Atomic Force Microscopy (AFM) is a powerful tool for nano-scale imaging, measuring and manipulating. The information is gathered by a mechanical probe interacting with the sample surface (Fig 1).

AFM operates primarily in contact mode and tapping mode. In the contact mode (Fig 2a), the AFM tip is always in contact with the sample and a nearly constant cantilever deflection is maintained by the feedback loop as the AFM scans across the sample to render the sample topography image. In the tapping mode (Fig 2b), the AFM cantilever is vibrated by an external source so the AFM tip interacts intermittently with the sample. The amplitude or the phase or the frequency shifts of tip oscillation are used to extract information about the topography surface properties.

Can AFM be used for characterizing the RF-MEMS switches? YES!

Residual Stress

How to measure residual stress?

\[ \sigma_{residual} = \frac{1}{R_{edge}} - \frac{1}{R_{center}} \]

Linear model: 

\[ \left( k_b \right)_{edge} = cY + eY \]

\[ \left( k_b \right)_{center} = eY + cY \]

Coefficients \( c \), \( e \), \( \sigma \) are found by numerical simulations, \( \left( k_b \right)_{edge} \) and \( \left( k_b \right)_{center} \) are found by experiments, to get \( Y \) and \( \sigma \).

Adhesion Forces

The Derjaguin approximation

\[ F(D)_{sphere-sphere} = 2\pi \left( \frac{R_1 R_2}{R_1 + R_2} \right) W(D)_{sphere-plane} \]

If \( R_2 \gg R_1 \), then \( F(D)_{sphere-sphere} \approx 2\pi R_1 W(D)_{sphere-plane} \)

Where \( W \) is the work of adhesion between plane-plane.

Experimental Results

Experiments show that the edges stiffness is significantly smaller than the center stiffness and there is an asymmetry between the two edges. Residual stress study provides a calibration method for the material properties of the MEMS switches.

Adhesion force measurement by AFM provides a validation method for MD simulations.