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Application Note: Precision Displacement Test Stand Rev A

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Discussion:
The explosive growth in the field of thin-film piezoelectric materials highlights the greatest weakness facing researchers: some devices have displacements so small they are swamped by ambient environmental effects in the test fixtures holding the devices under test. As well, the vast majority of thin-film devices come in a wide range of shapes and geometries leaving no possibility for standard fixturing. Radiant Technologies has been acutely aware of this problem for two reasons. First, Radiant has built into all of its testers the ability to capture displacement information from a wide variety of sensors. Radiant's products can measure bulk ceramics that move microns as well as thin film capacitors that move Ångstroms. While the bulk ceramics have proved relatively easy to measure, the full functionality of Radiant's testers cannot be applied the displacements of thin-film capacitors because their scale is smaller than the ambient environmental noise or the natural mechanical drift in the test fixtures. As well, the most sensitive non-contact displacement sensors use an optical beam and are subject to distortive turbulence in the atmosphere. Finally, thermal currents in the test fixture can cause changes in the absolute optical path difference from the sensor to the sample that are as large or larger than the sample displacements being measured.

The second issue for Radiant with measuring the piezoelectric properties of thin film devices arises from Radiant's technology development. We fabricate a wide variety of thin film actuators and sensors using thin PZT films but we have been stymied in the characterization of all but the largest devices because of a lack of *flexible* fixturing that is *quiet* at the Ångstrom level.

Radiant has worked for over a year to develop a low-cost solution to this issue. Our new Precision Displacement Test Stand quiets the environmental and mechanical noise levels of the test environment so that super-sensitive displacement sensors may be used in a laboratory setting to achieve clean measurements at the Ångstrom level. The PDTS was designed in conjunction with the Advanced Piezo Task in the Vision Library. The PDTS eliminates mechanical vibration and turbulence so the Advanced Piezo task can employ averaging and smoothing to improve the quality of the piezoelectric butterfly loops measured with Radiant testers. The measurement of the 15Å displacement of the top electrode surface of a 1μ-thick film of 4/20/80 PNZT using a laser vibrometer mounted in the PDTS is shown in Figure 1.

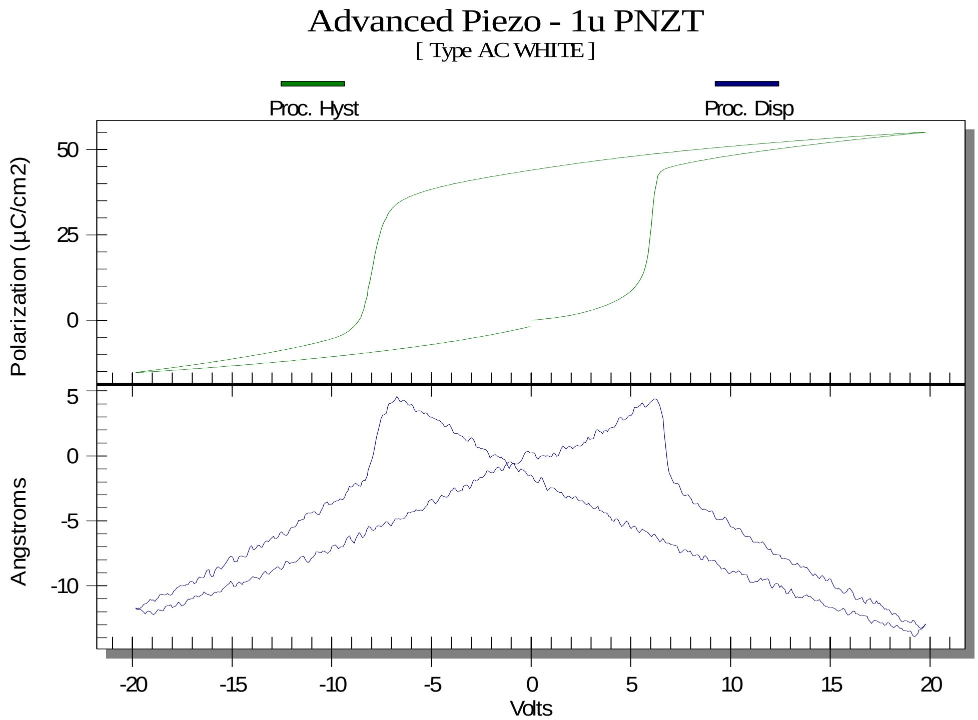


Figure 1
Piston Motion of 1µ of 4/20/80 PNZT

The noise level in Figure 1 is less than 0.5Å even though the measurement was made in a warehouse. "Down" in the plot is away from the substrate surface and towards the sensor.

