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The Resonant Phenomenon in the PL Spectra Measured in the Tensile-Strained Ge Microbridges

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Abstract

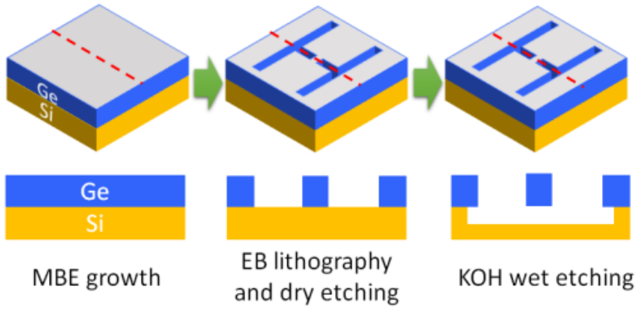
Resonant light emission peaks with Q-factors of about 180 in room-temperature photoluminescence spectra from uniaxially tensile-strained germanium microbridges have been observed in our experiment, which are found to correspond to the resonance in Fabry-Perot (FP) cavity formed transversely to the uniaxial stress axis. Based on this phenomenon, a Fabry-Perot cavity by adding distributed Bragg reflectors laterally to the microbridge is designed with a Q-factor of about 1400.

1.Introduction

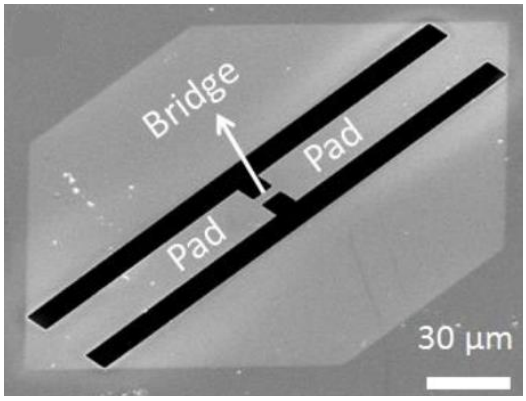
Silicon (Si) photonics is becoming as a more and more promising platform for short-reach optical interconnects [1]. However, because of the indirect bandgap, silicon is not a good light source material. Germanium (Ge) can be grown on Si substrate easily [2] and its direct valley is only slightly higher than the indirect one in conduction band, so it's a potential material to become a light source. To realize efficient Ge light source, tensile strain has been introduced to change its band structure [3]. However, it's not easy to make a resonator on it because any modification on the microbridge will affect the achieved strain level. In this paper, we have observed obvious resonant light emission peaks in the photoluminescence (PL) spectra. Inspired by this observation, a high-Q optical resonant based on the distributed Bragg reflectors (DBRs) without any modification on the microbridge structure is proposed and simulated in this paper.

2. Measurement results and discussion

The fabrication process of the microbridge is shown in Fig.1(a). First, we made a Ge-on-Si (GOS) wafer by solid-source molecular beam epitaxy (MBE). After MBE, the pattern of the microbridge was defined by electron beam (EB) lithography, and inductively coupled plasma reactive-ion dry etching. Finally, KOH wet etching was used to remove the Si under the microbridge to get a free-standing structure. The scanning electron microscope (SEM) image of our microbridge device is shown in Fig.1(b), where a narrow bridge is connected by two wide pads, and also we can clearly see the bridge is totally suspended.



(a)



(b)

Fig.1 (a) Fabrication process flow (b) SEM image of the Ge microbridge on Si substrate.

The PL spectra were measured here, as shown in Fig.2 (a). It can be seen very clearly that the wavelength and the PL intensity of the emission peak of the microbridge is larger than those of the pad and the unpatterned area because of the tensile strain in the microbridge. Moreover, several obvious resonant peaks were observed in the PL spectrum of the microbridge. We fit the resonant peak at 1.945 μm, and Q-factor of about 185 was obtained, as shown in Fig.2 (b). The free spectral range of the peaks is 5.6THz, we can calculate the optical path length of the FP cavity to be 26.8μm. Considering the group refractive index of Ge, the FP cavity is most likely formed along the width direction if the group refractive index of Ge is assumed to be 6.7. These resonant peaks are thus identified as FP resonance transverse to the uniaxial stress axis between the two Ge/air interfaces.

