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Control of piezoelectric properties of PZT-based ferroelectric thin films on silicon through the crystal growth for mass-sensor and actuator applications

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Ferroelectric oxides, such as Pb $(Zr_{0.52}Ti_{0.48})O_3$ (PZT), are very useful for electronic and photonic devices, as well as piezomechanical actuators and sensors. The ferro- and piezo-electric properties are strongly related to the crystal orientation as well as the crystal growth of the epitaxial PZT thin films. Successful integration of these devices into silicon technology is therefore not only dependent on the ability of crystal growth on silicon substrates, but also the control of the crystallographic orientation of the deposited PZT thin film. In this study, the all-oxide piezoelectric stacks (PZT thin films are sandwiched between oxide-electrodes) were grown on buffer-layers/silicon substrates using pulsed laser deposition. The microcantilever structures (length: 400 µm and width: 100 µm) consisting of a piezoelectric stack (electrode/PZT/electrode) grown on a seed-layer buffered 10-µm thick Si supporting beam were then fabricated by backside etching of a silicon-on-insulator wafer. The piezoelectric measurements show that the (110)-oriented PZT films with columnar grain structure have a higher longitudinal piezoelectric coefficient $d_{33,f}$ but smaller transverse piezoelectric coefficient $d_{31,f}$ of the (001)-oriented films with dense structure or without the clear columnar growth structure. This finding indicates that the piezoelectric properties can be changed by changing the density of the PZT. It is very important for choosing the proper film growth orientation for specific applications which require either a large in-plane (such as piezoelectric micro-machined ultrasonic transducers, micro-diaphragms and energy harvester) or out-of-plane (such as mirror structure for ultraviolet wavelengths) piezoelectric displacement.

Biography

Minh Duc Nguyen received his PhD in 2010 in Physics from University of Twente, The Netherlands. He is a Post-doctoral researcher in University of Twente. His current research focuses on various piezoelectric MEMS devices, concentrates on piezoelectric micro-diaphragms and micro-cantilevers for micro-fluidics and micro-biosensors applications. These devices are based on the epitaxial- and polycrystalline lead-based thin films, such as $Pb(Zr,Ti)O_3$ (PZT) and $0.67Pb(Mg_{1/3}Nb_{2/3})O_3$-$0.33PbTiO_3$ (PMN-PT), and lead-free thin films such as $Ba(Sr,Ti)O_3$ (BST), $BaTiO_3$ (BTO), $K_{0.5}Na_{0.5}NbO_3$ (KNN) and $Bi_{0.5}Na_{0.5}TiO_3$ (BNT), fabricated on Si wafers using pulse laser deposition (PLD) and sol-gel techniques.

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