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Low-temperature crystal growth technique by using bismuth surfactant effect

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I introduce low-temperature crystal growth technique of III-V compound semiconductors. So far, they tend to be grown at higher temperatures to obtain good crystalline quality to fabricate electronic and optical semiconductor devices such as transistors, photovoltaic cells, light emitting diodes, laser diodes, and so on. However, a peculiar III-V semiconductor, bismuth (Bi)–containing semiconductors, which needs to be grown at low temperatures has recently received considerable attention.

$GaAs_{1-x}Bi_x$, which is one of Bi–containing III-V compound semiconductors has unusual fundamental properties including a large reduction and low-temperature dependence of the bandgap[1–4], and a strong enhancement of the spin orbit splitting[5, 6] owing to the incorporation of Bi atoms. These properties open up the possibilities of application of Bi–containing semiconductors to long-wavelength optoelectronics, photovoltaics, and spintronics.

In the molecular beam epitaxial growth of $GaAs_{1-x}Bi_x$ on GaAs substrate, temperature of the growing surface must be as low as 350˚C because Bi atoms are easily desorbed from the growing surface if the temperature is high. Moreover, As flux should be adjusted in a limited range on the brink of the As shortage on the growing surface because Bi atoms are incorporated into As site in GaAs crystal lattice. Based on these growth condition, it cannot be expected that the crystalline quality of $GaAs_{1-x}Bi_x$ should be high. However, laser operation of $GaAs_{1-x}Bi_x$ was demonstrated in the previous studies[7–9]. This suggests that III-V compound semiconductors with high crystalline quality can be obtained by using Bi atoms during the crystal growth at as low as 350˚C. Because Bi has been utilized as a surfactant in the growth of III–V semiconductors at higher temperatures, it can be presumed that Bi may have surfactant effect even at low growth temperatures. A possible mechanism of this surfactant effect will also be introduced.

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