Quantification of induced stiction in a MEMS

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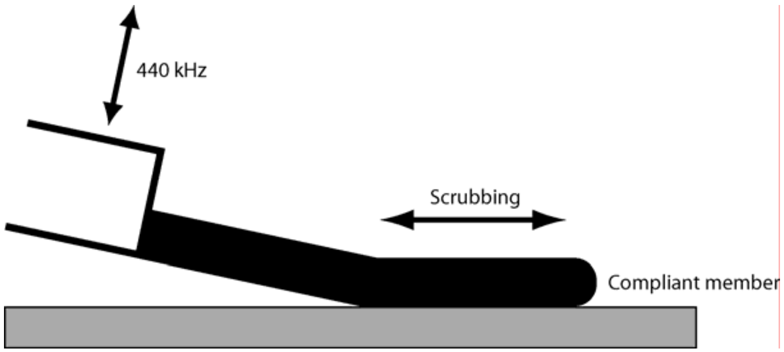
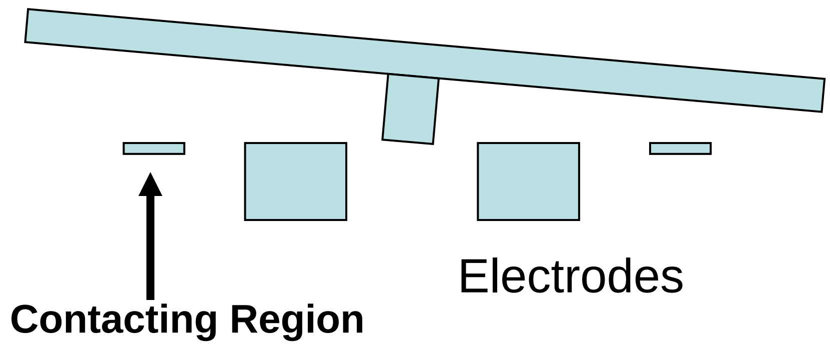
Objective

Improve fundamental understanding of stiction in MEMS devices allowing decreased packaging complexity and cost reduction.

- **Use MOEMS as a test bed for stiction and friction characterization studies**
  - **Develop a model for the quantification of induced stiction under controlled operating conditions**
  - **Study the effect of stiction under elevated operating temperatures**

