Supplemental Document

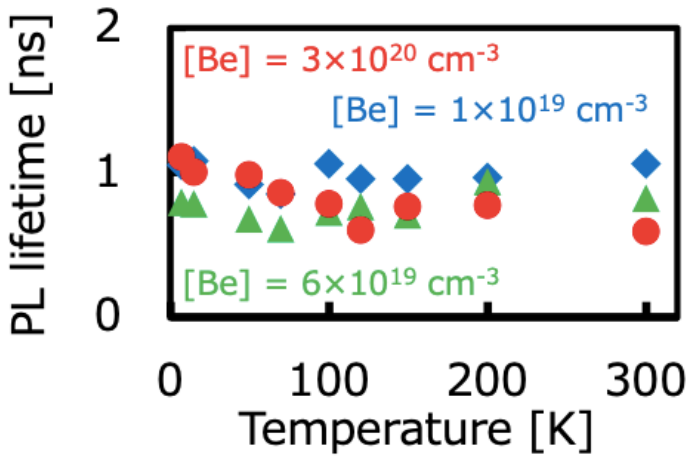

Figure 1: Temperature dependences of the slow PL lifetime for Be-doped GaAsN. Solid diamonds (blue), triangles (green), and circles (red) show the PL lifetime values for Be-doped GaAsN with [Be] of 1×10^{19}, 6×10^{19}, and 3×10^{20} cm^{-3}, respectively.

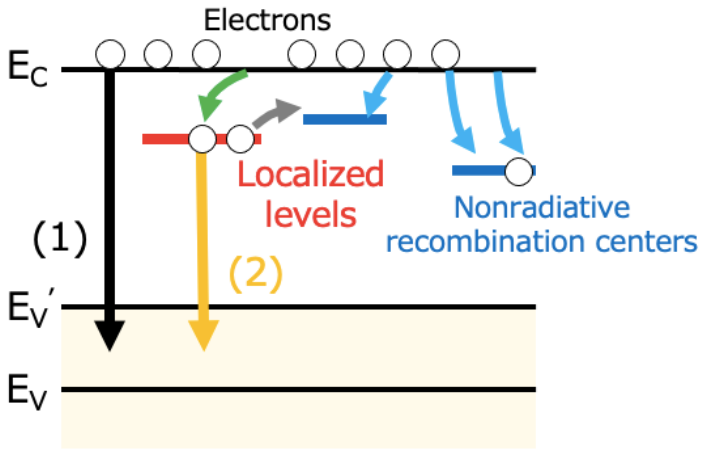

Figure 2: Energy levels around the forbidden band and PL processes for Be-doped GaAsN. PL processes consists of optical transitions from (1) the bottom of the conduction band (E_C) and (2) localized levels. Hole concentration values were independent of temperature, so Be-doped GaAsN layers grown in this study were degenerate. Therefore, the end point of each PL process is described between the top of the valence band (E_V) and the modulated level of E_V by the bandgap narrowing (E_V') as an analogy of a previous study for degenerate p-type GaAs. The slow PL lifetimes correspond to the optical transition expressed as (2).