Doping and Surfactant Behavior of Gallium in Low-Temperature Silicon and Germanium Growth

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Silicon-germanium-tin (SiGeSn) compounds are interesting as potential direct bandgap CMOS compatible materials. Sn precipitation and surface segregation occur for growth and annealing temperatures substantially below standard Si and Ge growth temperatures [1]. Molecular beam epitaxy (MBE) growth at the low temperatures needed to achieve significant Sn incorporation can also result in a degradation in Si and Ge film quality. Fig. 1 demonstrates the detrimental effect on Si film roughness and pseudo-optical constants resulting from decreasing Si growth temperature from 600°C to 200°C. Understanding and improving the low temperature growth of Si and Ge may improve SiGeSn film quality for optoelectronic applications. Gallium has been investigated by crystallographic techniques as a dopant and surfactant in low-temperature Si epitaxial growth [2,3,4], and as a dopant in GeSn [1]. In this work we investigate the relationship between pyrometer calibrated MBE growth temperature (150°C - 600°C), growth rate, and the doping/surfactant behavior of Ga in low temperature Si, Ge, and SiGeSn epitaxy, paying particular attention to film electronic and optical properties. Changes in surface roughness as determined by AFM are used to indicate whether Ga provides a beneficial surfactant effect. Ga incorporation as a dopant is investigated by Hall Effect measurements. Film optical properties are measured by variable angle spectroscopic ellipsometry. Changes in crystalline structure and quality resulting from the presence of the Ga and from Sn incorporation are measured by XRD.

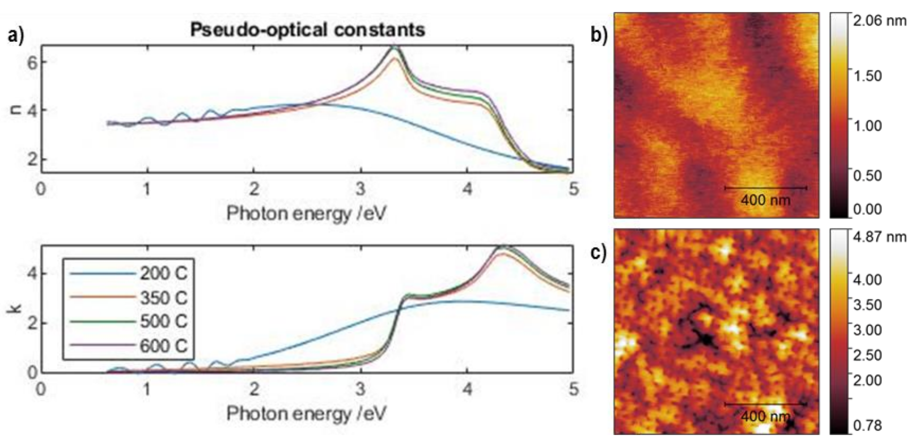

Figure 1. Effect of growth temperature on homoepitaxial Si film quality, demonstrated by a) changes in the pseudo-optical constants of 500nm Si films on float-zone Si wafers, and the AFM-determined surface features of homoepitaxial Si films grown at b) 600°C and c) 350°C.

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