EVALUATION OF DIAMETER EFFECTS OF INDIVIDUAL COAXIAL SIC/SIO$_2$ NANOWIRES ON THEIR ACOUSTIC PARAMETERS

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Abstract
Nowadays, nanostructures, characterized by their excellent mechanical, electronic, optical and thermal properties as well as the advantages from their extremely small feature size, are worldwide investigated. Particular interest is shown for one-dimensional semiconductor nanostructures, such as nanowires (NWs), due to their potentially innovative applications in nanoelectromechanical systems. Consequently, several approaches and diffraction techniques (TEM, STM, AFM, etc.) have been developed to study experimentally and theoretically their mechanical behavior. However, few data were reported on such properties via nondestructive methods. In this context, we consider the scanning acoustic microscope technique, SAM, based on the propagation of ultrasonic waves to predict their elastic properties. To do so, we chose individual coaxial SiC(core)/SiO$_2$(sheathed layer) nanowires to investigate the effects of sheath diameters (D_s) and core diameters (D_c) on several acoustic parameters.The calculation methodology consists of several steps: determination of longitudinal and transverse wave velocities, calculation of refection coefficients, calculation of acoustic signatures, V (z), and Rayleigh velocity determination. Qualitatively, the usual oscillatory behavior of acoustic signatures was clearly obtained due to constructive and destructive interference between different modes. Quantitatively, it was found that changes in SiC/SiO$_2$ NW diameters over the ranges: 51 nm $\leq D_s \leq$ 200 nm and 12 nm $\leq D_c \leq$ 100 nm lead to variations of (i) critical angles of longitudinal mode from 8.3° to 6.2°, transversal mode from 15.6° to 11.5° and Rayleigh mode from 16.1° to 12.0°, (ii) acoustic impedances of longitudinal modefrom 11.9 Mrayl to 15.5 Mrayl and transversal mode from 6.6 Mrayl to 8.5 Mrayl, (iii) space periods in periodic V(z) curves varies from 59.8 µm to 118 µm, and (iv) longitudinal velocity from 5166 m/s to 6947 m/s, transverse velocity from 2793 m/s to 3756 m/s and Rayleigh velocity from 2597 m/s to 3493 m/s. For comparison, elastic parameters of both bulk pure SiO$_2$ and SiC are also computed to find that the acoustic values deduced for bulk pure SiO$_2$ are in good agreement with those obtained for the highest diameters of SiC/SiO$_2$ nanowires. Furthermore, to enrich this investigation, all the above variations were quantified via curve fitting to deduce semi-empirical relations that can be used to predict elastic properties of such nanomaterials by just knowing their diameters and vice versa.
Key words: Nanowires, SiC/SiO$_2$, elastic properties, V (z), reflection coefficient, semiconductors.