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Interfacial Adhesion of PZT Ferroelectric Thin Films Determined by Nano-Indentation Method

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In this paper, we propose an elastic groundsill beam model with piezoelectric effect considered to assess the interfacial adhesion of ferroelectrics thin films, complemented and validated by nano-indentation fracture test of Pb $(Zr_{0.52}Ti_{0.48})O_3$ (PZT) thin films deposited by metal organic decomposition (MOD). In the experiment, it was observed that the hardness and the elastic modulus of thin films depend on the indentation depth, but the dependence could not be explained by strain gradient theory. From the load-indentation depth curves and atomic force microscopy (AFM) images, it was also found that the fracture failure of PZT thin films induced by nano-indentations could be divided into three typical stages: no damage, bulging and spallation. The delamination of brittleness thin film system could be modeled as an interfacial crack propagation problem and characterized by the energy release rate, which could be determined from the elastic groundsill beam model in good agreement with experimental results. For PZT thin films deposited on single Si substrate with thickness of 350 nm and 500 nm, the energy release rates per unit of new crack area are in the range of 3.399–52.432 J/m^2 and the phase angles are constant of 13.357 degree. The corresponding mode I and mode II stress intensity factors are in the range of 0.413–1.622 MPa·m$^{(1/2)}$ and 0.554–2.176 MPa·m$^{(1/2)}$.

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