Even more important, the PDTS does not require any specific sample geometry. The stand provides a high degree of freedom in sample mounting and sensor alignment so even the most basic thin-film capacitors may be mounted and measured by enterprising graduate students in a university environment.

Issues with Ångstrom-Level Test Fixturing

As the measurement scale approaches the Ångstrom level, the effect of ambient environmental noise becomes a major issue, primarily because the amplitude of the environmental noise may exceed that of the displacement to be measured. There are four sources for ambient noise:

Vibration
Thermo-mechanical drift
Mechanical drift
Air turbulence

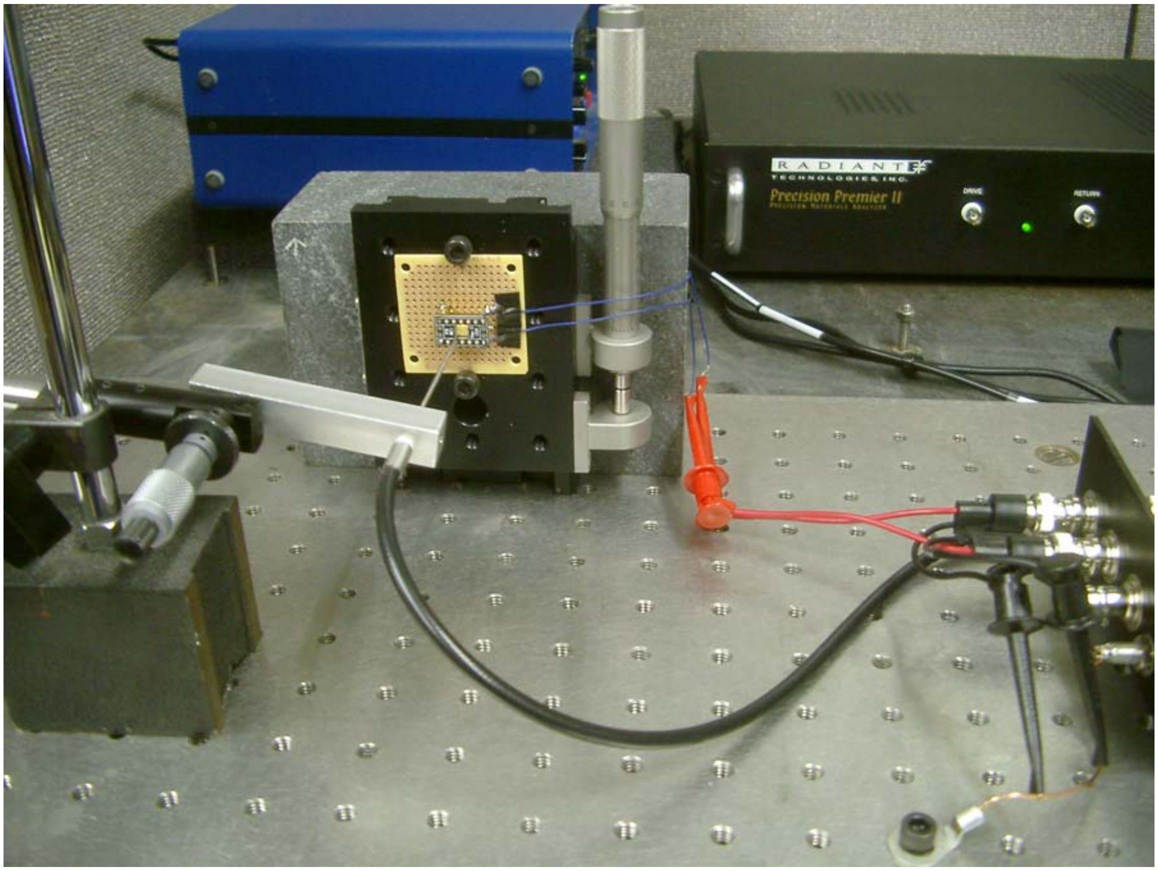
The Precision Displacement Test Stand and Advanced Piezo are designed to work together to reduce all four effects to manageable levels. The PDTS reduces vibration and air turbulence effects while Advanced Piezo removes the mechanical and thermal drifts. For more information about Advanced Piezo, go to www.ferrodevices.com/displacement.html.