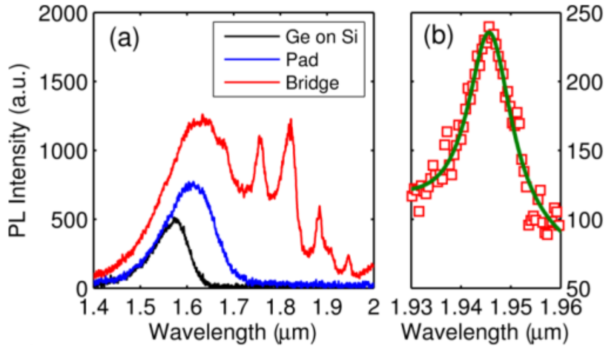
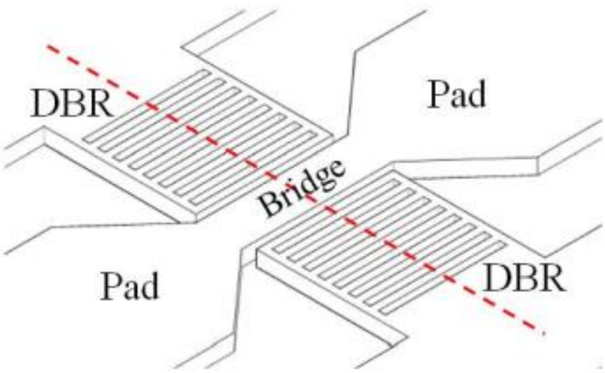
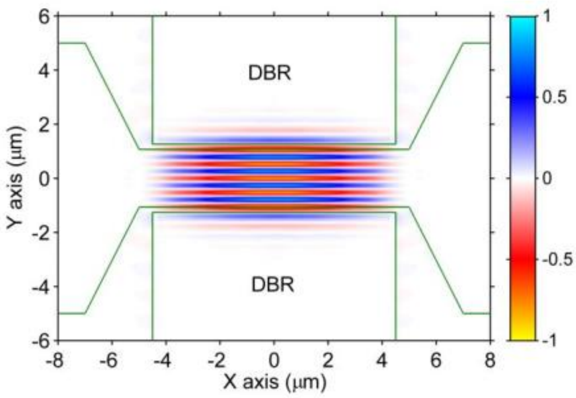


Fig.2 (a) Room-temperature PL spectra of Ge microbridge measured at bridge center, pad, and unpatterned area. (b) Zoomed view and Lorentz fitting of the resonant peak around 1.945 μm.

Although an optical resonant cavity is obtained in microbridge, the Q-factor is too low to be used in laser devices because of the low reflectivity at Ge/air interface (<37%). To increase the reflectivity, a DBR structure is used, because DBR structures can enhance the reflectivity easily [4]. The new microbridge structure with lateral DBR resonator is proposed, as shown in Fig.3. In this new structure, the DBR resonator is totally isolated from the bridge structure, so it won't affect the strain in the microbridge. The bridge length is 10μm. The normal grating period is a=400nm. The periods of the six nearest gratings to the bridge are linearly decreased with a step of da. All the grating periods keep the same duty cycle of 50%. The cavity length is set to be L_{cavity}=5a, indicating that the bridge width is 5a+a_6/2. A resonant mode with Q-factor about 1400 at the wavelength of 1.876μm is obtained by 3D finite-difference time-domain (FDTD) simulation. Moreover, the electric-field distribution is also simulated, as shown in Fig.3 (b). It can be easily seen that the light is well confined in the bridge.



(a)



(b)

Fig.3 (a) Schematic drawing of the microbridge with a DBR resonator (b) Simulation of the electric-field distribution in the device.

3.Conclusion

In this paper, a resonant light emission was observed, which were identified to correspond to FP cavity formed transversely to the uniaxial stress axis between two mirrors of Ge/air interfaces. Based on this, a microbridge with two lateral DBRs are proposed and simulated. These results indicate that the microbridge with DBR resonator is a potential structure for realizing the Ge laser on Si substrate in the future.

Acknowledgements

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