Abs. 1313, 206th Meeting, © 2004 The Electrochemical Society, Inc.

Nanostructures and optical properties of Ge self-assembled quantum dots with hot wall UHV/CVD

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Research on self-assembled Ge quantum dots (SAQD) by Stranski-Krastanow growth mode has become attractive for their unique optical and electrical properties. There are several methods for preparing Ge SAQDs on Si substrates. In previous work, we have demonstrated that multiple Si/Ge QDs layers with superior quality and optical properties by using hot-wall UHV/CVD[1-2]. In this article, the nanostructures and optical properties of single layer of SAQDs are reported. The dependence of QDs morphology on growth temperature was observed in our UHV/CVD system. The size of Ge QDs and intermixing effect between Ge QDs and Si influence their confined energy level. Ge QDs with high uniformity in size can be achieved at the growth temperature of 600°C. With growth interrupt of one hour before Ge deposition, the uniformity, size and density of QDs can be improved.

In this work, Ge QDs were grown on Si (100) at 550, 575 and 600 °C in a hot-wall UHV/CVD. Pure SiH_4 and 5 %GeH_4 diluted in He were used as precursors. Figure 1(a) shows the AFM image of 6.8 eq-ML hut-shape Ge QDs with a high density grown at 550 °C. However, the facet planes are higher than {105}. With increasing Ge deposition, the dome-shape QDs become dominant as shown in Fig 1(b). After Si capping, the PL peak of 6.8 eq-ML QDs was located at 0.85 eV (Fig. 2). Our results also indicate the dependence of Ge nanostructures on the growth rates. Table I summarizes the 12 eq-ML Ge QDs with its morphology and density at different growth temperature. This result demonstrates that Ge QDs with high uniformity in size can be achieved at 600 °C. Microstructures, AFM image and PL spectrum are shown in Fig. 3. The shift of PL peak from 0.85 at 550 °C to 0.8 eV at 600 °C indicates a larger size of Ge QDs and/or more intermixing of Si/Ge QDs at higher temperature.

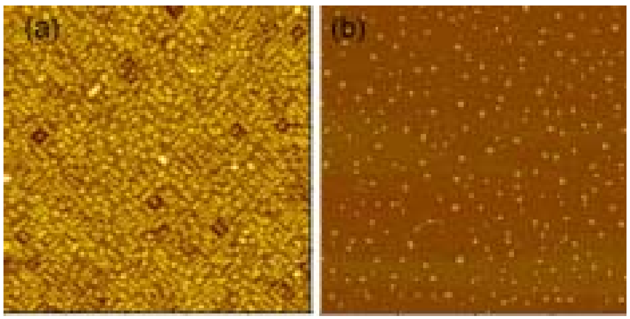

Fig. 1 AFM images of (a) 6.8 eq-ML QDs (1×1 um^2) and (b) 24.1 eq-ML (10×10 um^2) Ge QDs grown at 550 °C.

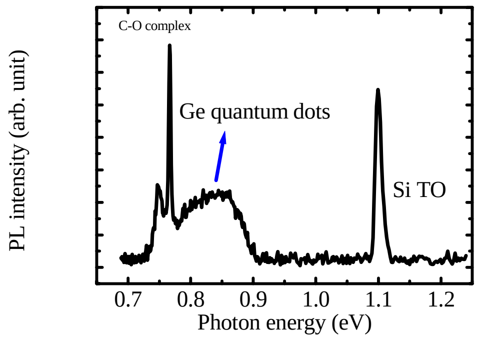

Fig. 2 The PL spectrum of 8.3 eq-ML Ge QDs with a Si capping grown at 550 °C

Fig. 4 depicts the dependence of size and density of Ge QDs on the Ge deposition at 600 °C. With a 12 eq-ML Ge deposition, high density and small size of QDs can be achieved. With growth interrupt of one hour, Ge QDs with the larger size are observed, however its density improves by 45 %. The optimum parameters for the Ge QDs growth using hot-wall UHV/CVD are discussed in this articles.

Table 1 Summary of 12 eq-ML Ge QDs with its morphology and density grown at 550, 575 and 600 °C

	550 °C	575 °C	600 °C
Hut density ($\times10^{10}$)	6.2	1.1	0
Pyramid ($\times10^{10}$)	0.14	0.58	0.13
Dome like ($\times10^{10}$)	0.07	0.014	0.97

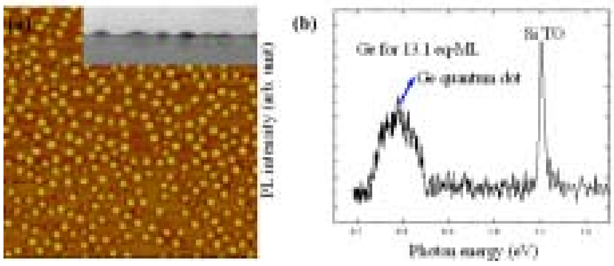

Fig. 3 (a) AFM scan image of 13.1 eq-ML Ge QDs grown at 600 °C (the inset is XTEM image) (b) The PL spectrum of 13.1 eq-ML Ge QDs with a Si capping layer.

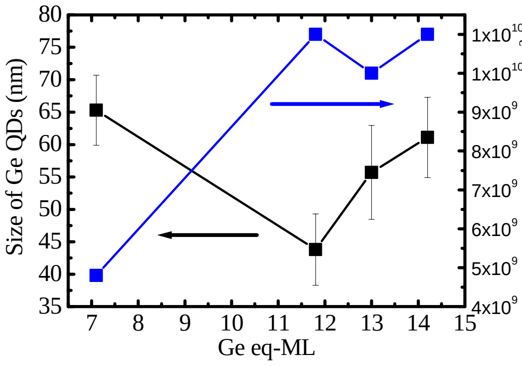

Fig. 4 Dependence of size and density of Ge QDs on the Ge deposition at 600 °C.

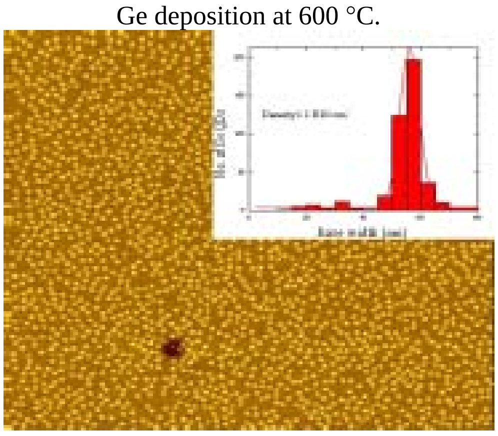

Fig. 5 AFM scan image of 13.1 eq-ML Ge QDs (5×5 um^2) with growth interrupt of one hour grown at 600 °C (The insert is the histrogram of size distribution of Ge QDs).

Reference:

[1] Wen-Hao Chang, An-Tai Chou, Wen-Yen Chen, Hsiang-Szu Chang, Tzu-Min Hsu, Zingway Pei, Pang-Shiu Chen, S. W. Lee, Li-Shyue Lai, S. C. Lu and M. –J. Tsai, Appl. Phys. Lett, **83** 2958 (2003).

[2] Wen-Hao Chang, Wen-Yen Chen, An-Tai Chou, and Tzu-Min Hsu, Pang Shiu Chen, Zingway Pei and Li-Shyue Lai, J. Appl. Phys. 93 4999 (2003).