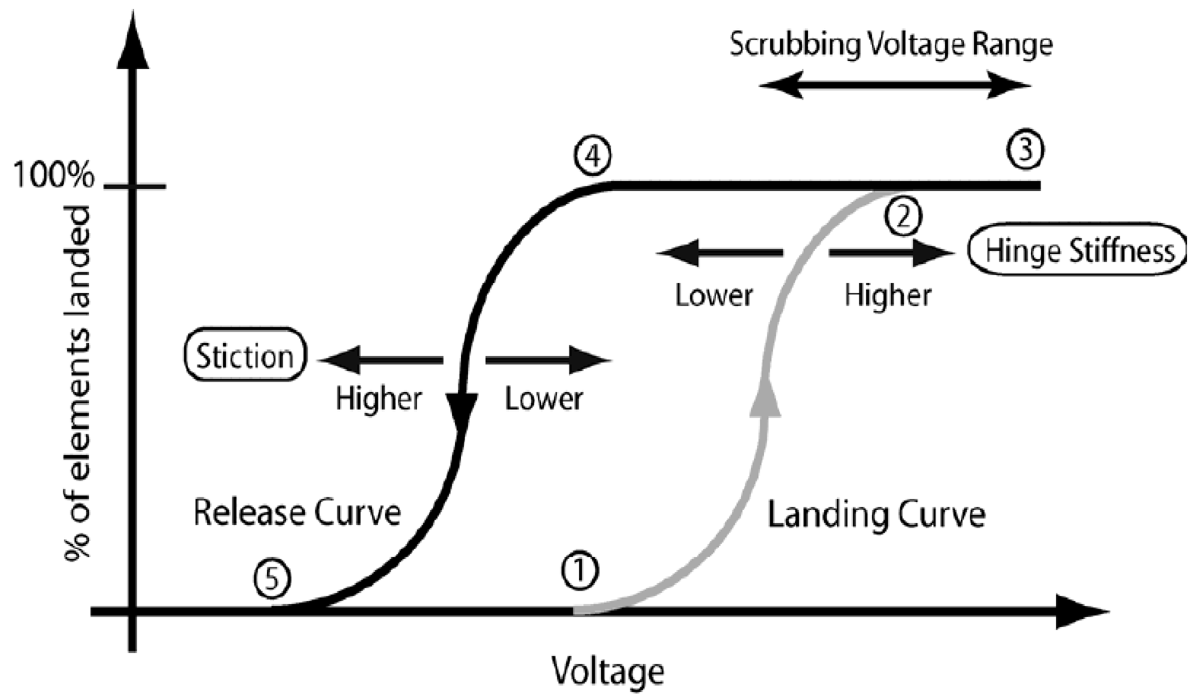
Background



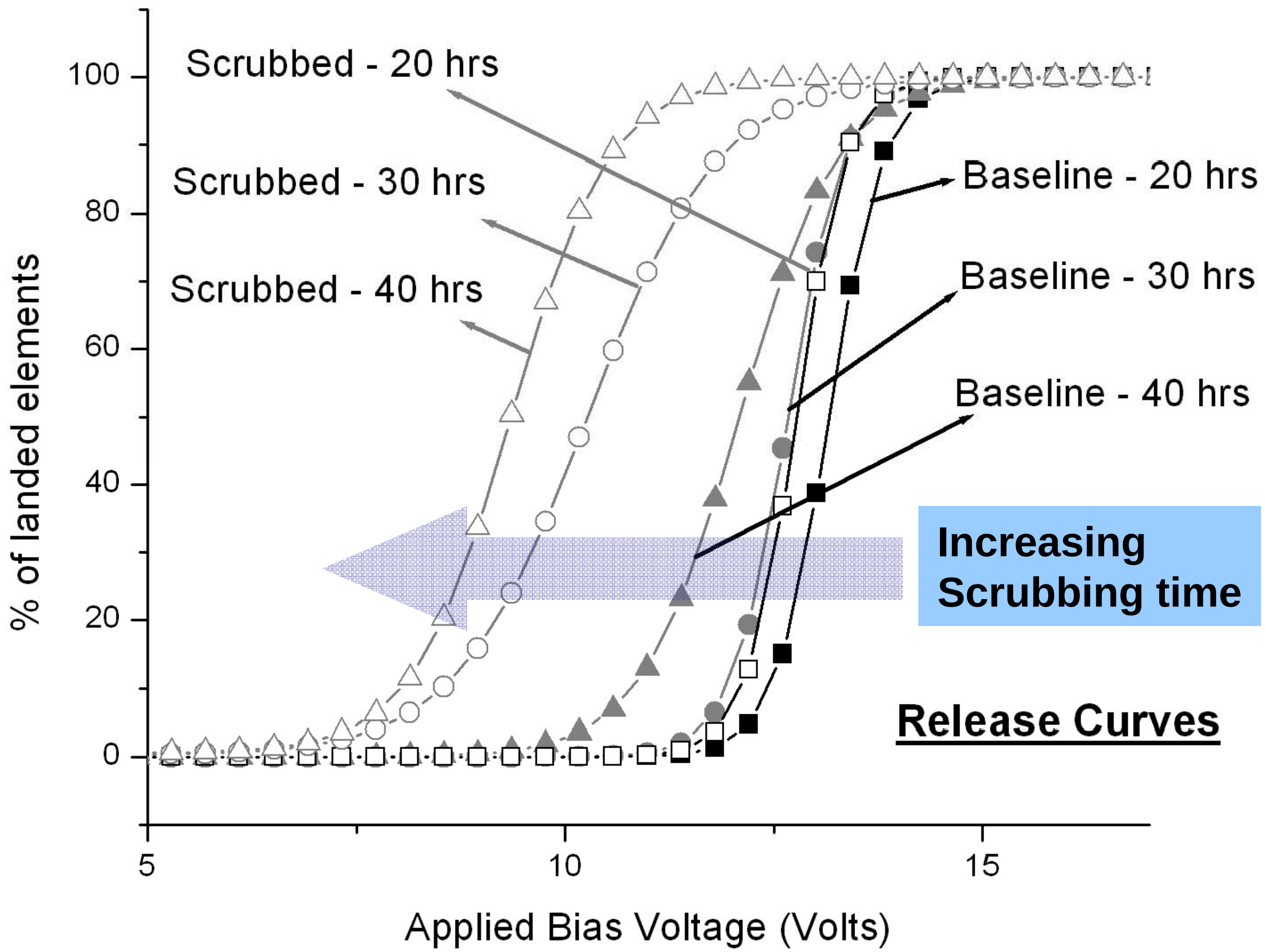


Scrubbing – Accelerated aging procedure by which a high frequency waveform is impressed on top of the standard DC bias applied to the micromirrors

Scrubbing initiates back and forth motion increasing Stiction inducing interactions.

