Low-temperature Homoepitaxial Growth of Two-dimensional Antimony Superlattices in Silicon

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Silicon-based imaging arrays have a variety of scientific and commercial applications, and are at the heart of NASA's optical space telescopes and instruments. Operation in space brings the challenge of dealing with radiation effects. For example, protons cause displacement damage within the silicon lattice, resulting in stable defects or "traps" within the device. Traps accumulate over time leading to increased dark current, hot pixels, and charge transfer inefficiency; adversely affecting performance and science return. JPL-invented delta-doped and superlattice-doped ("2D-doped") detectors offer high durability, high stability and high sensitivity to wavelengths spanning the UV, visible, and near IR spectral regions. Importantly, JPL's 2D-doped detectors offer a vast improvement in stability against damaging radiation over conventional devices.

For device passivation by 2D-doping, dopant concentrations in the range of 10^{13}-10^{14} cm^{-2} are typically used, and delta layers are confined to within a few nanometers of the surface. P-type doping with boron from an effusion cell is relatively straightforward. Boron evaporates as an atomic beam, and the small boron atoms incorporate with the silicon crystal lattice. Conversely, n-type doping of silicon using antimony presents many challenges, arising primarily from the tendency of antimony to segregate to the surface. This phenomenon can be avoided by employing low temperature growth to kinetically limit dopant segregation. However, this approach may compromise epitaxial growth (leading to amorphous layers) and often results in poor dopant incorporation and activation.

Despite these challenges, it has been shown that at sufficiently slow silicon deposition rates it is possible to maintain epitaxial growth for finite thicknesses even at low temperatures [1]. We previously reported on the low-temperature growth of antimony delta-doped silicon [2]. We demonstrated ~85% dopant activation, activated dose concentrations as high as 2×10^{14} cm^{-2}, and sharp dopant profiles (~35 Å FWHM). We also showed that the low temperature antimony delta-doping process is effective for passivating back-illuminated, high-purity, p-channel CCDs [3,4]. In this presentation, we will discuss the extension of our n-type delta doping capabilities to the growth of n-type superlattices. Electrical characterization and preliminary device measurements will be included.

[1] D. Eaglesham, et al., *PRL* **65**, 1227(1990). [2] J. Blacksberg, et al., J. Cryst. Growth. **285**, 473(2005). [3] J. Blacksberg, et al., *APL* **87**, 254101(2005). [4] J. Blacksberg, et al., IEEE Trans. Electron Devices. **55**, 3402(2008).

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Supplementary Page (Optional)

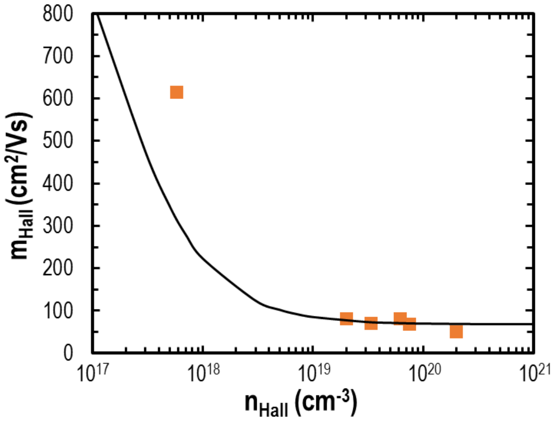

Figure 1. Carrier mobility (m_{Hall}) vs. carrier concentration (n_{Hall}) for several Sb delta-doped samples. The solid black line shows bulk mobility for P-doped silicon.

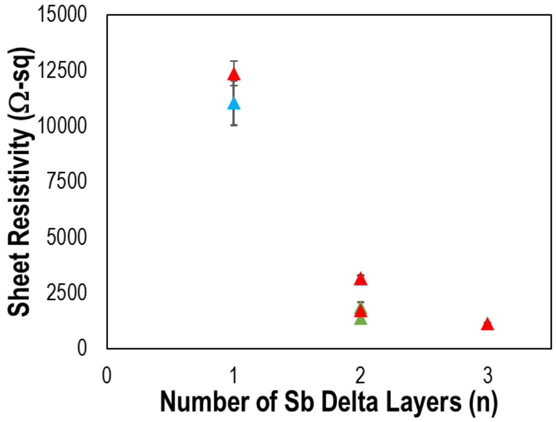

Figure 2. Sheet resistivity vs. number of Sb delta layers. The red, green, and blue points distinguish samples prepared at 350 °C, 325 °C, and 300 °C, respectively.