# *Interfacial Force Microscope (IFM) Application to MicroElectroMechanical (MEMS) Metrology*

*by* **J. E. Houston**

**Motivation—**One of the weaknesses facing Sandia's MEMS-development effort involves the inability to accurately characterize the normally in-plane forces generated by the active elements, as well as how these forces progress through the chain of coupling components. At present, no technique is available for making such measurements. We are presently developing such a capability designed around the Sandia-developed Interfacial Force Microscope (IFM), which has the capability to obtain quantitative data of both normal and lateral forces at selective sites within a MEMS device. One particularly appealing candidate for such measurements involves a passive, bi-stable spring-element device being developed at Sandia.

**Accomplishment—**Preliminary IFM demonstration measurements on a bistable MEMS device presently under the advanced stages of development are very encouraging, although the present model of the IFM is not ideally suited for this application and cannot be considered to be a true metrological instrument. Initial data were obtained on components similar to the one illustrated in Fig. 1a. Here, a shuttle is suspended by uniquely designed non-linear springs, which cause the device to be bistable, requiring a certain level of lateral force to cause the shuttle to change "state". The instability presents a particularly difficult problem for any force-measuring device. However, because of the inherent stability of the IFM concept, such measurements are possible on Sandia test units of this device. To implement the analysis, the IFM tip is optically located, for example, in the center of the T-bar end of the shuttle, illustrated in Fig. 1b, and the component is moved against the tip while recording the lateral force vs. the displacement. This process proceeds until the point of instability, at which the shuttle suddenly "snaps" to its second stable position leaving the sensor behind under zero force. The tip is then located in the center of the "tab" on the other end of the shuttle and translated in the reverse direction. The two results are then matched at the point at which the forces suddenly go to zero. The result is shown in Fig. 2 (red) along with the modeling prediction (blue). Error bars indicate the confidence levels for the modeling and sensor calibration. Note that the instability occurs at the point at which the force slope changes sign, NOT at the maximum and minimum points.

**Significance—**For the first time, using IFM, we have shown that direct measurements of MEMS structures are available for comparison with finite element model predictions. This is an important step towards achieving model validation by directly measuring key parameters used in modeling and mechanism design. The overall observed force-displacement curve shapes are similar to simulation curves, but the critical parameter, i.e. the point of instability, is not the same, and the discrepancy remains even if the IFM result is scaled to have the same overall magnitude. At this point the designers believe that this discrepancy is due to residual stresses remaining in the device after fabrication. This IFM metrology has the potential for providing feedback data useful for design compensation of processing problems, ensuring that design criteria are acceptably met for all components distributed on the wafer.

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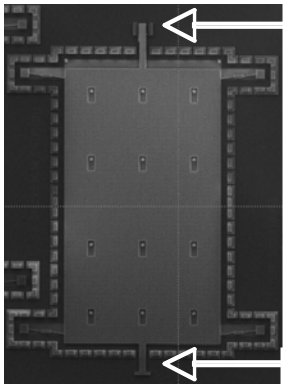
**Contact:** Jack E. Houston, Surface & Interface Sciences, Dept. 1133
Phone: (505) 844-8939, Fax: (505) 844-5470, E-mail: jehoust@sandia.gov



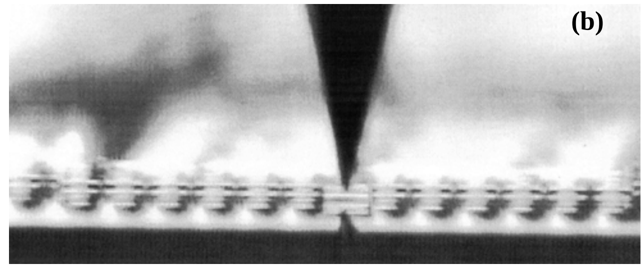




**Figure 1**. (a) A SEM image of the bistable MEMS component. The central shuttle is supported by nonlinear springs on each corner and is mechanically accessed by a "T-Bar" on the bottom and a "Tab" on the top. (b) A micrograph of the device viewed edge on from the bottom showing the IFM tip located in the center of the T-Bar in preparation for the displacement of the device downward to make contact with the tip.

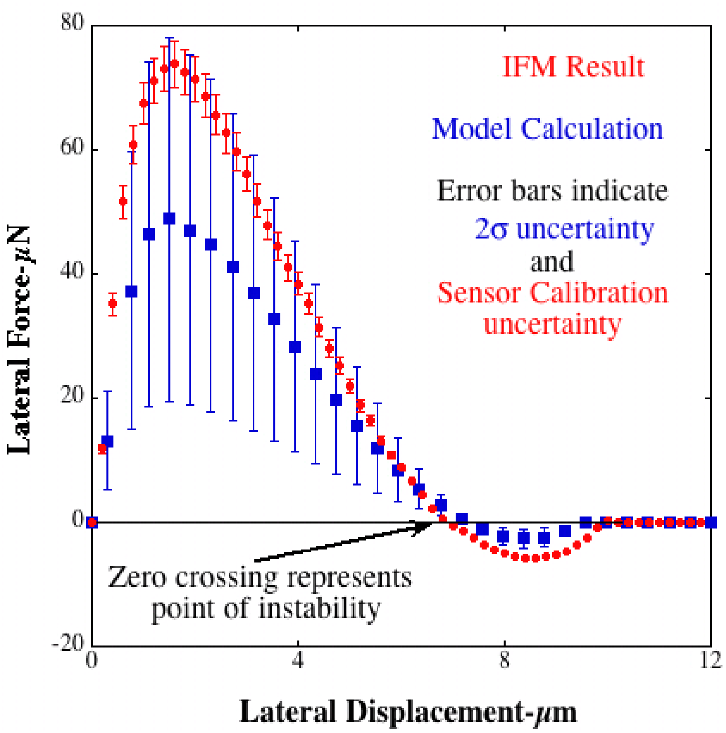



**Figure 2**. IFM results, shown in red, along with the model predictions in blue. The error bars indicate the confidence level of the modeling and the calibration of the IFM sensor. The IFM results are within the error bars for model but differ in scaling. However, even if the scaling is compensated, there still remains a significant discrepancy between the measured and predicted values for the instability point, i.e., where the slope of the two curves changes sign. This value represents the critical parameter in qualifying device performance.