UNIVERSITI TEKNOLOGI MARA

IMPLEMENTATION OF LEAD NIOBATE ZIRCONATE TITANATE (PNZT) THIN FILMS AS PASSIVE MONOLITHIC MICROWAVE INTEGRATED CIRCUIT ELEMENTS

SUHANA SULAIMAN

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AUTHOR'S DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of University Teknologi MARA. It is original and is the result of my own work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been submitted to any other academic institution or non-academic institution for any other degree or qualification.

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Name of Student	:	Suhana Sulaiman
Student ID No.	:	2007235014
Programme	:	EE990
Faculty	:	Electrical Engineering
Title	:	Implementation Of Lead Niobate Zirconate Titanate (PNZT) Thin Films As Passive Monolithic Microwave Integrated Circuit Elements
Signature of Student	:	....
Date	:	August 2013

ABSTRACT

Lead zirconate titanate (PZT) and lead niobate zirconate titanate (PNZT) belong to the ferroelectric family. They have high dielectric constants whereby the use of these materials allows reduction of circuit size. This research is focused on microwave characterization of films made of these materials for monolithic microwave integrated circuit (MMIC) applications. Both films are deposited on silicon substrates using different deposition techniques. PZT films are deposited with sputtering to give thickness of 0.5 μm. The films have morphotrobic boundary phase since their Zr/Ti ratio is 50/50. In contrast, PNZT films are grown using metal organic deposition to give thickness of 1 μm. PNZT films are doped with 4 % of niobium (Nb) with a Zr/Ti ratio of 20/80. Capacitors and transmission lines made of PZT and PNZT were fabricated using standard semiconductor processing. High frequency wafer probes were used to carry out microwave measurement from 5 to 20 GHz, and from this the results were used to correlate microstructure properties to high frequency behavior. X-ray diffraction and scanning electron microscopy were employed to investigate grain texture and crystalline properties. The X-ray diffraction results show that PNZT has higher peak of intensity as compared to PZT. This indicates that PNZT is more crystalline than PZT. Scanning electron microscope image also shows both samples have smooth surfaces. Estimations of the grain size of both samples were made using Scherrer's formula to yield values of the order of 20 nm. Capacitor test structures of area 50×50 μm^2 are used to analyze capacitance, permittivity and loss tangent of the films. The wafer probes were calibrated using short-open-load calibration technique prior to microwave measurement. Capacitance values were then extracted from S-parameter data; the findings indicate that the permittivity of PNZT is higher than PZT. For PNZT the permittivities range from 800 at 40 MHz and decreased to 20 at 20 GHz. On the other hand, for PZT the values decreased less drastically from 350 at 40 MHz to 110 at 20 GHz. However, the PZT samples were less lossy, with loss tangents of the order of 0.18 at 40 MHz to 0.07 at 20 GHz. The fact that PNZT samples showed higher permittivity is due to the effect of doping which conform to theory. Thus, for circuit miniaturization purposes, PNZT is preferred due to the higher permittivity. Transmission lines of length of 100 μm and width 5 μm were constructed on these films in microstrip and co-planar waveguide forms. For this purpose, short-open-load-thru (SOLT) calibration technique was implemented prior to insertion loss measurement. The results indicate that the performance of microstrip and co-planar waveguide were dependent on both the structure and the films used. Specifically, PZT-based coplanar waveguide showed slightly higher insertion loss than microstrip. On the contrary, PNZT-based co-planar waveguide and microstrip show comparable performances. This was probably due to the higher crystallinity showed by PNZT. Detailed analysis of the test structures using electromagnetic simulations reveal the loss was mostly caused by the impedance mismatch between the transmission line and the wafer probes. Extensive characterization at microwave frequencies carried on these films show that they are good candidates for use in MMIC. These appeared to be direct correlation between film property and high frequency behavior. The films exhibited considerable loss at high frequencies as expected of ceramic films.

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