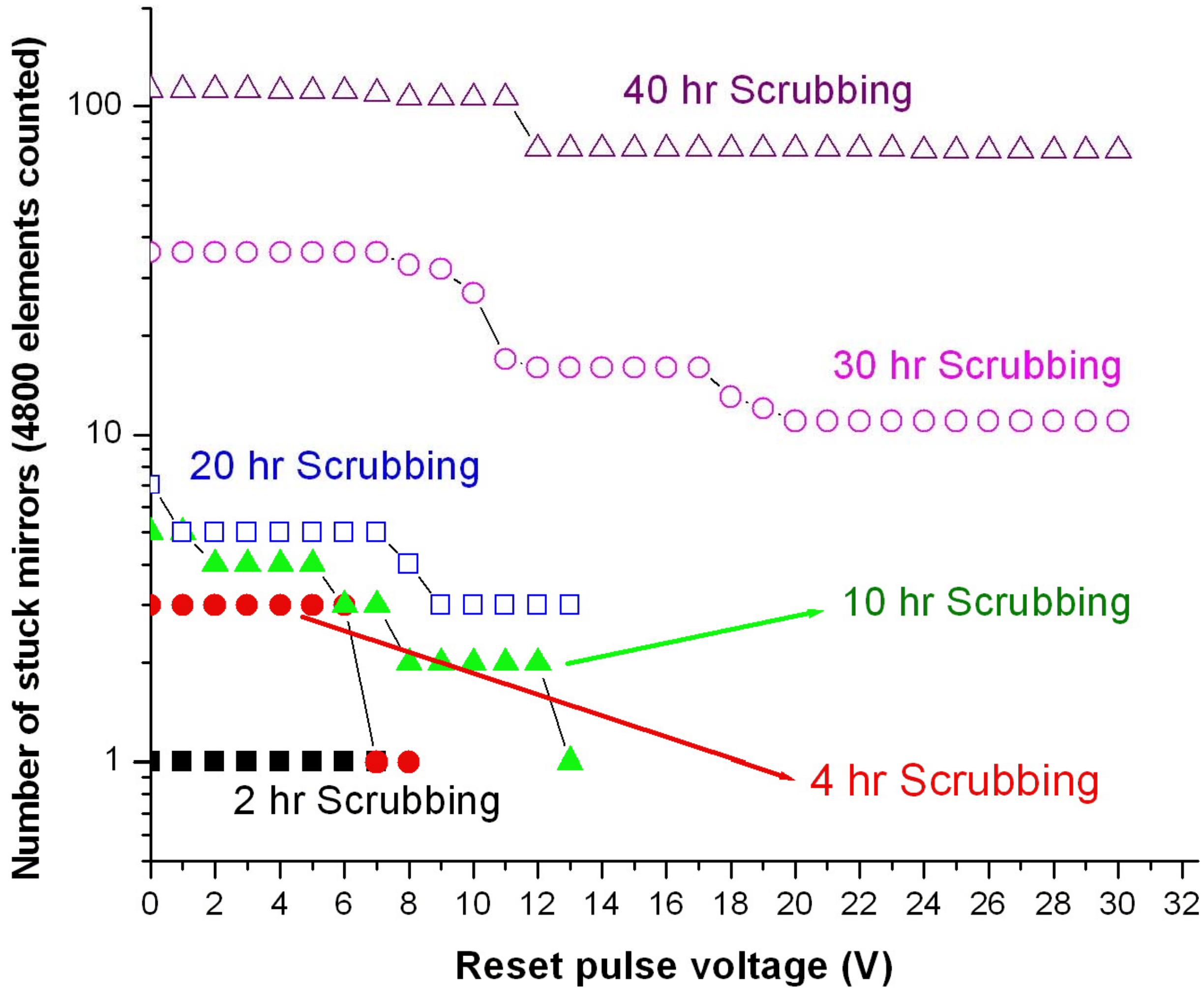


Typical Results



Scrubbing successful in promoting stiction with longer scrubbing time increasing Surface stiction

Typical results…. cont'd



Bias Adhesion mapping – Application of progressively increasing magnitude reset pulses to release stuck mirrors

Release Voltage and Reset pulse voltage values – Good Stiction indicators

Device modeling – Capacitance based modeling

Equation of motion

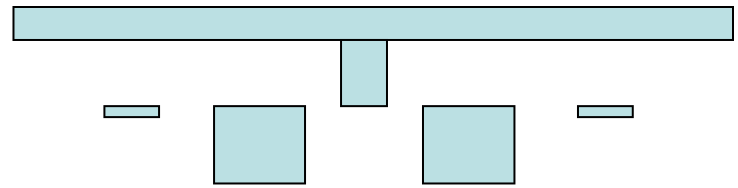
$$I\frac{d^2\theta}{dt^2}+\eta\frac{d\theta}{dt}+k_\theta\theta=M_e$$

Energy of the system

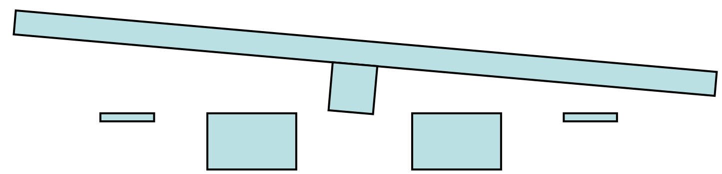
$$W=\frac{1}{2}CV^2$$

System Capacitance

$$C=\frac{\varepsilon_o w}{\theta}\ln\left[\frac{1-\left(\frac{x_1}{g}\right)\tan\theta}{1-\left(\frac{x_1+L}{g}\right)\tan\theta}\right]$$



