Optical Resonant Modes in Tensile-Strained Ge Microdisks Fabricated via Laser-Induced Liquid-Phase Crystallization

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Ge based lasers are expected to be key components of Si photonic integration technology, because they realize light sources compatible with Si-CMOS technology. Ge has indirect band structure same as Si, but we can modulate it and enhance the optical properties by applying tensile strain and incorporating Sn atoms. The critical issues are crystalline defects generated during the growth on Si substrates caused by large lattice mismatch and low solubility of Sn atoms in Ge. To address these issues, we have been developing laser-induced liquid-phase crystallization (LLPC) and shown the high quality of the tensile-strained Ge and GeSn layers fabricated by LLPC [1]. In this paper we show the analysis of optical resonant modes observed from the tensile-strained Ge microdisks fabricated via LLPC.

A 200-nm-thick amorphous Ge film was deposited on a Si substrate having a 1-μm-thick SiO_2 layer by sputtering and patterned into 10 μm × 7 mm wires. A 1-μm-thick SiO_2 layer was capped on the Ge wires and LLPC was performed using a 450 nm laser. Ge microdisk resonators were fabricated using electron beam lithography and reactive ion etching. The diameters range from 3 to 8 μm (Fig. 1). Photoluminescence (PL) spectroscopy was performed at room temperature using a 647 nm laser (1-2 μm diameter spot).

Typical PL spectra from the microdisks are shown with the references in Fig. 2. We see that the spectra from the microdisks and wires are red-shifted due to ~0.55% tensile-strain. We also see clear resonant fringes in the spectra from the microdisks depending on the diameter.

Principal resonant modes of a microdisk resonator are whispering gallery modes (WGM), where light circulates around the periphery by undergoing repeated total internal reflection. However, the resonance energy spacing (free spectral range) observed in our experiments corresponds to those of radial modes, where light propagates along the radial direction between the center to periphery. Frequency-domain electromagnetic simulation showed the optical modes enhanced in the microdisks strongly depend on the light source position in the disks and supports our observations. The details will be shown in the presentation.

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[1] H. Oka *et al.*, Ext. Abstr. IEEE Int. Electron Devices Meeting (IEDM), 2017, p.16.3.1.

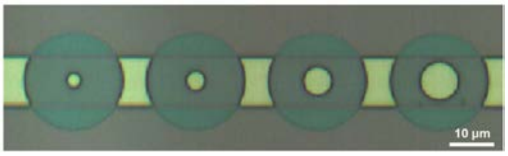

Fig. 1 Optical microscope image of Ge microdisk resonators with diameters of 3, 4, 6, 8 μm.

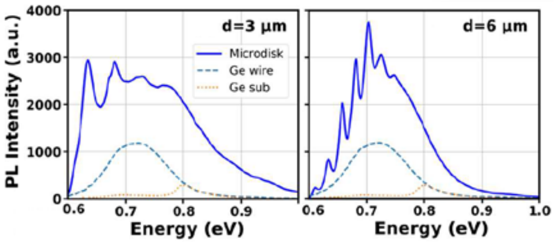

Fig. 2 PL spectra of Ge microdisk resonators with diameters of 3 and 6 μm. The spectra of Ge wires and Ge substrates are shown as reference.