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Visible light electroluminescence in manganese-doped GaAs light-emitting diodes

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Light emissions due to *d-d* transitions of transition metal (TM) ion doped in solid crystals are of particular interest due to their possible applications in solid-state light-emitting devices. For example, transitions from the ^2E states to the $^2T_2$ ground states of Ti^{3+} ions doped in sapphire have been utilized in tunable titanium-sapphire lasers [1]. However, *d-d* transitions of TM atoms doped in small gap semiconductors, such as GaAs or Si, have not been investigated so far. In this work, we report on visible light electroluminescence of Mn doped GaAs (here, referred as GaAs:Mn) light-emitting diodes (LEDs). Our LEDs consist of 20 nm-thick p+ GaAs:Mn (Mn 1%) / 150 nm-thick n-type GaAs:Si (electron concentration $n = 1\times10^{18}$ cm^{-3}) / n+ GaAs substrate, from the top to the bottom. We applied a reserve bias (~ -6 V) on the LEDs, such that a high electric field (1.4×10^6 V/cm) is built up in the depletion layer. Holes are injected to the depletion layer either by Zener tunneling from the conduction band or by diffusion of minority holes from the valence band of the n-type GaAs layer. These holes are accelerated to high energy by the intense electric field in the depletion layer, and excite *d* electrons of Mn in the p+ GaAs:Mn layer by impact excitations. Figure 1 shows the electroluminescence spectrum of a LED when biased with a voltage of -6 V and a current density of -1.2 A/cm^2, measured at room temperature. Besides the strong band-gap emission at E_0 = 1.43 eV, the LED shows visible light emission at E_1 = 1.89 eV and E_2 = 2.16 eV, which are exactly the same as those of the $^4A_2(^4F) \rightarrow {}^4T_1(^4G)$ and $^4T_1(^4G) \rightarrow {}^6A_1(^6S)$ transitions of Mn in ZnS:Mn [2]. Furthermore, the positions of E_1 and E_2 peaks show no dependence on temperature, which contrasts the strong temperature-dependence of E_0. This indicates that the visible light emissions at E_1 and E_2 are due to *d-d* transitions of Mn in GaAs. This work is supported by Grant-in-Aids for Scientific Research including the Specially Promoted Research, and the Project for Developing Innovation Systems of MEXT.

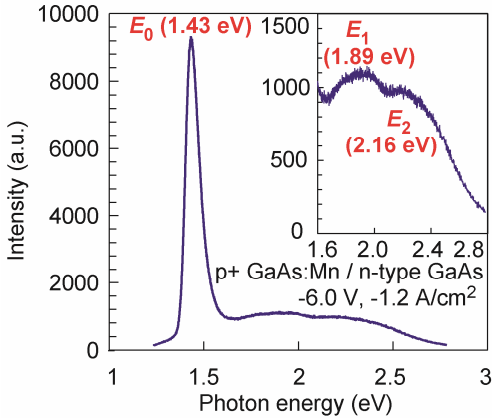

Fig. 1. Electroluminescence spectrum of a LED consisting of 20 nm-thick p+ GaAs:Mn (Mn 1%) / 150 nm-thick n-type GaAs:Si (electron concentration $n = 1\times10^{18}$ cm^{-3}) / n+ GaAs substrate, biased with a voltage of -6 V and a current density of -1.2 A/cm^2. The spectrum was measured at room temperature. The strong peak at 1.43 eV is due to the band-gap emission, while those at 1.89 eV and 2.16 eV are due to the *d-d* transitions of Mn. Inset shows the magnified view of the visible spectrum.

References

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