Muonium Acceptor States in High-Ge SiGe Alloys

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Muon spin rotation and resonance studies of Czochralski-grown silicon germanium alloys in the high-Ge content region, where the conduction band minimum changes between Si-like and Ge-like character at roughly 85% Ge, have determined muonium donor and acceptor energy levels. High-TF and RF μSR measurements on 90% and 84% Ge content SiGe alloys show Mu acceptor energy levels of 13.5 ± 5.2 meV and 77 ± 12 meV, respectively, as well as a split tetrahedral Mu hyperfine signal [1]. Negatively charged muonium is predicted to prefer the tetrahedral cage region of the SiGe lattice as opposed to a bond-centered location. These separate hyperfine signals are likely to result from tetrahedral Mu states with all Ge neighbors or with at least one Si neighbor. The additional signal may be a product of Mu^- having a significant preference for the Si environment, as predicted for H^- in high-Ge alloys [2]. In addition to observing two Mu_T states in these samples, we see a possible shallow acceptor signal in our transverse field data. TF-μSR spectra of our 84% sample exhibit a time-delayed process most likely arising from neutral Mu states. Our fits obtain a relaxing diamagnetic signal that shows a bond-centered Mu related process above 150K and a shallow signal below roughly 50K. This shallow state, with a hyperfine splitting of roughly 150 kHz, results in two oscillating signals that are split off from the diamagnetic frequency and are roughly 90 degrees out of phase with respect to each other which results in a beat pattern in the TF data. We will present our examination of this possible shallow acceptor state and the local environment of the observed Mu_T signals.

[1] P.J.C. King et al., Physica B 401-402 (2007) 617-620.
[2] R.N. Pereira et al., Phys. Rev. B **73**, 085201 (2006).