Growth and characterization of Rhodium-doped InGaAs and InP by gas-source MBE

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Intentional doping of epitaxial semiconductor layers with deep acceptors is crucial for several device applications, such as buried-heterostructure lasers [1] and photoconductive THz emitters and receivers [2]. Iron is the most common and well studied deep acceptor for InP and $In_{0.53}Ga_{0.47}As$ and has been used as a dopant in solid-source MBE, in gas-source MBE, and in MOVPE epitaxial methods. On the other hand, iron is known to cluster at high doping concentrations, to diffuse into adjacent layers, and to build interstitial defects under certain growth conditions.

Early studies of MOVPE grown InP and $In_{0.53}Ga_{0.47}As$ consider further transition-metal dopants as possible alternatives to Fe, such as Ru, Rh, Ti, and Ir [3]. These materials did show significantly lower diffusion and superior electrical compensation properties. Contrary to Fe with atomic covalent radius of 0.152 nm, Ru, Rh, and Ir have atomic covalent radius of 0.142 nm, which is identical with covalent radius of Indium. This coincidence implies a minimal crystal cell deformation around the dopant in InP. All three – Ru, Rh, and Ir – are inert noble metals, which excludes the possibility of the source contamination via arsine, phosphine, and /or oxygen. Out of these three potential dopants, Rh has the highest vapor pressure and is therefore more straightforward to use in MBE using conventional thermal evaporation cells.

In this paper we describe the properties of Rh-doped InP and $In_{0.53}Ga_{0.47}As$ grown on InP substrates by gas-source MBE. 4N-purity Rh was evaporated using conventional high-temperature doping cell with pyrolytic-graphite crucible at temperatures between 1300℃ and 1800℃. We demonstrate residual carrier density concentrations down to 2×10^{12} cm^{-3} at room temperature, and electron-hole recombination times in $In_{0.53}Ga_{0.47}As$:Rh down to 0.1 ps. These results open up a potential of using the MBE-grown $In_{0.53}Ga_{0.47}As$:Rh on InP as an absorber material in future commercial photoconductive THz emitters and receivers.

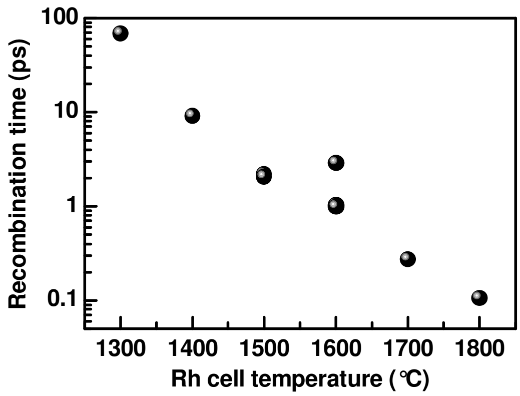

Fig. 1. Electron-hole recombination time measured in $In_{0.53}Ga_{0.47}As$:Rh as a function of Rh-cell temperature.

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