Un-actuated mirror



Mirror tilted to one side

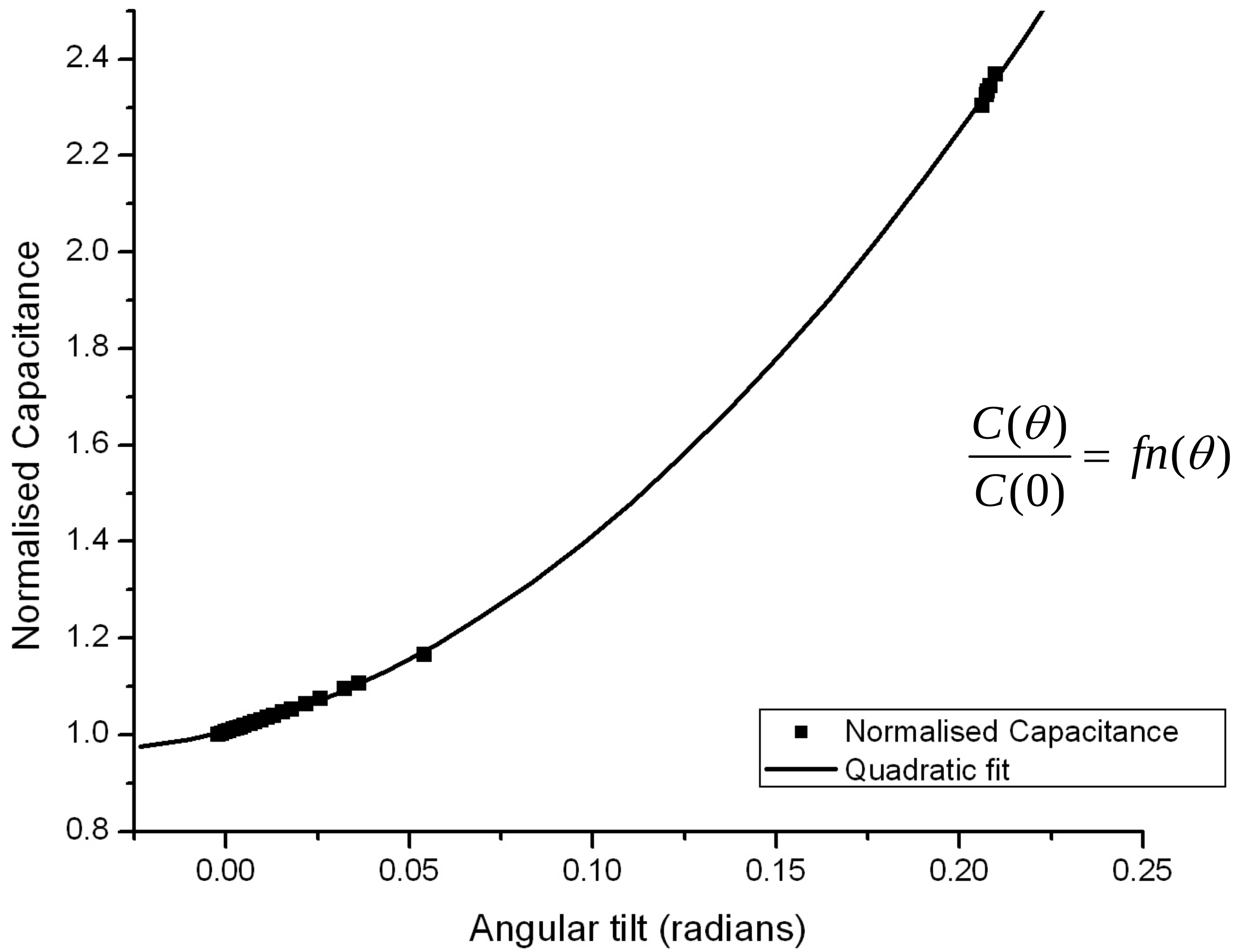
Energy of the system

$$W=\frac{1}{2}V^2C(0)\left[fn(\theta)\right]$$

$$\frac{C(\theta)}{C(0)}=fn(\theta)$$

Electrostatic torque is given by the negative gradient of the energy with respect to the angular tilt.

