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Influence of the Si cap on electroluminescence of Ge quantum-dot diodes

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1. Introduction

The electroluminescence (EL) properties of Ge quantum-dot (QD) diodes were extensively researched in the last decade [1, 2]. These reports showed that the spectral emission peaks of Ge QD is affected by dot size, dot shape, and fold number of Ge QD, etc. Besides, the EL of Ge QD starts to decrease above 100K. In this study, the influence of Si cap on EL performance of Ge QD diodes was investigated. The integrated EL intensity of Ge QD with thick Si cap shows a different temperature-dependence from the thin Si capped diode. A blue shift of the emission energy is also observed of the thick Si capped Ge QD diode.

2. Experiments and Results

The samples in this work are p^+-p^--n^+ diodes with 10 layers of Ge QDs grown by UHVCVD system at 600℃. The deposition sequence is as follows: a 70-nm-thick p^- Si buffer layer, ten layers of Ge dots separated by 18-nm-thick Si spacer, a 28-nm-thick (sample-A) or 98-nm-thick (sample-B) Si cap, and a 100-nm-thick contact layer with boron doping of $1\times10^{19}cm^{-3}$. Fig.1 shows the schematic cross section of sample-A and -B.

Fig.2 shows the EL spectra at different measurement temperatures. The peaks located at 0.86eV and 1.08eV are attributed to Ge QDs and Si-TO, respectively [2]. Significant Si-TO signals from Si cap are observed of sample-B at low temperature. The integrated EL intensity of Ge QD and Si-TO as a function of measurement temperature is shown in Fig.3. For sample-A, the intensity of Ge QD signals decreases with increasing temperature. This can be attributed to the thermal emission of holes from Ge QDs. Only weak Si-TO signals are observed at room temperature. As for sample-B, the Ge QD signals show a slight increase with respect to temperature and then decrease above 210K. The significant Si-TO signals at low temperature of sample-B can be explained by the carriers (holes) blocked by the thick Si cap. As the increasing of temperature, more energetic holes can overcome the barrier and captured by Ge QDs, leading to the decreasing of Si-TO signals and increasing of Ge QD signals. When temperature is above 210K, the temperature-dependence of sample-B is the same as that of sample-A. The thin Si cap in sample-A provides the probabilities of carrier tunneling thus no Si-TO signals are observed at low temperature. Fig.4 represents the mechanism described above.

Fig.5 shows the peak energy of Ge QD in sampl-A and -B. The blue shift with increasing temperature has been discussed in our previous research [1]. However, a blue shift of the emission energy (~20meV) is observed of the thick Si capped diode comparing to the thin Si capped one. This may be due to more strain induced Si-Ge intermixing in the thick Si cap sample.

3. Conclusions

We have shown that the integrated EL intensity of Ge QD with thick Si cap shows a different temperature-dependence comparing to the thin Si capped diode because of carriers blocked by Si cap. The peak energy of Ge QD also shows a blue shift in the thick Si capped diode which may be due to more Si-Ge intermixing occurs.

References

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[2] L. Vescan, T. Stoica, O. Chretien, M. Goryll, E. Mateeva, and A. Muck, J. Appl. Phys. **87**, 7275 (2000).

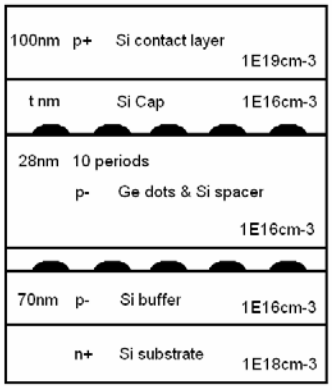


Fig. 1 Schematic cross section of $p^+/p^-/n^+$ Ge QD diodes. The thickness of Si cap (t) is 28nm for sample-A and 98nm for sample-B.

