HYSITRON™

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MEMS Slider Friction Characterization

Actuation of MEMS Devices with the Hysitron TriboIndenter™

Introduction

Compliant MEMS mechanisms are capable of large out-of-plane displacements induced by in-plane actuation. An attempt to actuate the compliant MEMS device with the nanoindenter resulted in the slider fracture due to device design flaws [1]. In addition to the forces associated with the mechanism deformation, frictional forces become important at the device level, and need to be accounted for. Lateral force of 2.5 mN was necessary to move the slider disconnected from a MEMS device, which is comparable to the forces required to actuate the device itself. High frictional forces are attributed to the indenter tip conical geometry and the slider design [2]. Unfortunately, conical geometry cannot be avoided when using the probe needles, thus the slider design needs to be optimized to account for the probe geometry.

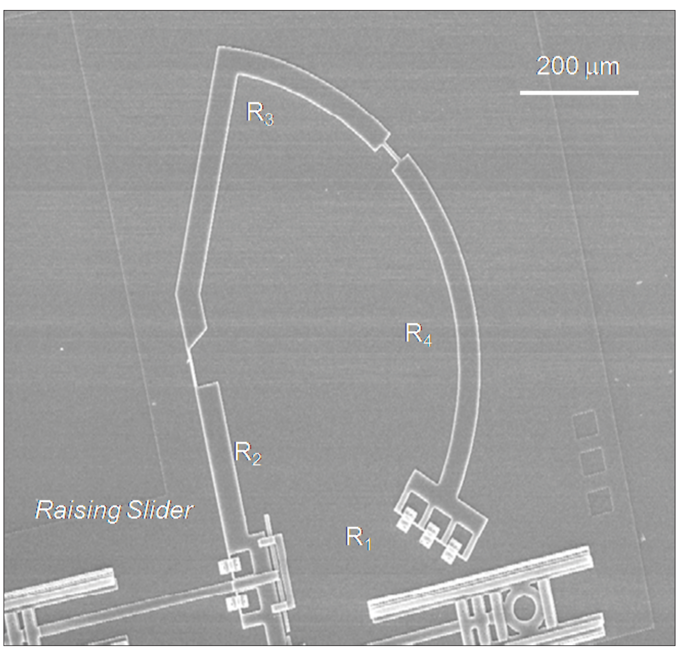

Figure 1. SEM image of the compliant MEMS device.

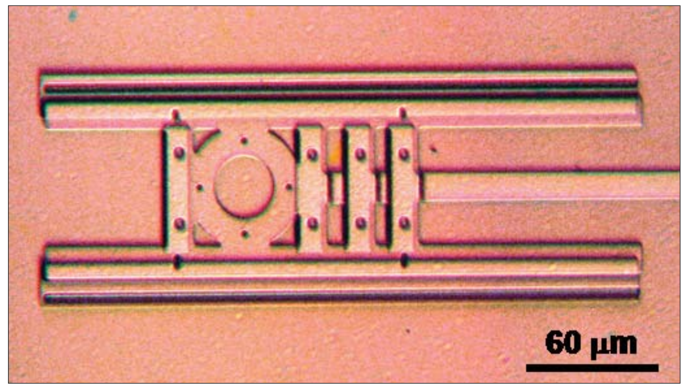

Figure 2. Optical image of the MEMS slider.

Figure 1 shows the first stable positions of the compliant MEMS device. The device consists of three major parts: two sliders and one compliant spherical four-bar mechanism. Link R2 is the input link, while links R2 and R4 are fixed to the surface by a hinge [1]. Sliders are designed as the actuators and are connected to the link R2. Ideally, when the raising slider is moved to the left, links R3 and R4 will move out of the plane, while moving the lowering slider to the right causes the structure to go back to its original in-plane position. Initial attempts to actuate the device resulted in its fracture [1] thus, a disconnected slider with a four-bar mechanism was tested (Figure 2).

Procedure

The experiment was conducted using the Hysitron TriboIndenter with a 1 μm tip radius conical indenter operating in the scratch mode. First, the center of the slider hole was located using in-situ SPM topographical imaging, after which a scratch was performed (Figure 3) to characterize friction in the slider.

