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# Optical properties of Ge-Sn nanoparticles grown by ion-implantation

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We are exploring solid state precipitation methods to grow high-quality Ge-Sn nanoparticles with controlled compositions and band gaps. There have been decades of research to produce semiconductor nanoparticles using wet chemistry synthetic techniques, however many of these approaches are not compatible with current CMOS device manufacturing. Si-Ge-Sn alloys offer great new material properties, such as a direct bandgap, but there are challenges in their fabrication.[1]

We present experiments showing the advantages of ion implantation to grow high-quality GeSn nanoparticles, with morphology, composition, and size distribution controlled by implantation dose, temperature, and defect engineering. In particular, He bubbles are used as templates to nucleate and grow GeSn nanoparticles. Previously we were able to establish conditions favourable for He bubble formation and determine isotopic effects related to this process[2]. GeSn nanoparticles have been fabricated by ion implantation at energies of 30-90 keV, at 300K into Si(001) substrates, placing Ge and Sn into the same depth region. Growth of the GeSn nanoparticles has been characterized using I-V analysis, ellipsometry, Rutherford Backscattering Spectroscopy, Raman Spectroscopy, X-ray Photoelectron Spectroscopy (XPS) and X-ray diffraction (XRD). Preliminary results indicate the enhancement of diffusion in the presence of He bubbles leads to formation of nanoparticles with different sizes and morphologies. Achieving direct bandgap Sn-based materials strongly depends on the applied strain within the epilayers, our work leads to ways to control and modify the strain, especially the plastic strain relaxation of Ge-Sn nanoparticles grown in Si substrates.

1. Wirths, S., D. Buca, and S. Mantl, Si-Ge-Sn alloys: From growth to applications. Progress in Crystal Growth and Characterization of Materials, 2016. 62(1): p. 1-39.
2. Moutanabbir, O., et al., Influence of isotopic substitution and He coimplantation on defect complexes and voids induced by H ions in silicon. Physical Review B, 2007. 75(7): p. 11.

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