Impact of Intrinsic Stress on Multiple Resonance Modes in Silicon Nanowires

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Abstract

Nanowires (NWs) are fundamental building blocks for next-generation sensors and micro-/nanoelectromechanical systems (MEMS/NEMS) due to their unique electrical, mechanical, and optical properties. However, these properties are significantly influenced by intrinsic stresses that can develop during fabrication or post-fabrication treatments. For instance, the buckling behavior of suspended silicon (Si) NWs due to intrinsic stresses can result in variations in mechanical properties and the dopant diffusion mechanism within the NWs. With the increasing technological focus on utilizing Si NWs as resonators, it is crucial to investigate the impact of intrinsic stresses on their resonant frequencies to ensure the reliable design of next-generation devices. This study systematically induces and characterizes stresses in Si NWs and evaluates their effect on multimodal resonant frequencies. A top-down fabrication approach was used to create double-clamped Si NWs with lengths of 40 μm and sub-micron widths and thicknesses, all fabricated on a stress-free substrate. The Si NWs are obtained in a suspended configuration with an etch depth of up to 2 μm, making them suitable for vibrational analysis. Once the samples were prepared, Raman spectroscopy was used to measure the intrinsic stresses in the as-fabricated Si NWs. The resonant frequencies up to the first three vibrational modes were then measured using a Laser Doppler Vibrometer (LDV). Following the initial measurements, standard thermal processing was applied to induce additional stresses in the Si NWs. Raman characterization was conducted again to confirm the presence and quantification of the stress induced by thermal processing. Subsequently, resonant frequencies were measured to assess the effect of intrinsic stresses across three vibrational modes. The results demonstrated a significant variation in the resonant

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frequencies of the Si NWs after the introduction of stresses. These findings emphasize the critical role played by intrinsic stresses in determining the vibrational behavior of Si NWs and provide a practical pathway for optimizing the functionality of Si NW-based resonators.