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PHYSICAL ACOUSTICS

Ultrasonic and Thermophysical Properties of Cobalt Nanowires

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Abstract—We have estimated elastic, mechanical, thermal and ultrasonic properties, in high temperature regime, of cobalt nanowires (Co-NWs) having a hexagonal close-packed (HCP) structure. The second and third order elastic constants (SOECs and TOECs) have been calculated using the Lennard–Jones potential model at 300 K. These elastic constants are used to find out mechanical properties, ultrasonic velocities, Grüneisen parameters and thermal conductivity of Co-NWs. Further, these properties are used to analyze the stability and bonding properties of the present system. The relaxation time, non-linearity parameter and ultrasonic attenuation have been computed using the associated parameters. The achieved results of the present investigation have been analyzed with other NWs systems.

Keywords: Co-NWs, elastic properties, thermal properties, ultrasonic properties

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1. INTRODUCTION

In current years, nanowires have considerable attraction of researchers worldwide due to their brilliant performance in numerous applications. Among these, the cobalt nanowires have fascinated significant care due to their foremost properties and applications such as unresolved magnetic properties [1], high-density magnetic storage media [2, 3], immune magnetic separation [4], gene delivery [5] and as targeted drug carrier [6] etc. A number of studies have been done by several researchers and scientists on the various properties of cobalt nanowires. Li et al. [1] synthesized cobalt nanowires with a mean diameter of about 100 nm by chemical reduction method in an aqueous solution under an external magnetic field and studied the magnetic properties of the same. Yang et al. [7] fabricated ordered arrays of cobalt nanowires by electrodepositing the similar materials into the pores of anodic aluminum oxide (AAO) membranes. Co-NWs of different diameters and lengths were investigated by Lavín et al. [8] using electro-deposition into nanopores of alumina and polycarbonate membranes. Hu et al. [9] constructed EAM-type many-body potentials for ten hexagonal close packed metals. They reported equilibrium density, cohesive energy, five independent SOECs and the vacancy formation energy. They also introduced a modification term for chosen metals with negative Cauchy pressure. Igarashi et al. [10] constructed Finnis–Sinclair (F–S) type many-body potentials for eight HCP metals: Co, Zr, Ti, Ru, Hf, Zn, Mg and Be.

As per the authors' information, no one has studied the Co-NWs for its mechanical, thermal, and acoustical properties. These lacks of information motivated us to investigate these additional properties of the Co-NWs. In present investigation, we computed the SOECs and TOECs using simple Lennard–Jones interaction potential approach. The obtained values of SOECs have been applied to find out the various mechanical modules such as Young's modulus, bulk modulus, shear modulus, Poisson's ratio and Zener's anisotropic factor. The ultrasonic velocity and thermal conductivity have been also evaluated. Further, these evaluated parameters have been used to find out thermal relaxation time, acoustic coupling constant and ultrasonic attenuation due to phonon–phonon (p–p) interaction and thermal relaxation mechanisms. Obtained results have been presented, compared and discussed with available findings of Co-NWs and other reported similar nanowires at room temperature.