Statistical Modeling and Contact Analysis of RF MEMS Surface

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Introduction: Radio frequency (RF) micro-electro mechanical system(MEMS) switch works in on/off modes controlled by electrostatic forces. In off mode, rough surfaces of electrodes come into a contact to shunt the RF signal. Surface contact area has been recognized as a key factor in RF MEMS performance and reliability. Topography of the surfaces and contact mechanics determine the contact area. The capability to predict contact quality becomes extremely important to meet the challenges in RF MEMS applications.

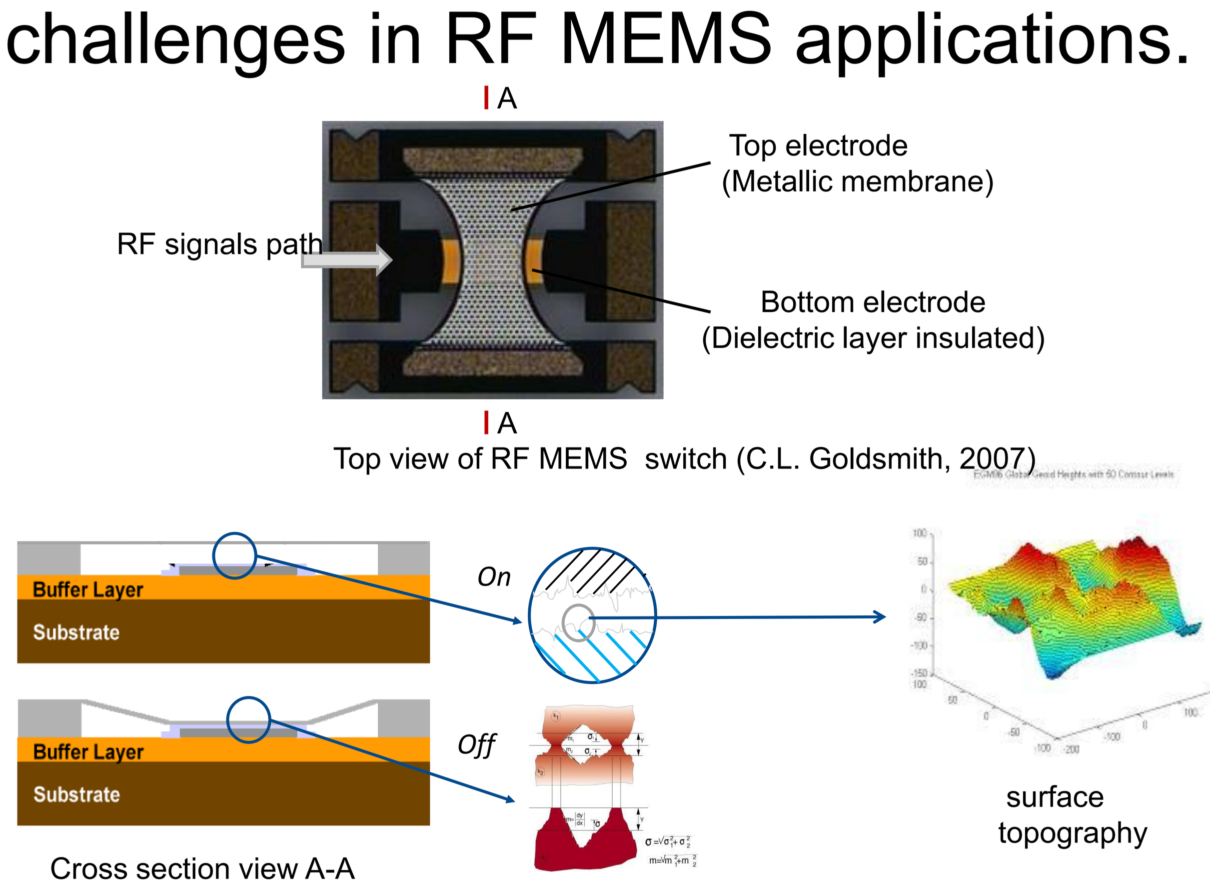


Figure 1. Top view of RF MEMS switch and Schematic of work status

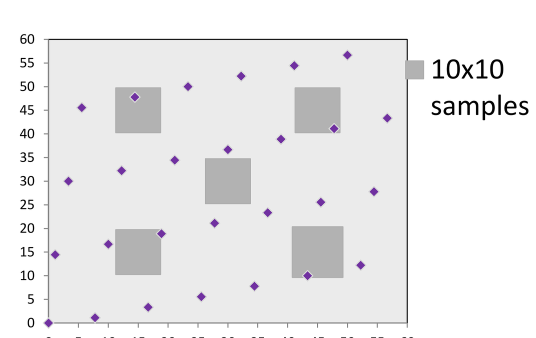
Computational Methods: Atomic force microscopy (AFM) was used to record the bottom electrode surface for the multi-scale topography.

Nested sampling plan

-- 60X60 μm2 (1 sample)

-- 10x10 μm2 (5 samples)

-- 1x1 μm2 (27 samples)



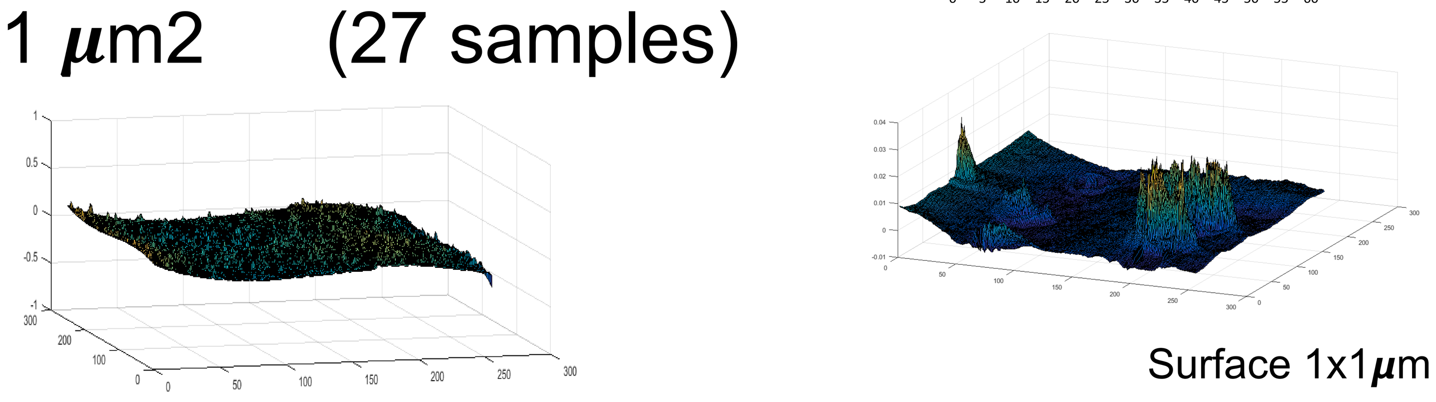
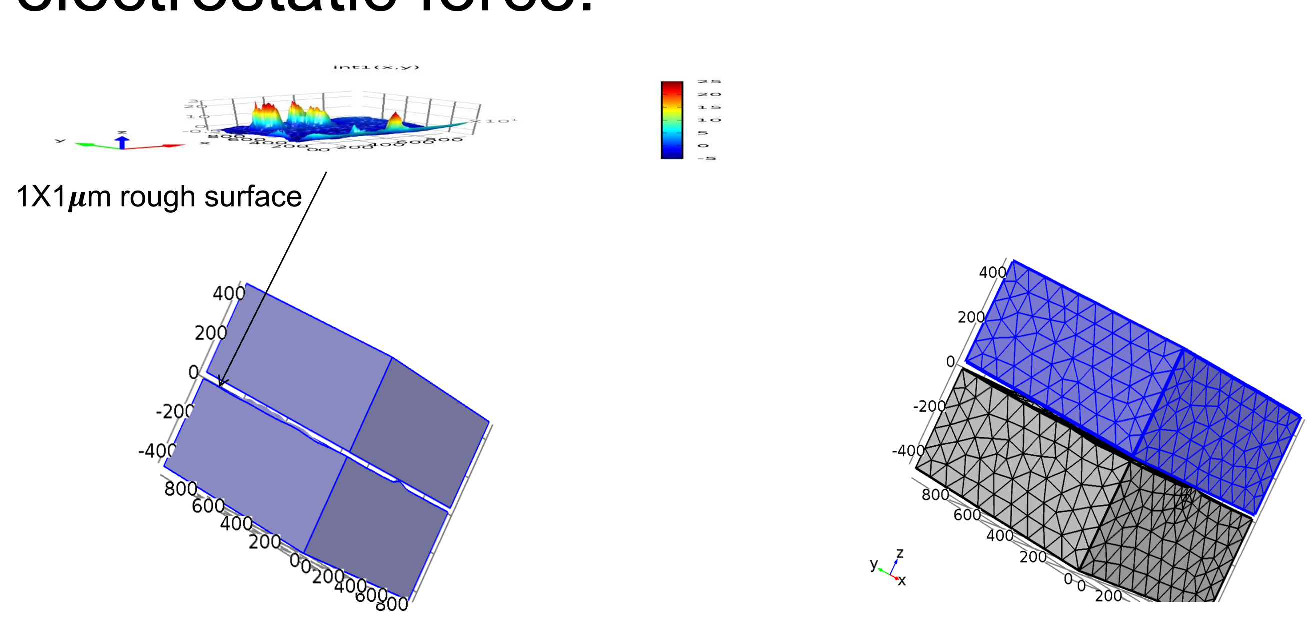