Results

The input normal force and the lateral displacement profiles are shown in Figure 4a. Figure 4b shows the resulting normal and lateral forces vs. lateral displacement during a 10 µm scratch. The slip-stick motion is observed when the tip scratches the polysilicon substrate and later when it moves the slider. Stick-slip motion is caused by high friction forces in the slider, which was successfully moved in this case. Before and after each scratch test, a topography scan was taken using the TriboIndenter in-situ SPM imaging mode as shown in Figure 3. Closer inspection of the moved slider showed a vertical scratch track left in the middle of the slider ring [2]. The front 2x2 µm spacer scratches the substrate during its motion, causing high frictional forces. The spacer contact area needs to be increased in order to decrease the substrate contact pressure, and thus reduce friction.

Conclusions

A slider connected to the four-bar compliant MEMS mechanism was scratched using the nanoindenter tip. The compliant MEMS device could not be successfully actuated using this procedure, and fractured. However, motion of the disconnected slider was achieved at the lateral force of 2.5 mN, which is over two times higher than the calculated device actuation force. High slider frictional forces are caused by the spacers, which plastically deform the substrate due to the high normal force component. Slider friction must be reduced by increasing the spacers contact area.

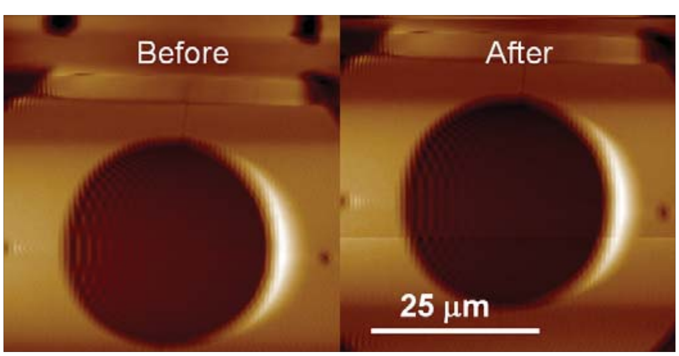

Figure 3. Topography images of the slider ring before and after the scratch.

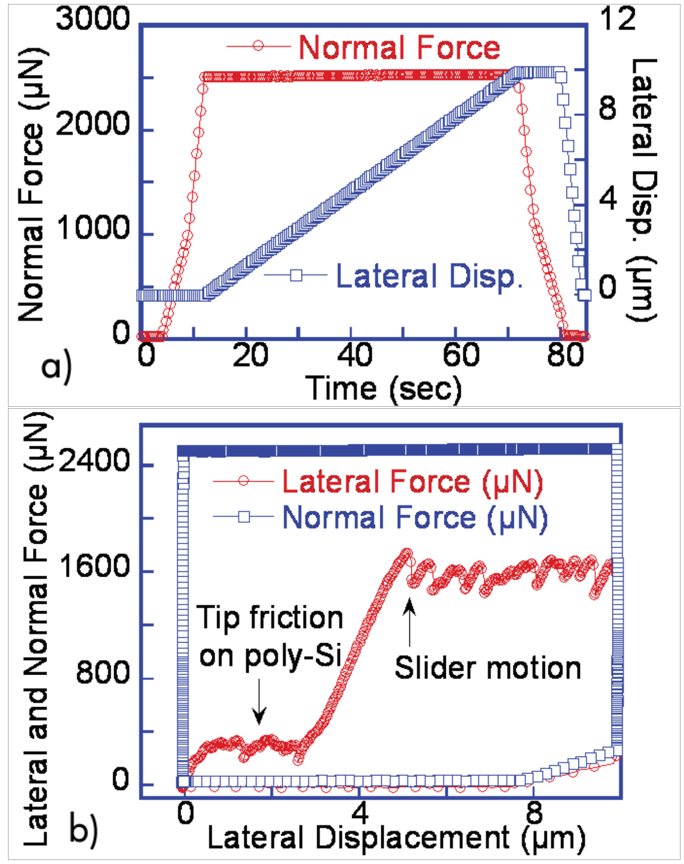

Figure 4. a) Input normal force and lateral displacement profiles for the slider motion test; b) The lateral force vs. lateral displacement of a disconnected slider showing stick-slip motion.

References

1. Compliant MEMS Motion Characterization by Nanoindentation, J.G. Choueifati, C. Lusk, X. Pang, A.A. Volinsky, Mat. Res. Soc. Symp. Proc. Vol. 1052, DD6.24, 2008

2. Compliant MEMS Device Actuation and Fracture, A.A. Volinsky, D. Ke, C. Lusk, 12th International Congress on Fracture Proceedings, Ottawa, Canada, 2009

Acknowledgements

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