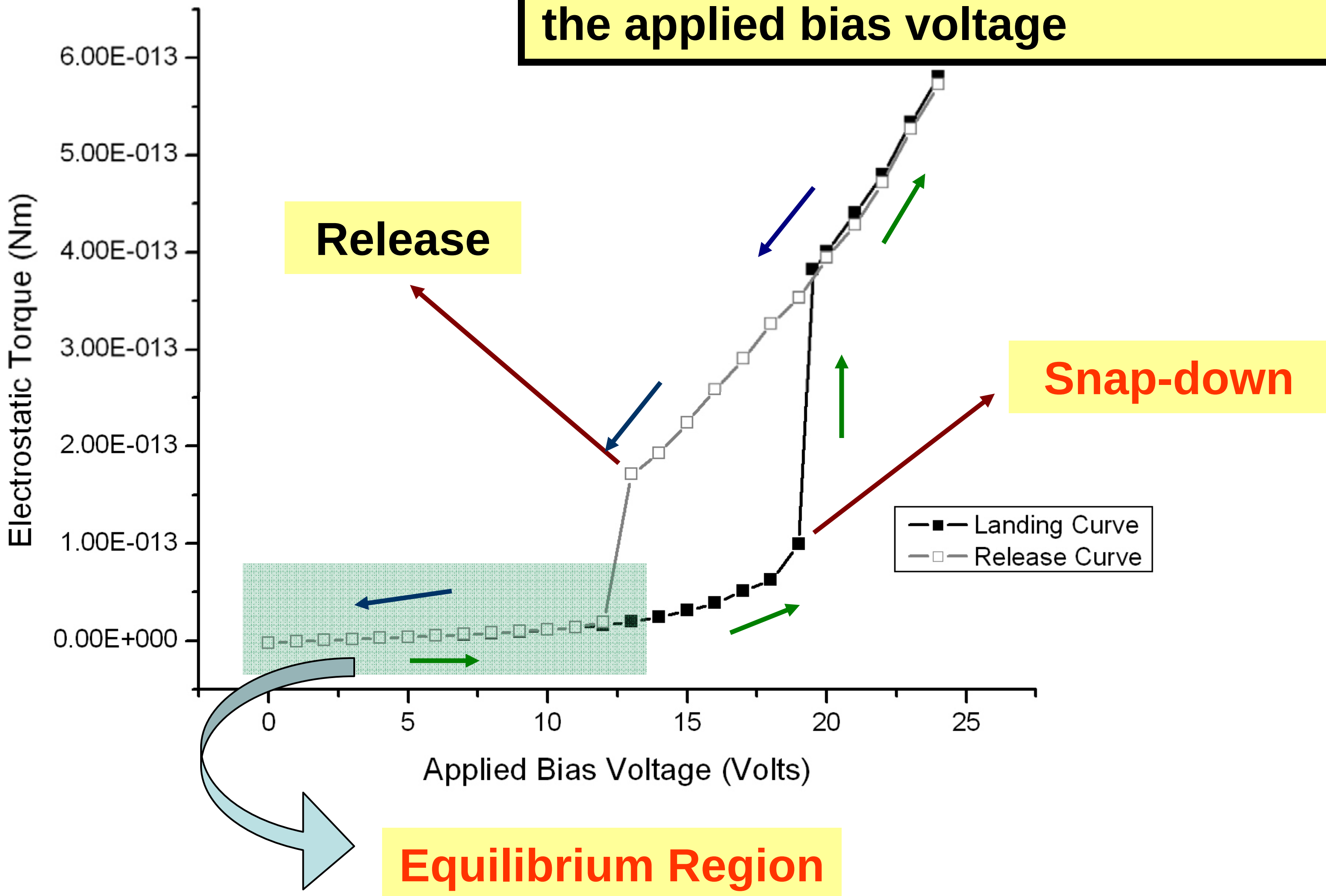
Modeling



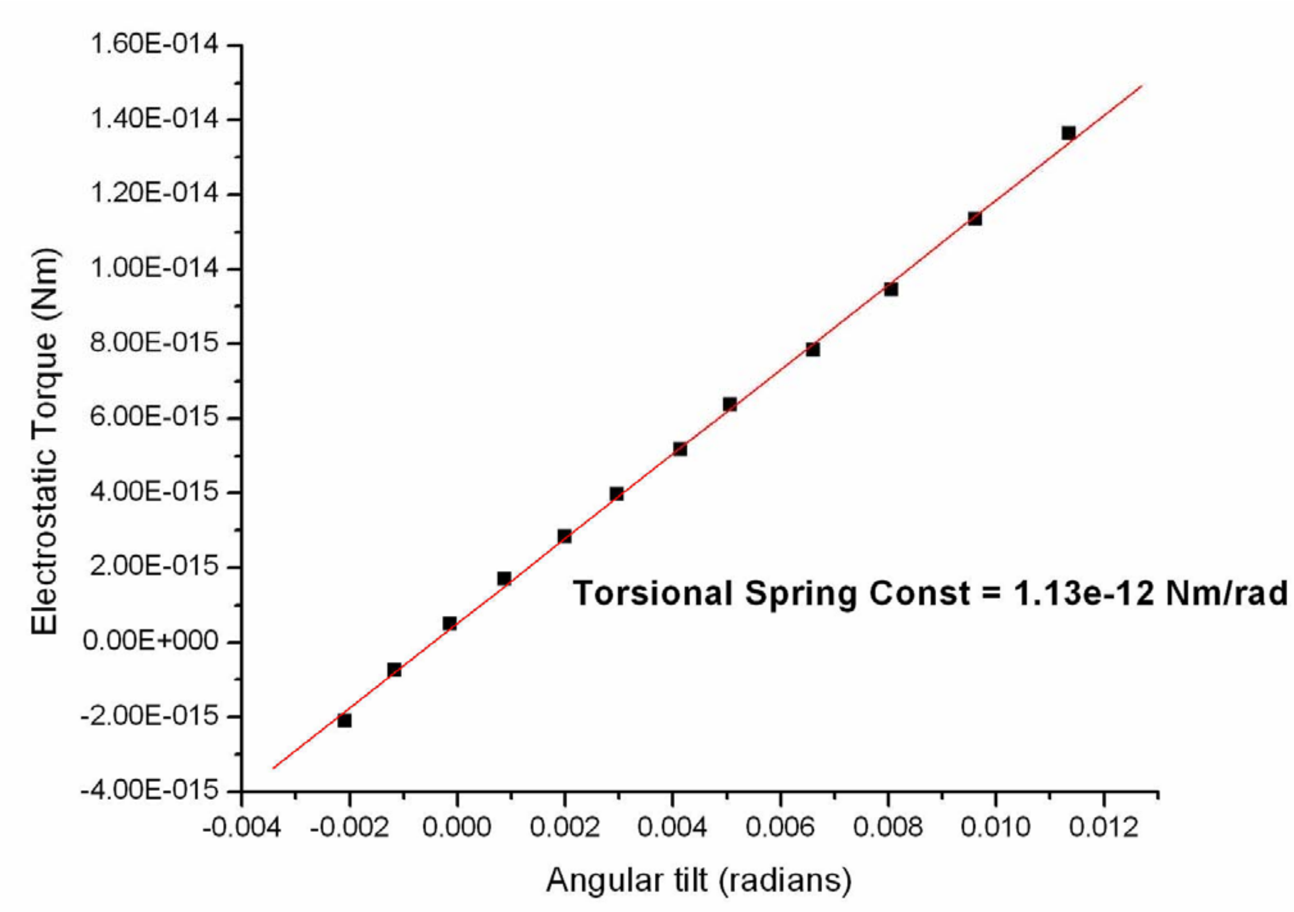
Normalized Capacitance of the landing side electrode

