Compensating defects in epitaxial Ge and Ge_xSn_{1-x}

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Increasing the carrier concentration in epitaxial Ge and GeSn above 10^{19} cm^{-3} poses a challenge from a defect point of view, as compensating defects are abundantly created in the growth of the layer. As the intent is to further increase the carrier concentration above 10^{20} cm^{-3} and semiconductor doping starts to resemble more alloying than traditional doping, we are entering unfamiliar territory when it comes to defect dynamics.

We have used positron annihilation spectroscopy (PAS) in combination with density functional theory (DFT) calculations to study compensating vacancy-donor complexes in epitaxial layers of Ge and GeSn doped with P and As. As expected the dopants form complexes with the native vacancy defects. In previous studies [1,2] both mono- and divacancy complexes have been observed in highly doped Ge. Whereas monovacancy complexes dominated in diffusion doped bulk Ge [1], divacancy complexes were observed in implanted and laser annealed Ge [2]. From the experimental results it is clear that monovacancies dominate the positron annihilation in all studied epitaxial layers. DFT calculations indicate that Sn does not have the desired effect of trapping vacancies, as the binding energies for V-Sn pairs is clearly lower than for complexes involving dopants. However, both experimental and computational PAS results results indicate that Sn is having an impact on the annihilation state of the positrons.

References

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