High Performance PZT Chemical Coating Solution and Films for Piezoelectric MEMS Devices

Masami Kawahara[1,*], S.S. Won[2], M. Hochido[1] A.I. Kingon[2], and Seung- Hyun. Kim[2]
[1]Kojundo Chemical Laboratory Co. Ltd., Sakado, Saitama 350-0284, Japan
[2]School of Engineering, Brown University, Providence, RI 02912, USA
*Masami Kawahara: kawahara.masami@kojundo.co.jp

Piezoelectric films have been key components of small-scaled MEMS-based high precision sensors, actuators and ultrasonic probes which play an important role in the maintenance of many critical industrial processes. Among ferroelectric family, the dominant piezoelectric material system is currently PZT, due to high piezoelectric coupling coefficients and high electromechanical conversion efficiencies that can be achieved. Therefore, the PZT film is a logical choice of material systems for current piezoelectric MEMS applications. However, the PZT thin film with sub-μm-thickness generally shows the stress due to clamping effect by the substrates and other degradation parameters such as low breakdown strength, reduced extrinsic domain wall contribution and insufficient poling, which have limited to be used in commercial MEMS applications. Therefore, it is necessary to fabricate high quality PZT films over a few μm-thickness with a simple process which can cover the important commercial technological gap between the sub-μm thin films and the bulk ceramics.

To achieve high performance PZT films for MEMS applications, we choose the chemical solution deposition (CSD) method using newly developed high quality PZT chemical coating solutions. In CSD processing, the selection of solvents, water content, starting reagents and chelating agents has been an important key factor for producing reliable solution and thin film. Although 2-methoxyethanol has been the most extensively used solvent for the chemical synthesis of piezoelectric perovskite films due to homogeneous formation of metal-oxygen-metal (M-O-M) bonds and the uniformity of the solution, a special procedure for handling this solvent is essential since it can result in birth defects and toxicity. To overcome these drawbacks, we used non-toxic solvent with a specific chelating agent for the solution preparation to reduce the toxicity and the reactivity of the hydrolysis and the condensation reactions, which provide the enhanced uniformity and stability. To simplify the process, we have used a series of high yield coating solutions with 200nm-thickness per one coating layer. The final film thickness over 2 μm was easily achieved just with 10 times coating sequences. Our high yield solution derived PZT film was very uniform and crack-free up to 10 μm and showed high piezoelectric (d_{33} > 180 pm/V, $|e_{31}|$ > 14 C/m^2) and dielectric properties (Ɛ > 1600) with low leakage current density (J < 10^{-7} A/cm^2).

Here, we introduce newly developed high yield chemical coating solutions for high quality PZT films in detail and also describe the possible piezo-MEMS device applications using our unique chemical solution-derived PZT films.