Modeling

Electrostatic torque as a function of the applied bias voltage

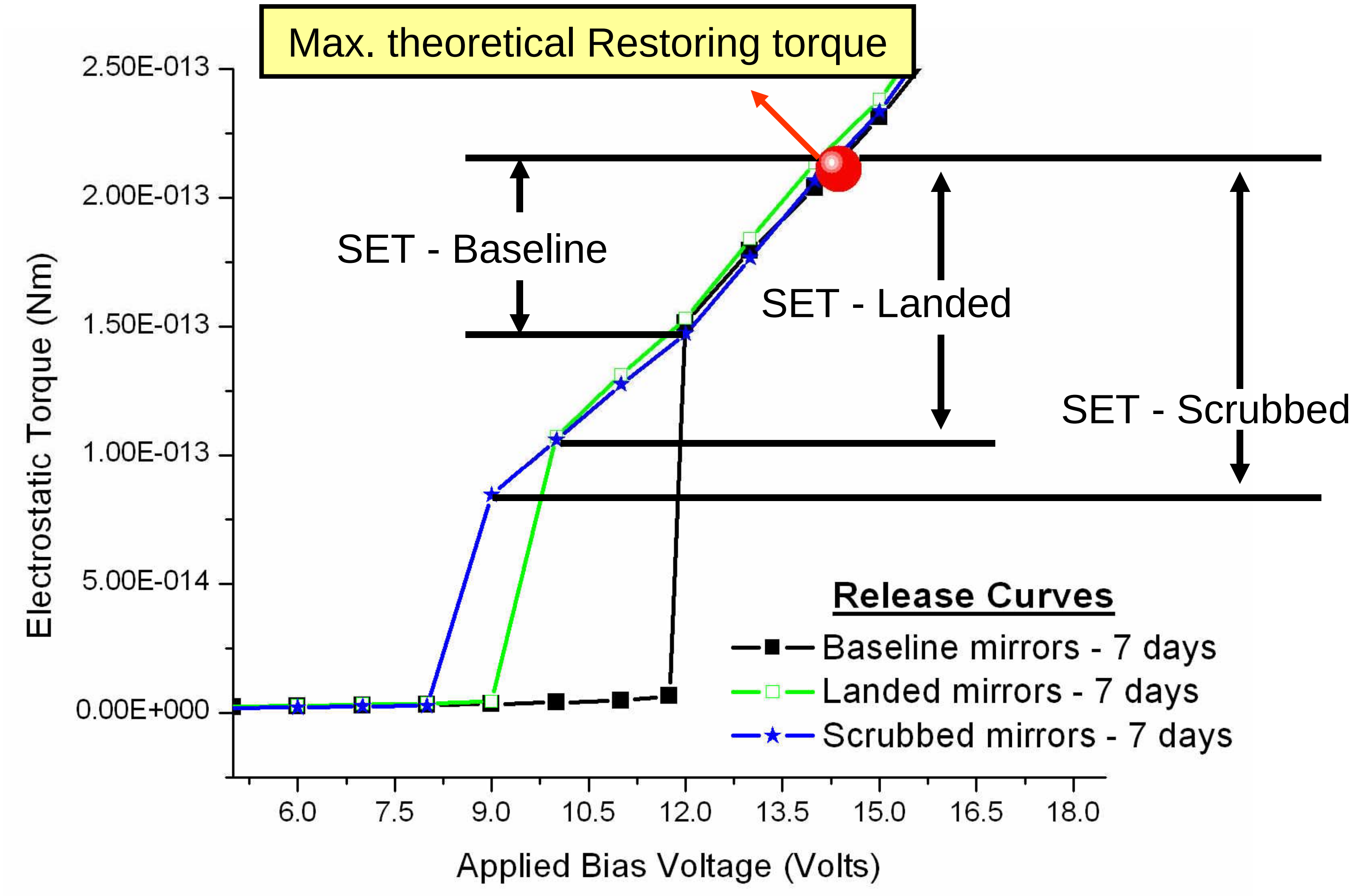


Calculation of Torsional Spring Constant



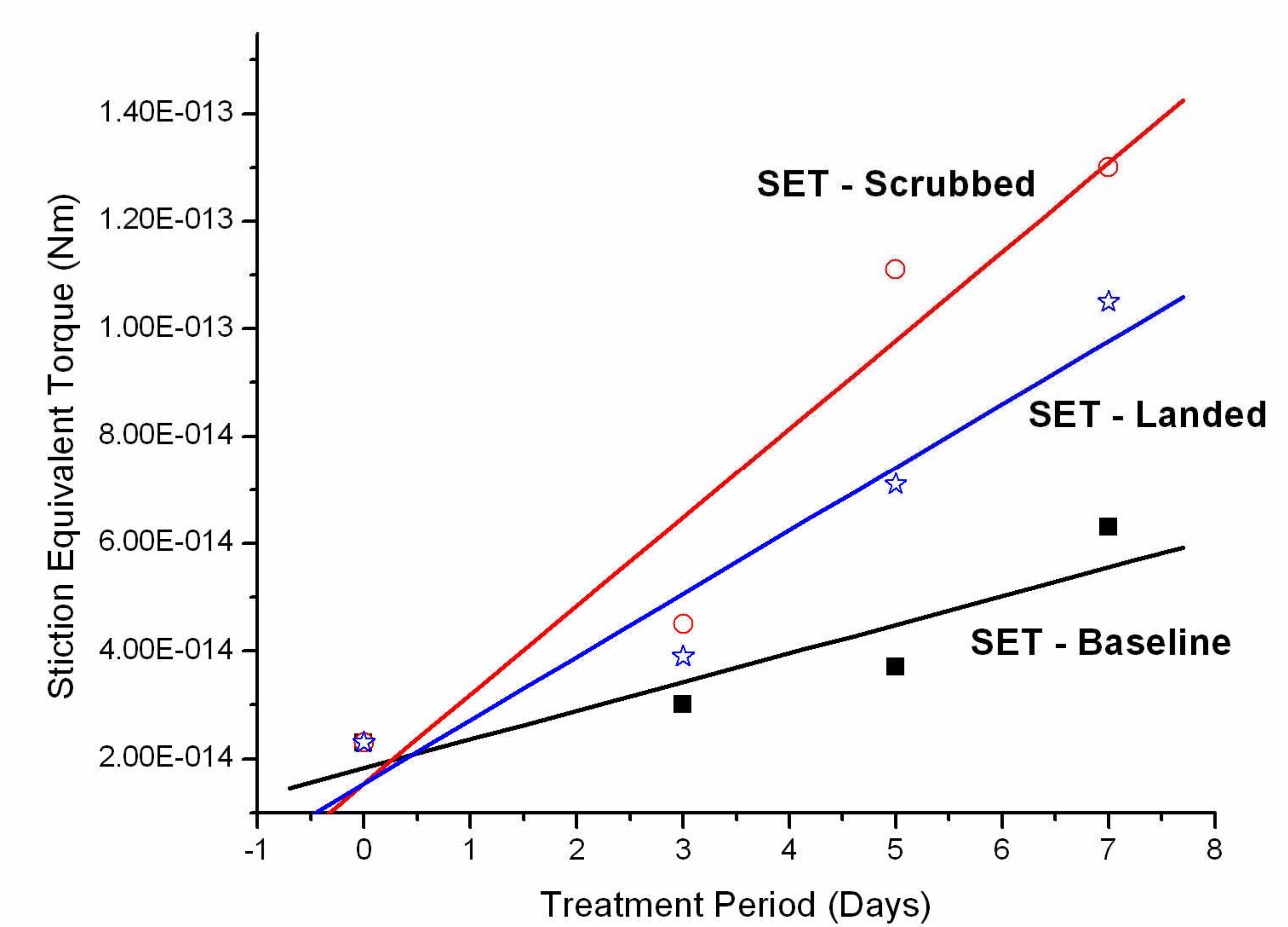
