Advances in Piezoelectric Thin Film Characterization and Reliability Testing

T. Schmitz-Kempen[1,*], S. Tiedke[1], R. Kessels[1], P. Mardilovich[2], T. Ebefors[3], and S. Trolier-McKinstry[4]
[1]aixACCT Systems GmbH,
Talbotstr. 25, 52068 Aachen, Germany
[2] Xaar Technology Ltd.,
316 Science Park, Milton Road, Cambridge CB4 0XR, U.K.
[3] Silex Microsystems AB
Bruttovägen 1, Järfälla, 17543, Sweden
[4] Materials Research Institute, Pennsylvania State University,
N-227 Millennium Science Complex, University Park, PA 16802, USA
*Thorsten Schmitz-Kempen: schmitz@aixacct.com

The increasing use of piezoelectric thin films in industrial MEMS applications creates new challenges in reliable and repeatable characterization as well as higher demands for reliability evaluation of films and devices. Widely used are PZT (lead zirconate titanate) based ceramic thin films which exhibit high piezoelectric coefficients, yielding high performance of the MEMS devices.
Therefore a precise knowledge of the effective piezoelectric coefficients, dependent on the mechanical boundary conditions and application, either lateral ($d_{33,f}$) or transverse ($e_{31,f}$) coefficients, is essential to predict and monitor device performance. Reliability greatly depends on any time-dependent changes in the material coefficients. To allow a prediction of lifetime, known methods comprise HALT (highly accelerated life testing) widely used to characterize capacitors [1] which allows a statistical estimation of lifetime based on early failures created by high field and high temperature stresses on a significant number of samples. The behavior of PZT films is much more complex as typical stress conditions are created not only by static field (DC), but also via dynamic excitation (AC), which creates a large range of variable parameters having different effects on the estimated lifetime.

Since the statistical evaluation requires destructive testing of a large number of samples and at the same time a large number of possible parameters, a specialized set-up is used to obtain statistically significant amount of data within a reasonable time frame and at the same time allowing a broad choice of stress conditions.
A lack of data and standardized test procedures is identified for the available choices of materials, film compositions and process conditions since they have a great influence on reliability and require repeated evaluation of their statistical failure performance. New results include derived acceleration factor for voltage and temperature, as well as $e_{31,f}$ measurements during temperature treatment to monitor degradation effects.
Details of the test setup and selected results on different piezoelectric thin films will be presented in view of electrical and electromechanical performance and additionally different methods of measurement of piezoelectric coefficients will be discussed.

[1] JEDEC Standard JESD92: Procedure for Characterizing Time-Dependent Dielectric Breakdown of Ultra-Thin Gate Dielectrics