# Dynamics of T-Site Muonium States in Gallium Phosphide

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Muon spin resonance results on semi-insulating GaP suggest the presence of two separate diamagnetic states above roughly 400 K. The diamagnetic RF-$\mu$SR resonance amplitude increases starting at that point, then decreases above 550 K, consistent with two signals displaying different dynamics. The second state, present from ∼400 to 630 K, is assigned to the negative ion, $Mu^t$, expected to reside in the tetrahedral (T) site with Ga near neighbours. The single state at lower temperatures is assigned to a mobile $Mu^+$, claimed [1] to hop among the T-sites with phosphorous neighbours above 300 K, even though the stable site for a stationary $Mu^+$ is bond-centered. Interactions between mobile Mu centers and Zn acceptors were reported [2] for p-type GaP, and assigned to charge exchange between $Mu^0_T$ and $Zn^0$ below ∼100 K and to Coulomb capture of $Mu^+_T$ by $Zn^t$ above 400 K. Here we report in detail on the motional dynamics of $Mu^t$ and the ionization processes related to the $Mu_T$ acceptor state. We obtain an energy of ∼0.82 eV from the growth step in the RF data for the standard $Mu_T$ acceptor-related hole ionization. The loss of the $Mu^t$ RF-component yields an energy of ∼1.7 eV, which is assigned to thermal promotion of an electron from $Mu^t$ to the conduction band, *i.e.* ionization of $Mu^t$. These two results place the $Mu_T$ acceptor level with respect to the valence and conduction band edges, respectively. The difference in these placements represents the Coulomb energy for $Mu^t$ in the positively charged $T_{Ga}$ region. Low-field spin precession and zero-field depolarization data on n-type GaP in the $10^{16}$ to $10^{18}$ $cm^{t3}$ concentration range show a peak in diamagnetic fraction below 300 K and a roughly linear increase in the net diamagnetic signal above that, nearing the full muon fraction only above 900 K. Both regions show characteristics of $Mu^t$. The onset of $Mu^t$ motion above 500 K overlaps with the loss an electron, making a clean separation of these processes in the depolarization data marginal; however, initial results give a barrier of nearlyg.9 eV. Additionally, a $Mu_T$ charge cycle sets in above the electron loss transition; however, it is not obvious at present whether this represents a +/0 or a 0/t cycle, or precisely which transition processes are active in n-type samples at the highest temperatures.

[1] R.L. Lichti, et al, Physica B 308-310 (2001) 862.
[2] R.L. Lichti, et al, Physica B 326 (2003) 167.