Maximum Restoring Torque = Spring Constant * Maximum angular deflection

Calculation of *Stiction-equivalent* torque (SET)



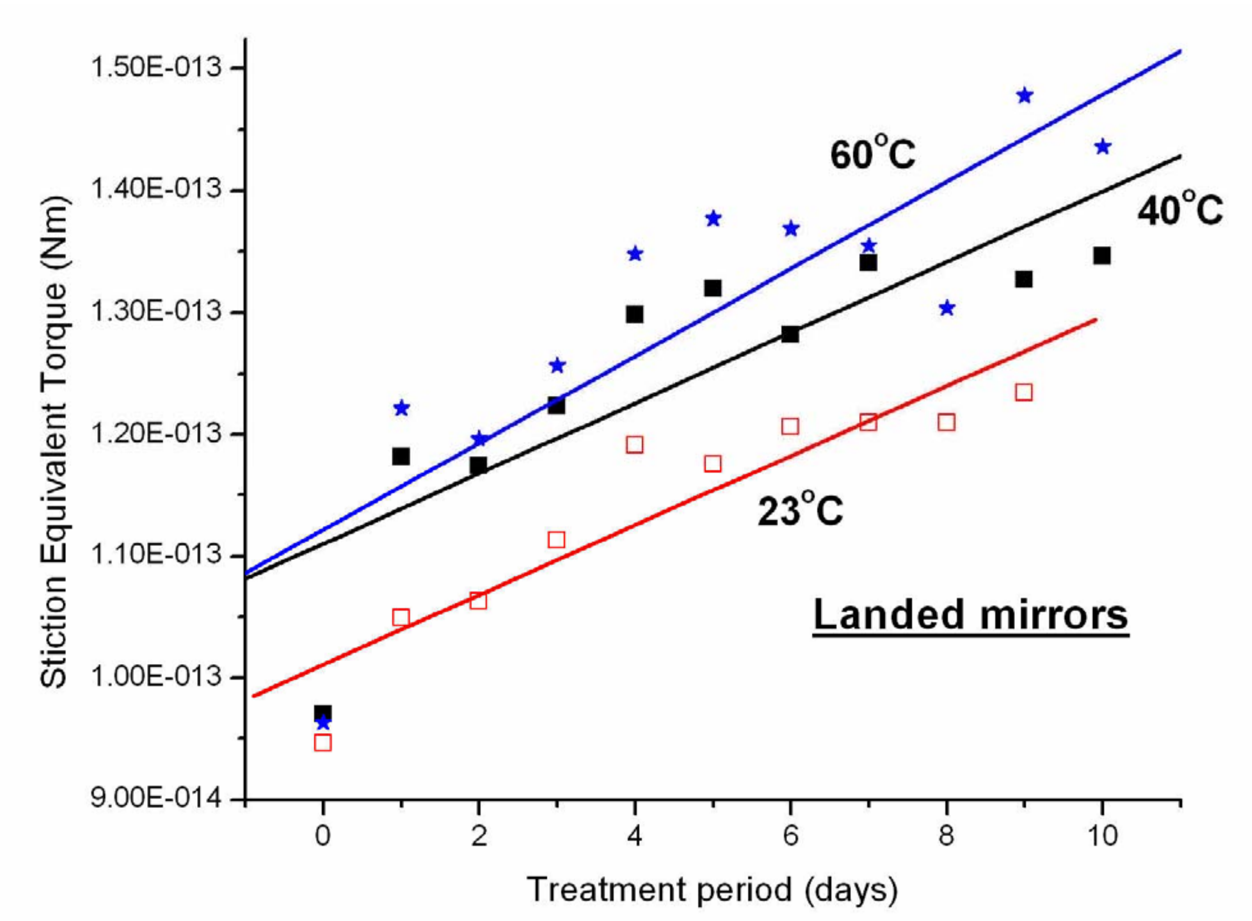
Stiction Equivalent torque translates Release Voltages into easily comparable torque values