Figure 2. AFM scanned bottom electrode surface

Regular (large bumps) and fractal patterns are observed on MEMS surface. A flexible regular-fractal model was proposed to simulate topography. Nonlinear Structural Materials Module is implemented for elasto-plastic contact analysis on 3D MEMS surface using COMSOL. Only part of MEMS surface are modeled due to isotropy and homogeneity characteristics of the fractal surface. Interference is applied on the top surface to mimic the electrostatic force.



Results: Regular pattern is the first part that comes into contact as well as deforms plastically .The contact area grows slowly and nonlinearly at small interference, which would verify the existence of the regular pattern. While contact area increases rapidly and linearly at large interference, which may implies the fractal part starts to contact at certain point during the plastic deformation of regular pattern,.

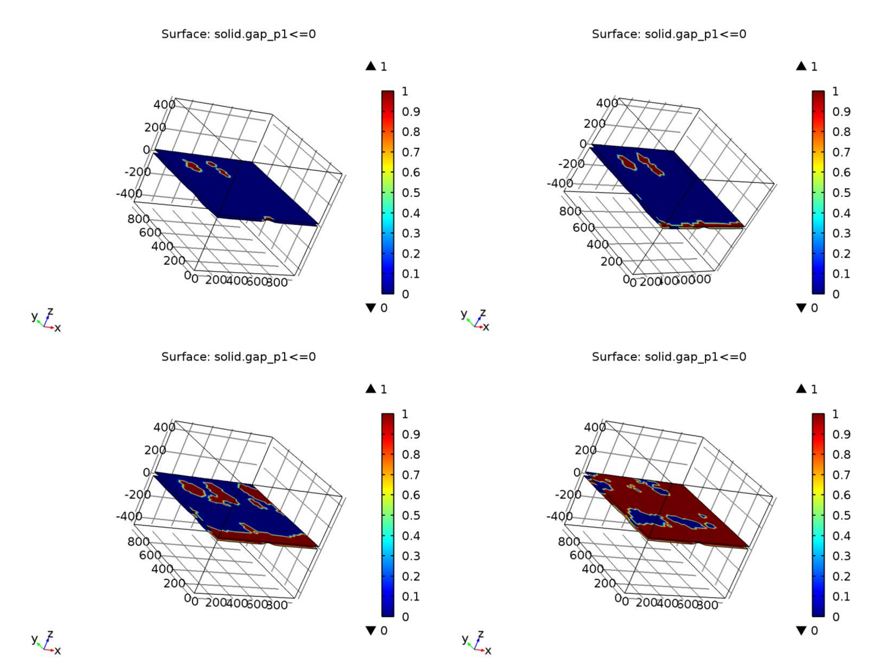


Figure 3. Contact area at different interference

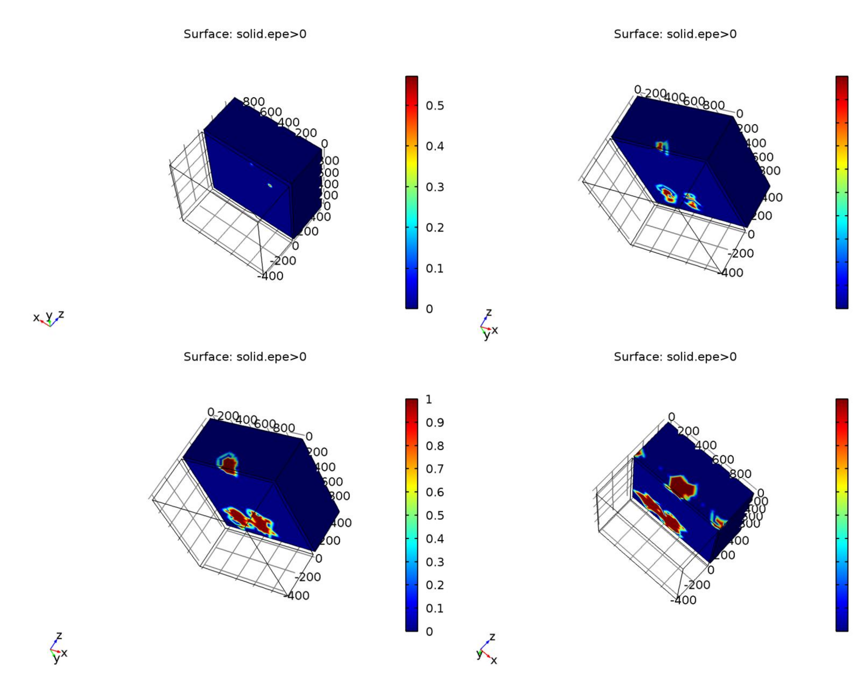


Figure 4. Plastic zone at different interference

Displacement (nm)	contact area (m^2)	percentage
20	3.07E-14	3.07%
25	8.69E-14	8.69%
30	3.08E-13	30.82%
33	8.44E-13	84.39%

Table 1. Percentage of contact area at different interference

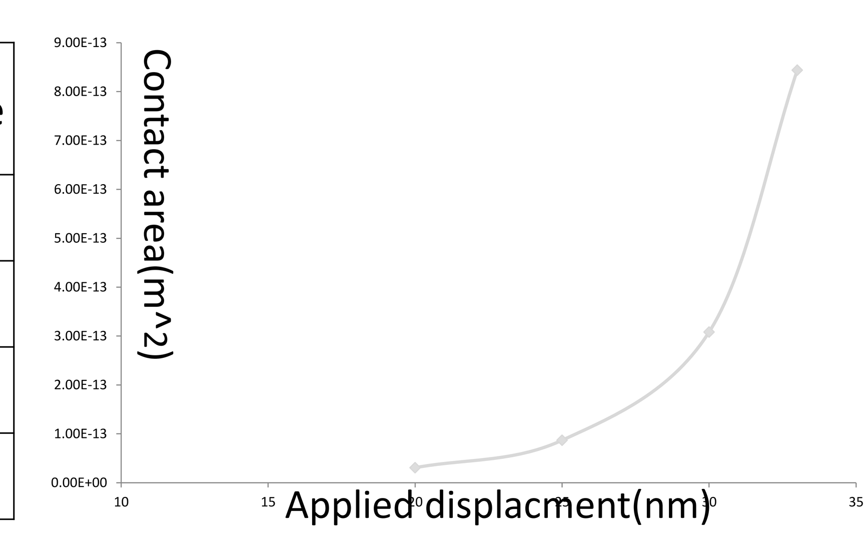


Figure 4. Contact area against interference

Conclusions: Regular-fractal structure on MEMS surface affect contact mechanics in different scales. The work is expected to replicate and explain the way that different regular patterns and fractal irregularity affect contacts between bumps and nano-scale asperities. Contact mechanics under cyclic loading/unloading behavior which mimics the electrostatic force is a promising study in the future.

References:

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