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Enhanced Magnetoelastic Response near Morphotropic Phase Boundary in Ferromagnetic Materials: Experimental and Theoretical Analysis

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Abstract : The morphotropic phase boundary (MPB) recently has attracted constant interest in ferromagnetic systems for obtaining enhanced large magnetoelastic response. In the present study, structural and magnetoelastic properties of MPB involved ferromagnetic Tb_{1-x}Gd_xFe₂ (0≤x≤1) system has been investigated. The change of easy magnetic direction from <111> to <100> with increasing x up MPB composition of x=0.9 is detected by step-scanned [440] synchrotron X-ray diffraction reflections. The Gd substitution for Tb changes the composition for the anisotropy compensation near MPB composition of x=0.9, which was confirmed by the analysis of detailed scanned XRD, magnetization curves and the calculation of the first anisotropy constant K₁. The spin configuration diagram accompanied with different crystal structures for Tb_{1-x}Gd_xFe₂ was designed. The calculated first anisotropy constant K₁ shows a minimum value at MPB composition of x=0.9. In addition, the large ratio between magnetostriction, and the absolute values of the first anisotropy constant │λ_S/K₁│ appears at MPB composition, which makes it a potential material for magnetostrictive application. Based on experimental results, a theoretically approach was also proposed to signify that the facilitated magnetization rotation and enhanced magnetoelastic effect near MPB composition are a consequence of the anisotropic flattening of free energy of ferromagnetic crystal. Our work specifies the universal existence of MPB in ferromagnetic materials which is important for substantial improvement of magnetic and magnetostrictive properties and may provide a new route to develop advanced functional materials.

Keywords : free energy, magnetic anisotropy, magnetostriction, morphotropic phase boundary (MPB)
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