High-Q resonance peak observed from metal-embedded InAs/GaAs quantum dot nano-cavity

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Interactions of semiconductor nanostructures with optical microcavites are one of the present most active research areas. Distributed Bragg reflector (DBR) microcavity pillars and photonic crystal nanocavities have been extensively studied. Metal-embedded structures have attractive features to tightly confine optical fields to nano-area and have been actively studied for nano-lasers, nano-cavities, and plasmonic effects. However, the resonance Q values reported have remained low due to the optical absorption associated with metals.

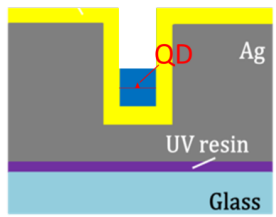

Fig. 1. Schematic of SPEM structure with InAs/GaAs QDs.

In this paper, we demonstrate the observation of high-Q cavity resonance mode from semiconductor pillar embedded with metal (SPEM) shown in Fig. 1. In this structure photo-excitation and photon extraction is limited to the surface area and efficient optical coupling is possible (recently we observed the photon collection efficiency of ~20%). One of the prepared structures is shown in Fig. 2. The silver (Ag) surface and the interface with the GaAs nanostructure is covered with SiO_2. The GaAs nanostructure includes InAs quantum dots (QDs) inside. One of the observed photoluminescence (PL) spectra is shown in the inset of Fig. 3. The temperature dependence of the PL peak is compared with that of GaAs energy gap by energy-shifting the well-known Varshni equation. The extremely weak temperature dependence demonstrates that this is the cavity resonance mode feeded from InAs QD emission. The observed Q value of ~7000 is the largest ever reported with the SPEM structures. This explores the high new possibilities for electrons interact with highly confined photonic fields in nano-PEM structures.

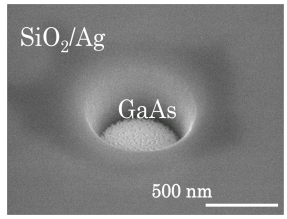

Fig. 2. One of fabricated structures observed with SEM.

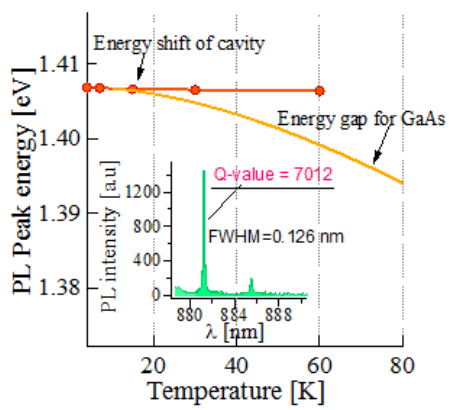

Fig. 3. Temperature dependence of PL peak energy. The observed peak (red) is much less temperature dependent. GaAs energy gap energy-shifted with the Varshni relation is shown in comparison (orange line).

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