Interlayer Assisted Growth of Polycrystalline Germanium on Silicon at Low Temperatures

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The growth of polycrystalline and heteroepitaxial germanium (Ge) on silicon (Si) is of interest for various electronic applications. Sputter deposition offers a simple and inexpensive process for deposition of homogenous Ge films on large-area substrates [1]. One challenge in growing high quality Ge on Si by sputtering method is the presence of native oxide on Si, formed during the pump down process. Also, the presence of excited and ionized oxygen created by plasma prior to Ge deposition can contribute to native oxide on Si. Our experimental observations indicate a native oxide of 1.5 - 2 nm thickness can form in the sputter chamber at mid-range vacuum (~10^{-6}–10^{-7} Torr). This corresponds to observations made by others [2]. Some prior reports achieved high-quality heteroepitaxial Ge on Si by desorbing the native oxide from the Si substrate prior to sputtering of Ge [3]. The oxide desorption involves a high temperature in-situ anneal (> 1000 °C) in the sputtering chamber at ultra-high vacuum (≈ 10^{-10} Torr). Desorption cannot be conveniently done in sputtering systems with a moderate vacuum. Also, desorption temperature is higher than the typical thermal budget for post-CMOS processing. It is relevant to investigate the growth of high-quality Ge films using a moderate pressure system without a high temperature step.

We report here a preliminary study of polycrystalline Ge film growth on Si by DC magnetron sputtering at moderate vacuum (~10^{-6} Torr) and at substrate temperature as low as 300 °C without a high-temperature in-situ oxide desorption step. Our approach involves the sputtering of a nanometer scale Si interlayer on the Si substrate, prior to Ge deposition. This is designed to disrupt the surface oxide on the Si substrate and ultimately assist the growth of high quality Ge on Si substrate. X-ray diffraction and Raman spectroscopic studies indicate the formation of polycrystalline Ge at 300 °C when Si interlayer is incorporated. Sputtering Ge on Si at 300 °C without a Si interlayer resulted in amorphous Ge. Prior studies have reported amorphous Ge on Si at 320 °C under similar sputtering process conditions, but without any interlayer [2]. Currently, the Ge/Si interfaces in this work are being characterized further by high resolution transmission electron microscopy.

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Supplementary Page

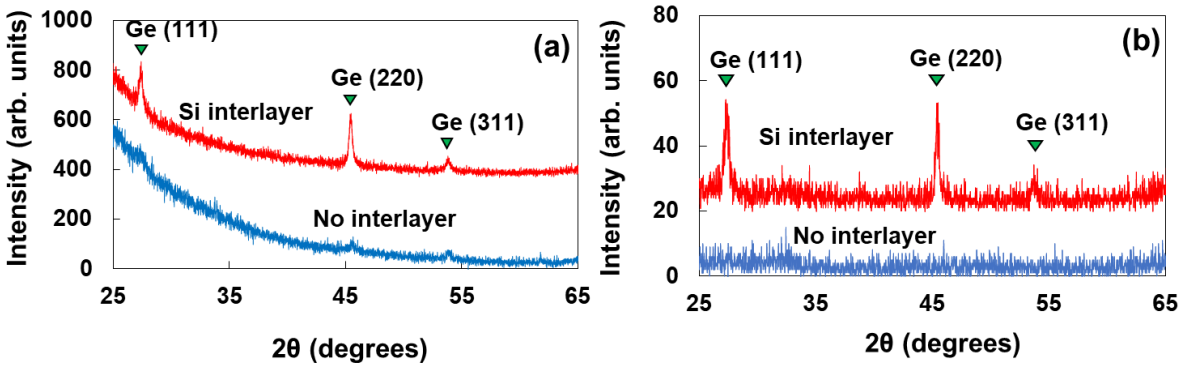

Figure 1. X-ray diffraction patterns of Ge grown on Si at (a) 325 °C, (b) 300 °C. Incorporating a Si interlayer results in polycrystalline Ge. In comparison, Ge grown on Si at the same temperature without a Si interlayer shows no specific Ge peaks, indicating an amorphous behavior.

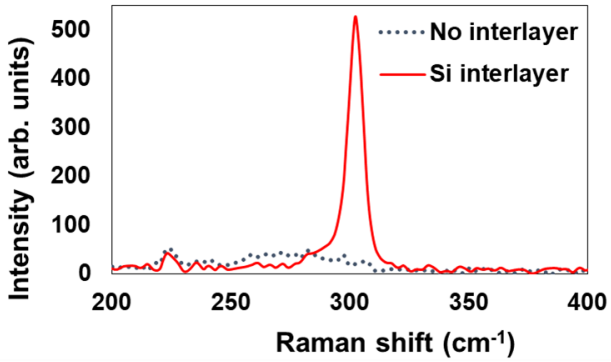

Figure 2. Raman spectra of Ge grown on Si by DC magnetron sputtering method. In the case of Si interlayer, a Ge-Ge peak corresponding to crystalline Ge is visible near 300 cm^{-1}. Ge grown on Si under the same conditions but without a Si interlayer forms amorphous Ge at the same temperature. This is indicated by the broad peak around 280 cm^{-1} in the corresponding spectrum.