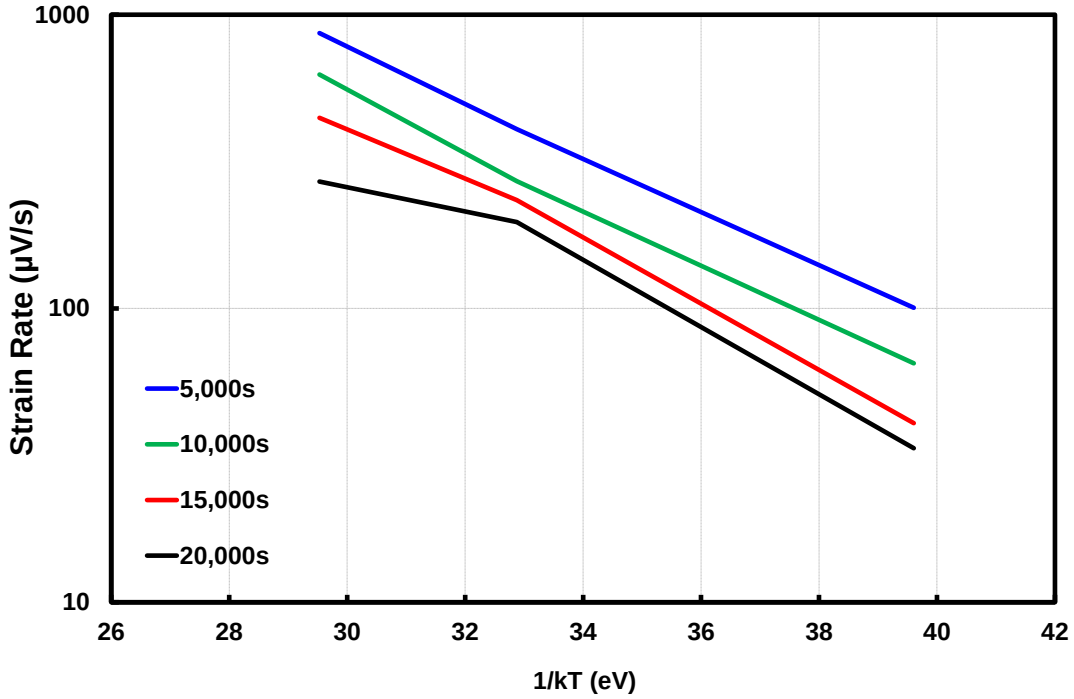


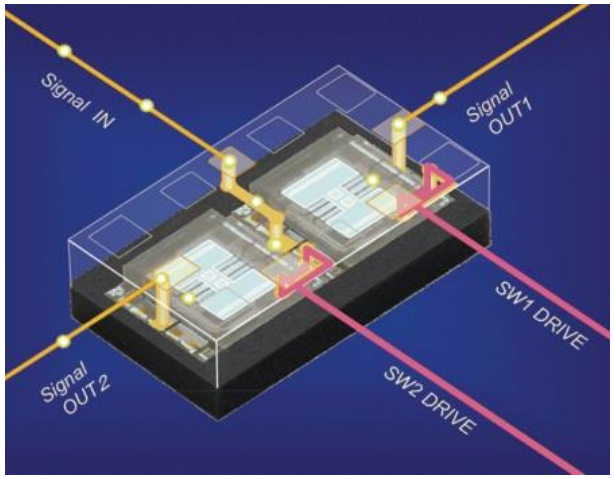


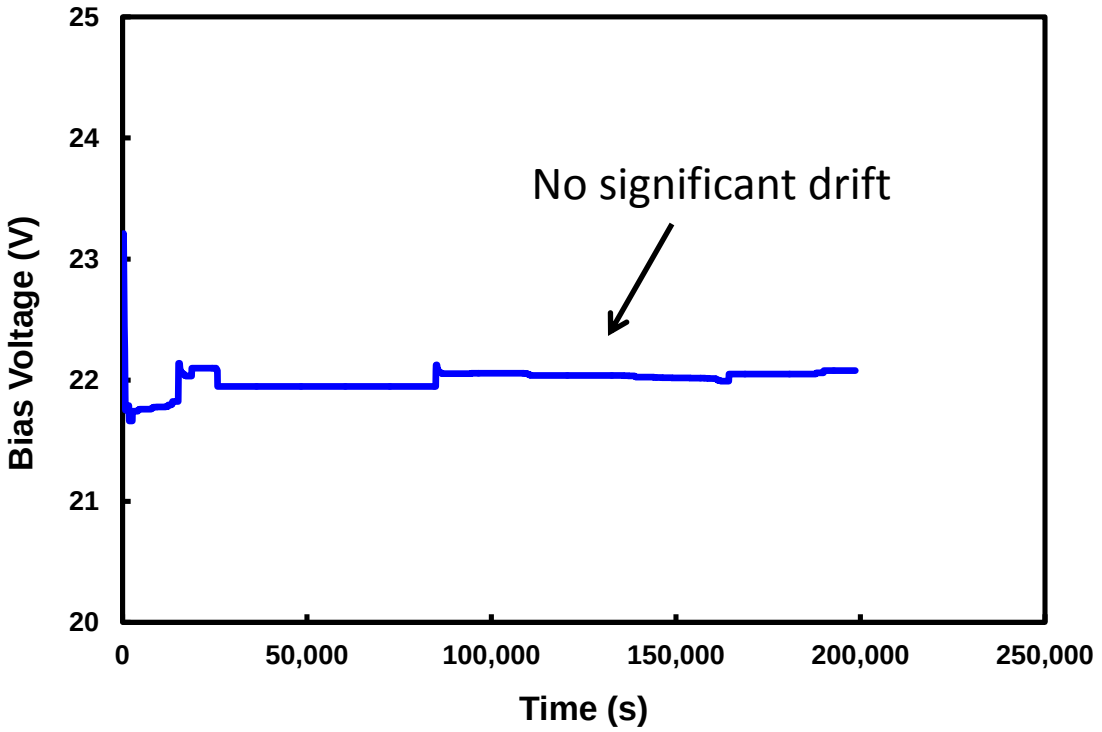
Activation energy = 0.22eV

Standard deviation = $8.8*10^{-3}$eV

Constant R_{on} servo monitoring of bias voltage

- Testing on OMRON MEMS switches
- Ru contacts and single cristal mechanical structure



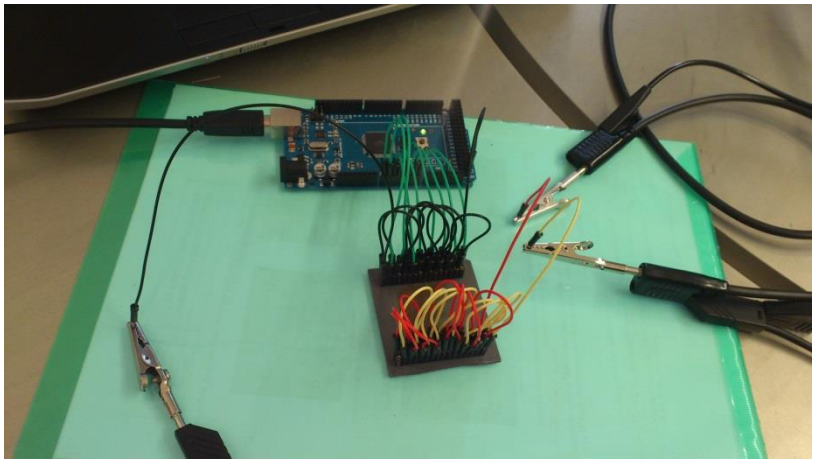


Conclusions - Creep

- Two methods have been proposed for creep characterisation in RF-MEMS switches
- RF transmission-based method permits observation of creep, but the influence is low and difficult to measure
- Constant R_{on} servo monitoring of bias voltage permits extraction of activation energy, and relatively fast and accurate characterization
- Single cristal structures and hard contact metal show little or no drift

Conclusion

- Acceleration testing using bias parameters
  - Set up of 48 switches measured in parallel (in progress)
  - Use of micro-controller



Thank you for your attention