Fall 2009

PROJECT BRIEF

Thermochemical and Electrochemical Issues Influencing Reliability in Lead Zirconate Titanate

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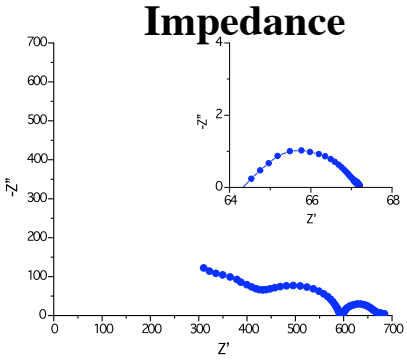
Background:

The automobile industry is interested in multilayer piezoelectric actuators for use in energy efficient diesel engines. Reliability is a major concern in current PZT actuator devices. The devices must perform under high electric fields and in high temperature environments; and as a result, the reliability and lifetime of the devices must be improved. The reliability of PZT actuator devices is believed to be controlled by oxygen vacancy transport and electromigration of electrode material under dc bias. Control and understanding of oxygen vacancy diffusion will help engineer more reliable actuator devices.



Evolution of possible grain boundary and ionic features in impedance spectra in PZT-0.5%Sc when introduced to N_2 atmosphere at 600ºC (inset: same sample in air)

Issues:

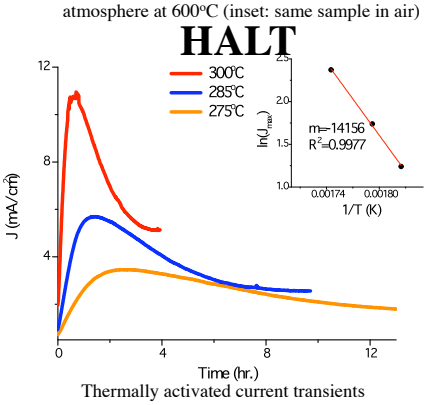
Perovskite titanates have been shown by Waser et al. to degrade by an oxygen vacancy de-mixing mechanism under dc bias. Oxygen vacancies can be introduced into a lead based perovskite material by a variety of methods, some of which are briefly described as follows:

Sintering in Reducing Conditions – $O_{Solid} \overset{PZT}{\Leftrightarrow} \frac{1}{2}O_{2\ Vapor} + V_O^{\bullet\bullet} + 2e'$

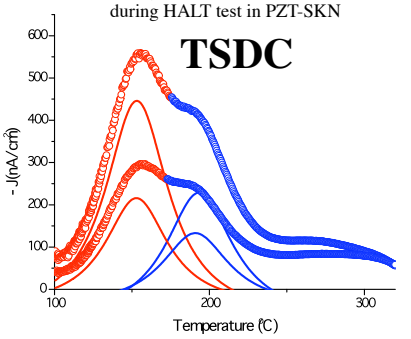
Evaporation of Volatile PbO – $PbO_{Solid} \overset{PZT}{\Leftrightarrow} Pb_{Vapor} + \frac{1}{2}O_{2\ Vapor} + V_{Pb}'' + V_O^{\bullet\bullet}$

Donor Doping of PZT – $A_2O_3 \overset{PZT}{\Leftrightarrow} 2A_{Ti,Zr}' + 3O_O^x + V_O^{\bullet\bullet}$

The defect chemistry of lead based perovskites is highly dependent upon the processing conditions. Better understanding of the combined effect of lead volatility at processing temperatures, segregation of dopants to grain boundaries, and amorphous PbO-rich grain boundary phases on electronic and ionic transport is needed in order to effectively characterize appropriate degradation mechanisms.



Thermally activated current transients during HALT test in PZT-SKN



Defect dipole (red) and possible bulk ionic charge transport (blue) in PMN

Future Work:

In-situ techniques such as impedance spectroscopy, highly accelerated lifetime measurements, and thermally stimulated depolarization current measurements will be developed in order to monitor the changes in ionic and electronic conduction in piezoelectric materials. The focus of this work will be to investigate the effect of processing in terms of dopants, sintering temperature and atmosphere, PbO activity during sintering, excess PbO used during batching, and electrode material on the degradation and electronic transport properties of PZT.

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