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Giant piezoelectricity on Si for hyper-active MEMS

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Smart materials that can sense, manipulate, and position are crucial to the functionality of micro- and nano-machines. Integration of single crystal piezoelectric films on silicon offers the opportunity of high performance piezoelectric microelectromechanical systems (MEMS) incorporating all the advantages of large scale integration on silicon substrates with on-board electronic circuits, improving performance and eliminating common failure points associated with heterogeneous integration. We have fabricated oxide heterostructures with the highest piezoelectric coefficients and figure of merit for piezoelectric energy harvesting system ever realized on silicon substrates by synthesizing epitaxial thin films of $Pb(Mg_{1/3}Nb_{2/3})O_3$-$PbTiO_3$(PMN-PT) on vicinal (001) Si wafers using an epitaxial (001) $SrTiO_3$ template layer. We have also demonstrated fabrication of PMN-PT cantilevers, whose mechanical behavior is consistent with theoretical calculations using the material constants of a bulk PMN-PT single crystal. These epitaxial heterostructures with giant piezoelectricity can be used for MEMS or NEMS devices that function with low drive voltage such as transducers for ultrasound medical imaging, micro-fluidic control and energy harvesting. Beyond electromechanical devices, our approach will open a new avenue to tune and modulate the properties of other multifunctional materials by dynamic strain control. This work was done in collaboration with S. H. Baek, J. Park, D. M. Kim, V. Aksyuk, R. R. Das, S. D. Bu, D. A. Felker, J. Lettieri, V. Vaithyanathan, S. S. N. Bharadwaja, N. Bassiri-Gharb, Y. B. Chen, H. P. Sun, H. W. Jang, D. J. Kreft, S. K. Streiffer, R. Ramesh, X. Q. Pan, S. Trolier-McKinstry, D. G. Schlom, M. S. Rzchowski, R. Blick. This work was supported by the National Science Foundation through grants ECCS-0708759.