The Precision Displacement Test Stand
The PDST consists of a small optical table, an air shield, cable stress reliefs, and the Brick. See Figure 2 below.

Precision Displacement Test Stand with Polytec Laser Vibrometer
Figure 2

Figure 2 shows the PDTS sitting on a granite base formerly belonging to an Ultratech stepper. The granite base is very stable, allowing the precision measurement in Figure 1. The optical table in the PDTS is small enough that relatively inexpensive pneumatic vibration isolation tables may be used to dampen vibration.

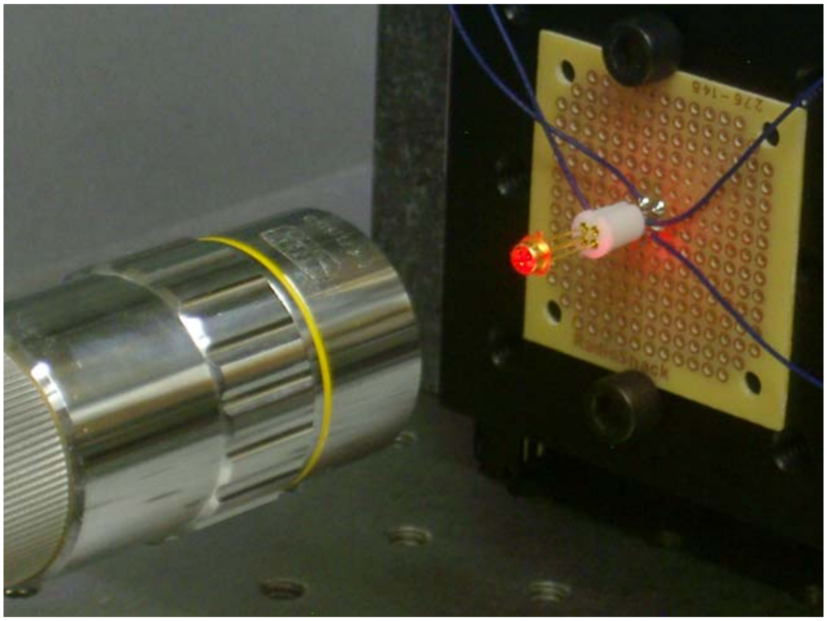
The key to the PDTS is the granite Brick on which the sample is mounted. It has the dimensions of 6” x 4” x 2.5”. It has a 5/8” hole through its center to allow double beam interferometry on the sample and bolt holes on its sample side to allow the attachment of a variety of optical mounts. The image in Figure 3 shows a packaged sample clamped to a translation table. X/Y/Rotation mounts could be used as well. Optical mounts are not necessary, though. The most quiet sample mount is electronic perf board held on the Brick by C-clamps!



The Brick with a Sample and an MTI Photonic Sensor on the PDTS
Figure 3

The granite gives the Brick a large mass to dampen vibration. Even more important is that the sides of the Brick are polished optically flat to match the surface of the optical table. Researchers can easily slide the brick across the table to align the sample with the sensor. The sensor itself can be clamped to the optical table for stability. The Brick is cut and polished to guarantee a 90° angle between its sample face and the optical table surface.

