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## **Report Title**

Annual Progress Report

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**UNIVERSITY OF ILLINOIS  
AEROSPACE ENGINEERING**

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**ANNUAL PERFORMANCE REPORT**  
**Reporting Period: 6/15/2012 - 7/31/2012**

**Mechanical and Ferroelectric Response of Highly Textured  
PZT Films for Low Power MEMS**

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**Program Manager: Dr. Larry Russell**

OCTOBER 2012

## **ABSTRACT**

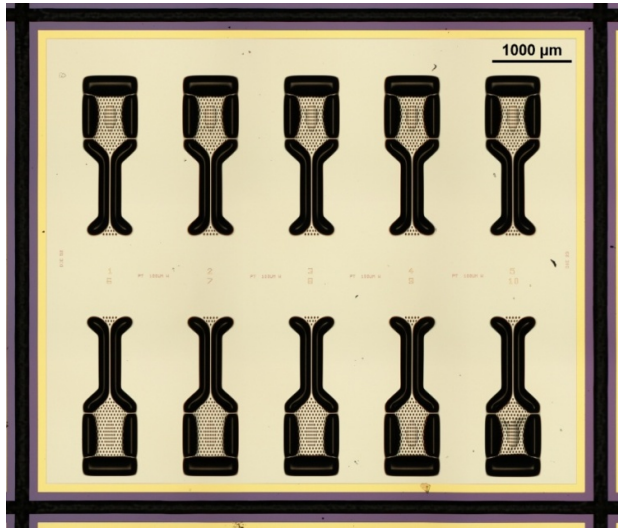
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### **I. Microfabrication of freestanding platinum films as PZT electrodes**

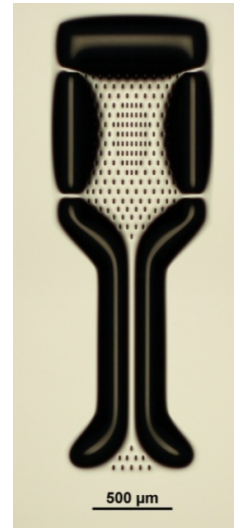
Microscale thin film platinum (Pt) specimens were designed at UIUC in collaboration with US Army Research Laboratory (ARL) in Adelphi, MD, and were fabricated at ARL using DC magnetron sputtering on Si (100) substrate. The Si wafer was etched out leaving freestanding Pt thin film specimens as shown in Figure 1(a). The fabrication process starts with the deposition of a base layer of Ti (~160 Å) on Si by DC magnetron sputtering at 50°C to serve as an adhesive layer, immediately followed by deposition of 1 μm thick Pt layer. Patterning of the Pt film to specified geometry and dimensions was done using Ar ion milling. The wafer was then scored to a depth of ~250 μm using a diamond saw to ease die separation after the Pt specimens were released. Prior to the etching process, the wafer was exposed to a 20 s reactive ion etching to remove the surface oxide developed on the exposed silicon surfaces. Next, the film was subjected to xenon difluoride (XeF<sub>2</sub>) isotropic etching to remove the Si underneath the metal layer to get freestanding Pt specimens. After release, the wafer was stealth diced to prepare individual dies containing 10 tensile specimens as shown in Figure 1(a). Figure 1(b) shows the top view of a freestanding Pt specimen with the pedal attached to the substrate by tethers for handling purposes.

### **II. Imaging of PZT films by Scanning Probe Microscopy**

PZT exhibits nonlinear elastic behavior [1] attributed to 90° domain switching upon application of stress [2,3]. Recent studies [4-5] have used scanning probe microscopy both in contact and non-contact mode to characterize piezoelectric materials. In the reporting period we worked on establishing the pre-requisite knowledge so that Atomic Force Microscopy (AFM) is used to probe local surface regions in PZT films while are subjected to tensile loading. High resolution AFM imaging could provide insight into strain localization due to domain switching in the textured PZT films to be studied in this research program. The custom built uniaxial tension apparatus is based on a previously designed apparatus and was rebuilt for the purposes of this project. It consists of a piezoelectric actuator for uniaxial loading and a load-cell for measurement of the applied force as shown in Figure 2(top). Such *in situ* experiments were tested using non-contact AFM imaging Ni specimens of the same dimensions as the proposed PZT specimens, as shown in Figure 2(bottom).

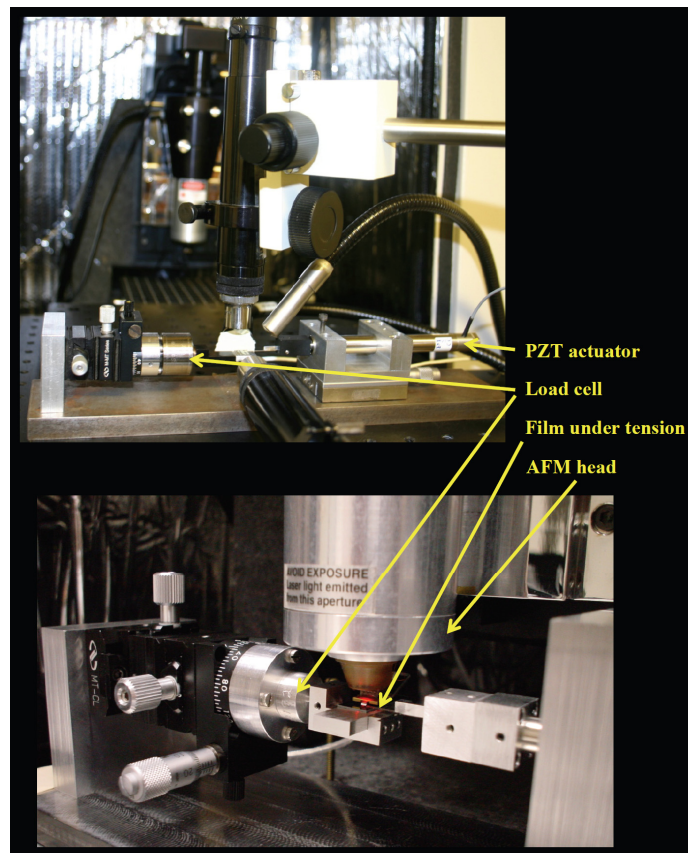


(a)



(b)

**Figure 1.** (a) Top view of a die containing 10 individual freestanding film specimens, (b) top view of a single freestanding specimen.



**Figure 2.** Custom built apparatus for microscale experiments placed under an AFM for high resolution imaging, and (bottom figure) close up photograph showing the AFM in action while the film is under tension.

### III. Ongoing Research

Pt films with 1  $\mu\text{m}$  thickness were received from ARL in early October of 2012. The films will be characterized for their elastic and failure properties at different strain rates at the PI's laboratory. In parallel, ARL is preparing the first batch of textured PZT films that will be ready later in this calendar year. Pt films with additional thicknesses will also be fabricated and characterized. Piezoresponse Force Microscopy (PFM) imaging of PZT films with random orientation will be carried out at UIUC to investigate and quantify domain reorientation in PZT films subjected to strains of the order of 0.4-0.5%. In PFM, a conductive probe is put in contact with the piezoelectric surface while an alternating current (AC) bias is applied to the probe tip to excite deformation of the sample. The ferroelectric domains locally expand or contract depending whether they are parallel or anti-parallel to the applied electric field.

### IV. References

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