Stiction equivalent torque (SET)



Increase in the stiction equivalent torque is highest in the case of the Scrubbed device for the treatment period

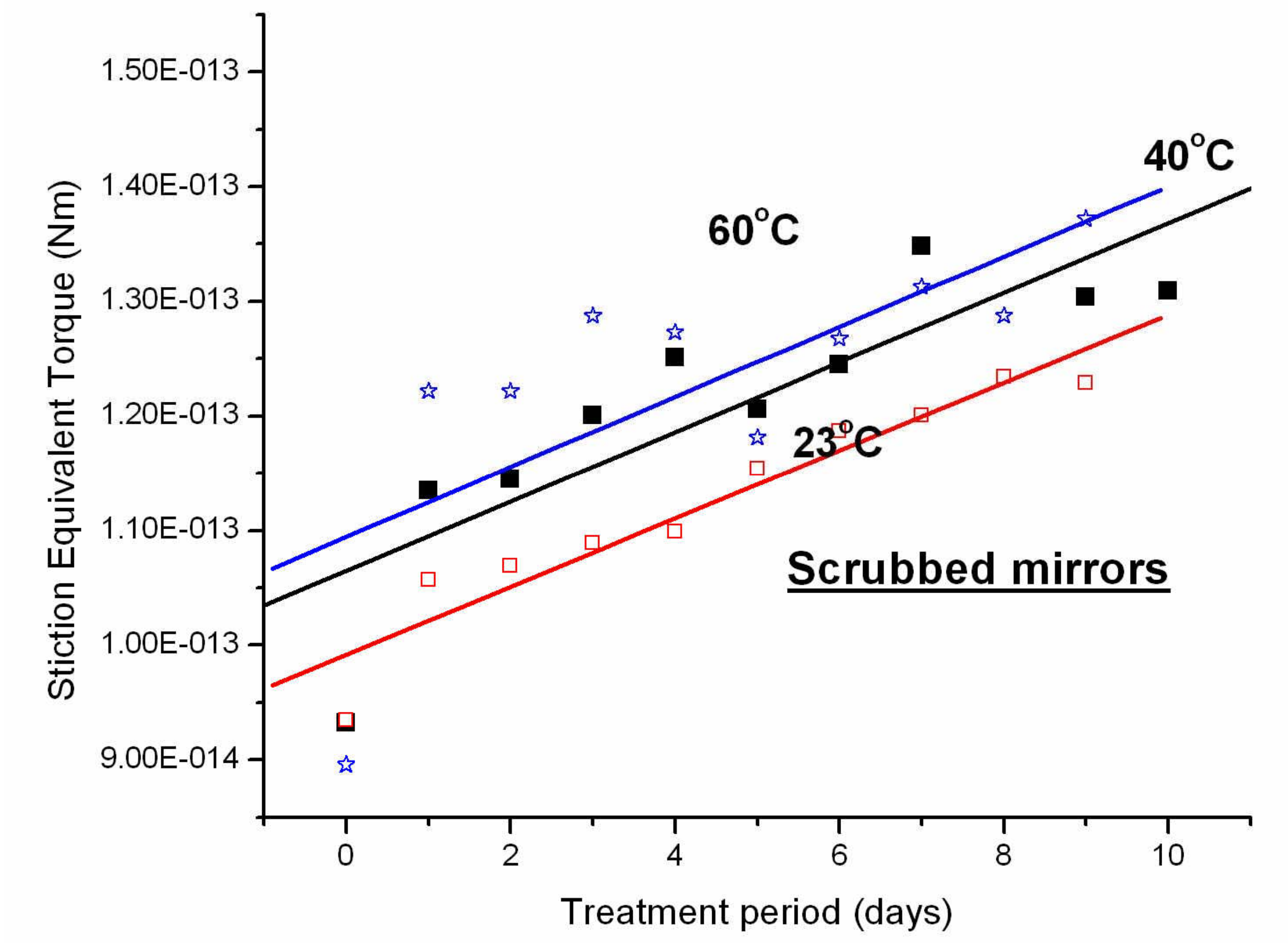
Stiction characterization under elevated temperature operation



De-lidded mirrors subjected to Scrubbing and uneven duty cycle operation at 23ºC, 40ºC and 60ºC for a period of 10 days.

Increase in Stiction observed with increase in operating temperature

Stiction characterization under elevated temperature operation



Change in the Stiction Equivalent torque with period of treatment is similar for the Scrubbed and Landed devices

Conclusions

- Established a reasonable model for translating Stiction indicators in terms of forces which can be easily compared
- Extended the analysis of Scrubbing technique for device operation under different temperatures
- Stiction is found to increase with increase in the operating temperature

Future work

- Model the effects of Temperature and Humidity combined and individual contribution on the Stiction accrual
- Model SET calculation for Reset Voltage application procedure
- Analysis of device operation under different lubricant environments to aid in better packaging techniques

Acknowledgements

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