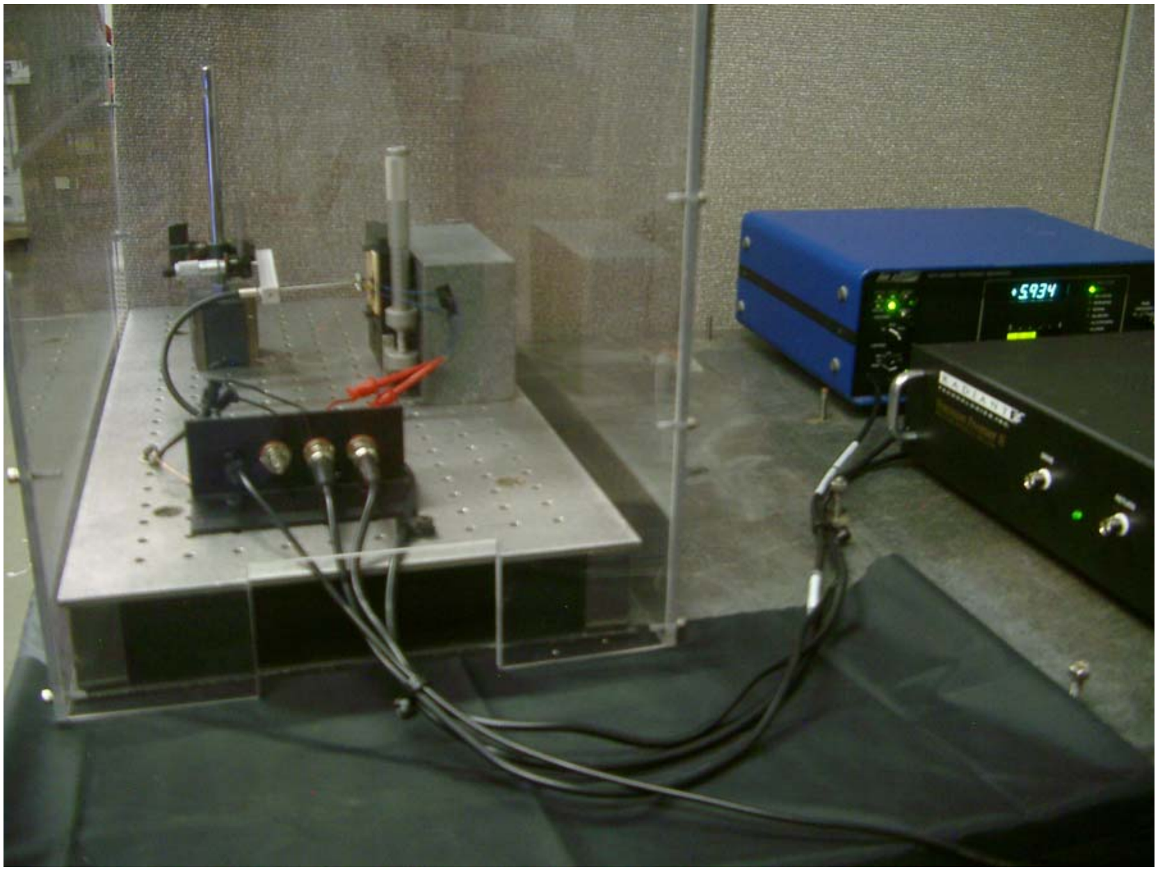
Sample Mounting
Any sample of any configuration may be mounted to the sample surface of the Brick. Electrical tape has even been used at Radiant to attach a piece of a silicon wafer to the Brick surface. Another approach is to attach the sample substrate or package to electronic perf board which itself is clamped to an optical mount on the Brick. Figure 4 illustrates such an arrangement which was used to capture the butterfly loop in Figure 1. The sample is mounted on the transistor header. The sensor is a Polytec laser vibrometer.



Typical Sample Mount Configuration
Figure 4

Discouraging Air Currents
Air currents and local air turbulence can overwhelm displacement measurements made with optical sensors. The PDTS has an air current shield that fits over the entire optical table as seen in Figure 2. In some cases, the optical path itself must be shielded. The PDTS provides plenty of space for the user to build a smaller air shield that fits over only the optical path of the sensor. Radiant does not provide such a small air shield because the necessary dimensions will vary between every customer, every sample, and every sensor.

Cable Strain Relief
Note in Figure 3 that the sample is powered by mini-grabbers and small-gauge wire. To prevent strain on the sample by the tester cables, the PDTS has a strain relief module, visible in the right hand side of Figure 3. Figure 5 below provides a bird's eye view of the PDTS with the sample holder, the sensor, and the cable strain relief. Note that the arrangement of the strain relief, the sensor, and the Brick is different between Figure 5 and Figure 2. This fact highlights the flexibility of the PDTS.



Cable Strain Relief on the PDTS
Figure 5

Conclusion

Radiant's Precision Displacement Test Stand is a quiet but highly flexible fixture that allows piezoelectric samples of any geometry to be mounted and measured down to the Ångstrom level.