

PIEZOELECTRIC, DIELECTRIC AND FERROELECTRIC THIN FILMS ON METAL SUBSTRATES FOR MICROELECTRONIC APPLICATIONS

by

SUDARSAN SRINIVASAN

A dissertation submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of the requirements for the Degree of
Doctor of Philosophy

DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING

Raleigh

2005

SRINIVASAN, SUDARSAN. Piezoelectric, Dielectric and Ferroelectric Thin Films on Metal Substrates for Microelectronic Applications. (Under the direction of Dr. Angus I. Kingon)

The purpose of this research has been to demonstrate the possibility of integrating piezoelectric, dielectric and ferroelectric- lead and barium based oxide thin films and PVDF polymer on flexible metal substrates for microelectronic applications. Investigations on the key processing parameters and properties relationship for lead zirconate titanate (PZT, 52/48) and barium zirconate titanate (BZT, 35/65) based thin films on Cu foils were performed and studied. The impact of the oxygen partial pressure on the electrical properties of PZT and BZT thin films during processing has been explored, and demonstrated that high quality films and interfaces can be achieved through control of the pO₂ within a window predicted by thermodynamic stability considerations. It should be noted that the high temperature processing of barium based ferroelectric oxides can be processed on Cu foils in a wider window of pO₂ compared to that of processing lead based ferroelectric oxides. Also, the high volatile nature of lead makes the processing of lead based ferroelectric oxides difficult. Considering these issues, this work shows the processing technique undertaken to achieve high quality barium and

lead based oxide thin films on Cu foils. The demonstration has broad implications, opening up the possibility of the use of low cost, high conductivity copper electrodes for a range of Pb-based and Ba-based perovskite materials, including PZT films in embedded printed circuit board applications for capacitors, varactors, and sensors; multilayer PZT piezoelectric stacks; and multilayer lead magnesium niobate-lead titanate-based dielectric and electrostrictive devices. In the case of ferroelectric PZT films on Cu foil, the capacitors do not fatigue upon repeated switching like those with Pt noble metal electrodes. Instead they appear to be fatigue resistant like ferroelectric capacitors with oxide electrodes. This may have implications for ferroelectric nonvolatile memories. The effect of electrodes on the electrical properties of lead zirconate titanate has been investigated and discussed. For systematic and comprehensive analysis of the electromechanical properties, an accurate analytical modeling has been developed. The analytical modeling derived can be applied to double end clamped (under various end conditions) beam geometry that is useful for the case of compliant actuator material (eg. PVDF polymers) and applications, that involve high resonance of operation. These analytical expressions represent the first set of derivations for flexural mode actuators under dynamic conditions, which yield both the resonant frequencies and the displacement at resonance of double end clamped piezoelectric actuators. These analytical expressions allow users to optimize the materials selection and dimensions of bimorph and unimorph actuators. The reliability of the analytical expressions derived has been investigated using experimental results performed on PVDF polymer as a piezoelectric actuator. The actuators were constructed as double end clamped beams (both bimorph and unimorph cases). They were operated in flexural mode. The two ends of the actuator were clamped such that the slope at both the ends of the actuator bending curvature at resonance is zero. This type of end condition results in increasing the resonance frequency.