Advances in AFM-based Characterization Techniques for Piezoelectric Materials

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Since the advent of atomic force microscopy (AFM) in 1986, diverse AFM-based characterization techniques have been developed. Taking advantages of physical interactions between a AFM probe and the surfaces of sample materials, diverse material properties can be locally probed by the AFM-based characterization techniques. Piezoresponse force microscopy (PFM) has been used to probe the microstructures of ferroelectric materials. When ac voltage is applied to the piezoelectric sample surface through the AFM probe, local converse piezoelectric effect is induced. This mechanical oscillation is different depending on the local polarization of the sample surface, and hence domain structures can be imaged by PFM technique. PFM has been widely used to study evolution process of ferroelectric domain structures under external electric field or mechanical stress. Furthermore, well-calibrated instruments such as dual-frequency resonance-tracking or band excitation methods were developed. While PFM works based on converse piezoelectric effect, conductive AFM (C-AFM) can be applied to piezoelectric nanomaterials via direct piezoelectric effect. That is, free-standing nanowires can be deflected by the AFM probe inducing piezoelectric potential difference in the nanomaterials. This effect was reported for the first time from n-type ZnO nanorods by Zhong Lin Wang in 2006. When the AFM probe is in contact with the compressed side of n-type ZnO nanorod, a Schottky barrier between the metal-coated AFM tip and n-type ZnO is formed, enabling current to flow through the AFM probe. Since then, this technique based on C-AFM has been applied to other piezoelectric nanomaterials with wurtzite structures. Although the piezoelectric effect of nanomaterials has been clearly characterized by C-AFM, it requires more systematic approach in that the physical interaction between the AFM probe and piezoelectric nanomaterials involves some other effects including triboelectricity and contact potential. To clarify this problem, lateral force microscopy (LFM) was used in conjunction with C-AFM. Through simultaneous acquisition of C-AFM and LFM signals, different relationship between C-AFM and LFM signals depending on the spring constant of AFM probes was observed. From this study, the current originating from triboelectric effect was confirmed. Furthermore, it was confirmed that triboelectric effect was more prominent when the larger set-point (that is, normal force) was applied to n-type ZnO nanorods.

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