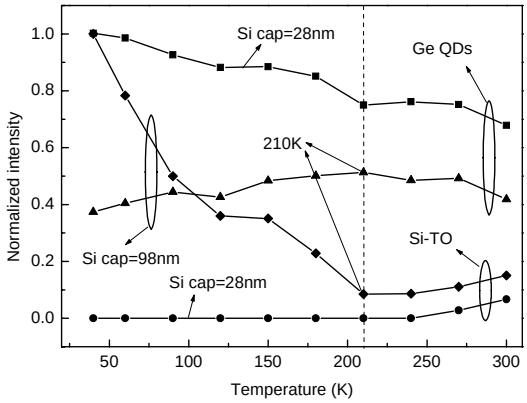
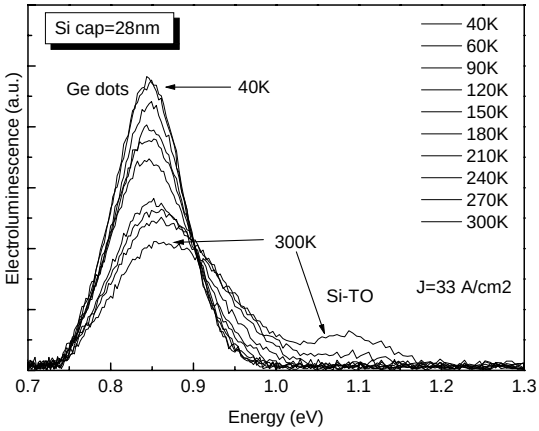
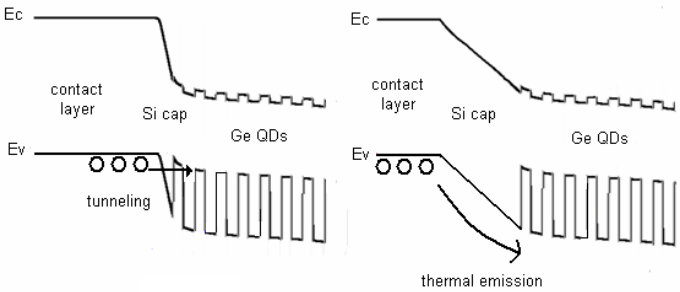


Fig. 3 Integrated EL intensity of Ge quantum dots and Si-TO of sample-A and sample-B at different measurement temperatures.

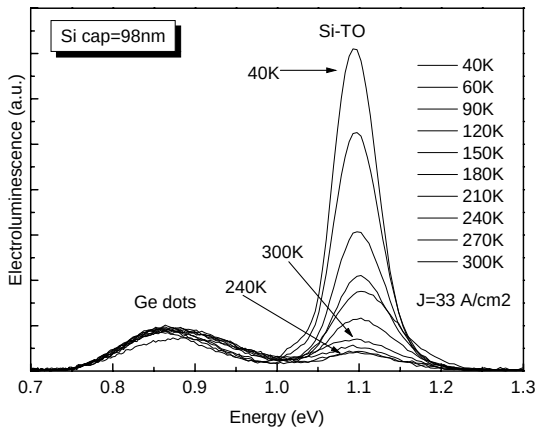


(a)



(a) (b)

Fig. 4 Behavior of carriers (holes) in (a) sample-A and (b) sample-B.



(b)

Fig. 2 Electroluminescence spectra of (a) sample-A and (b) sample-B at different measurement temperatures.

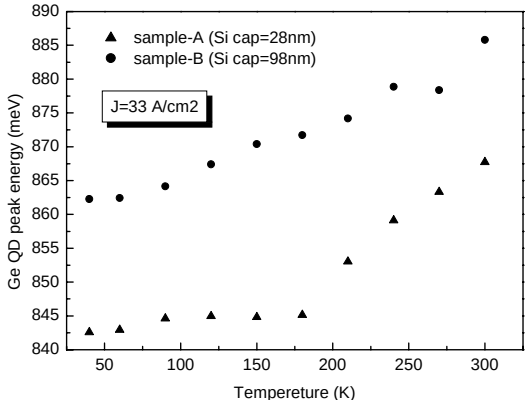


Fig. 5 Peak energy of Ge QD in sample-A and sample-B.