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Epitaxial growth and superconducting properties of thin-film PdFe/VN and VN/PdFe bilayers on MgO(001) substrates

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Abstract

© 2020 Mohammed et al. Single-layer vanadium nitride (VN) and bilayer Pd0.96Fe0.04/VN and VN/Pd0.92Fe0.08 thin-film heterostructures for possible spintronics applications were synthesized on (001)-oriented single-crystalline magnesium oxide (MgO) substrates utilizing a fourchamber ultrahigh vacuum deposition and analysis system. The VN layers were reactively magnetron sputtered from a metallic vanadium target in Ar/N2 plasma, while the Pd1-xFex layers were deposited by co-evaporation of metallic Pd and Fe pellets from calibrated effusion cells in a molecular beam epitaxy chamber. The VN stoichiometry and Pd1-xFex composition were controlled by X-ray photoelectron spectroscopy. In situ low-energy electron diffraction and ex situ X-ray diffraction show that the 30 nm thick single-layer VN as well as the double-layer VN(30 nm)/Pd0.92Fe0.08(12 nm) and Pd0.96Fe0.04(20 nm)/VN(30 nm) structures have grown cube-on-cube epitaxially. Electric resistance measurements demonstrate a metallic-type temperature dependence for the VN film with a small residual resistivity of 9 μΩ·cm at 10 K, indicating high purity and structural quality of the film. The transition to the superconducting state was observed at 7.7 K for the VN film, at 7.2 K for the Pd0.96Fe0.04/VN structure and at 6.1 K for the VN/Pd0.92Fe0.08 structure with the critical temperature decreasing due to the proximity effect. Contrary to expectations, all transitions were very sharp with the width ranging from 25 mK for the VN film to 50 mK for the VN/Pd0.92Fe0.08 structure. We propose epitaxial single-crystalline thin films of VN and heteroepitaxial Pd1-xFex/VN and VN/Pd1-xFex (x ≤ 0.08) structures grown on MgO(001) as the materials of a choice for the improvement of superconducting magnetic random access memory characteristics.

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Keywords

Epitaxial growth, Epitaxial superconductor-ferromagnet heterostructure, Palladium-iron alloy (PdFe), Superconducting spintronics, Vanadium nitride (VN)

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