Poster

OPTIMIZATION OF THE LUMINESCENCE EMISSION IN NANOCRYSTALLINE SIGE/SIO_2 MULTILAYERS

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The formation of a high density of SiGe nanocrystals with uniform size, less than 5 nm, embedded in a dielectric medium has potential applications in the fabrication of electronic and optoelectronic devices which can be integrated with the Si-based electronics [1]. A weak luminescence emission in structures with nanocrystals embedded in SiO_2 fabricated by LPCVD and annealing was reported previously [2]. This work is focused on the influence of the dimensions and the annealing conditions on the intensity of the luminescence with the aim of its maximization. The samples deposition was carried out in a commercial LPCVD reactor at 390 ºC. SiGe nanoparticles with a Ge fraction around 0.3 were deposited using Si_2H_6 and GeH_4. SiO_2 was deposited using Si_2H_6 and O_2. The deposition process is described elsewhere in detail [3]. Multilayer structures with five periods of SiGe/SiO_2 were deposited to increase the area density of nanoparticles. Four samples were fabricated with two diameters of nanoparticles (d) and two thickness of the SiO_2 interlayers (l), which are labelled A ($d \approx 5$ nm, $l \approx 20$ nm), B (5 nm, 50 nm), C (3 nm, 20 nm) and D (3 nm, 50 nm). The crystallization of the nanoparticles was achieved by subsequent annealing of the samples in N_2 atmosphere at temperatures between 700 and 1000 ºC for times up to 120 s using a RTA unit. SiO_2 films were also deposited and annealed in the same conditions for comparison. Figure 1 shows cross-section TEM images of samples B and C. Stacks of five layers of SiGe nanoparticles separated by SiO_2 interlayers can be observed. An estimation of the average number of nanoparticles per cm^2 is 1.2×10^{12} in each layer. Figure 2 shows Raman spectra of samples A and C (different nanoparticle size). In sample A (and B), with large nanoparticles, the intensities of the three Raman bands of crystalline SiGe increase with the temperature and annealing time. No further crystallization is detected above 900 ºC for 60 s. In sample C (and D), with small nanoparticles, the Raman bands slightly increase their intensity and are narrowed as the annealing temperature increases, indicating that crystallization is taking place. The crystallization does not progress if the annealing is prolonged at a fixed temperature. As the size of the nanoparticles decreases, the annealing temperature must be increased to crystallize them. Figure 3 shows RBS spectra of samples A and B (different oxide thickness). Annealing at a temperature of 800 ºC or lower does not cause diffusion of Ge in any case. In sample A (and C), with thin oxide interlayers, annealing at 900 ºC causes diffusion of Ge that results in the degradation of the structure of the sample. In sample B (and D), with thick oxide interlayers, a slight Ge diffusion also occurs at 900 ºC but the structure of the sample is not strongly affected. Annealing at temperatures higher than 900 ºC causes the loss of integrity of the structure in all cases. Figure 4 shows cathodoluminescence spectra of sample D. The spectrum exhibits similar features in all four samples. A strong increase of the intensity of the main emission band at 400 nm (3.16 eV) takes place as the crystallization proceeds. This band is associated to the presence of the SiGe nanocrystals, since it is not present in the spectra of either the as-deposited sample or the annealed oxide. Figure 5 shows the intensity of the luminescence at 400 nm in the four samples after annealing in different conditions. The intensity increases as the nanoparticle size decreases and as the SiO_2 thickness increases. A very intense luminescence is measured in sample D, with small SiGe nanoparticles and thick oxide barriers, annealed at 900 ºC for 60 s. These conditions represent a good compromise between the appropriate crystallization of the small nanoparticles and the limited degradation of the structure by Ge diffusion due to the thick SiO_2 interlayers.

References:

[1] S. H. Huang *et al.*, Nanotechnology **14** (2003) 25.
[2] M. I. Ortiz *et al.*, Nanotechnology **16** (2005) S197.
[3] M. I. Ortiz *et al.*, Physica Status Solidi (a) **203** (2006) 1284.

Figures:

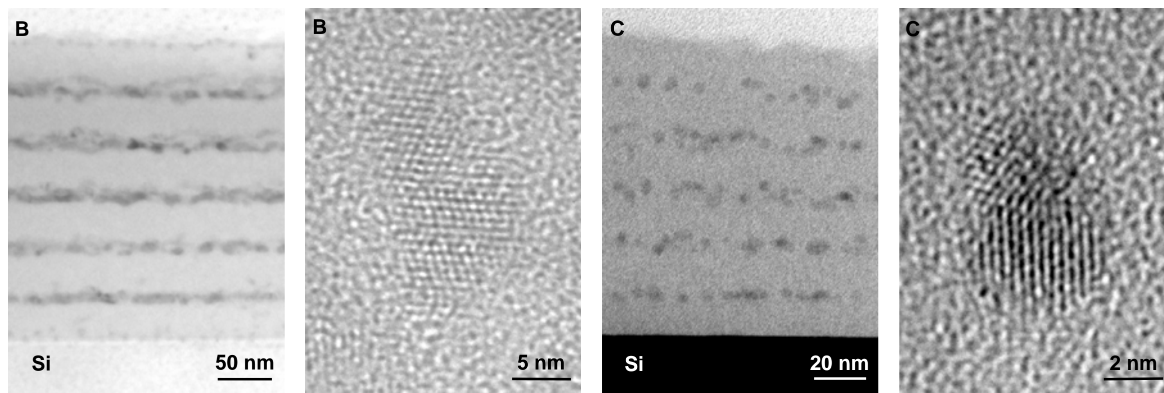

Figure 1. Cross-sectional TEM images of samples B and C annealed by RTA at 900 ºC for 60 s showing the SiGe (dark) / SiO_2 (bright) multilayers. The SiGe nanocrystals are visible in the high resolution images.

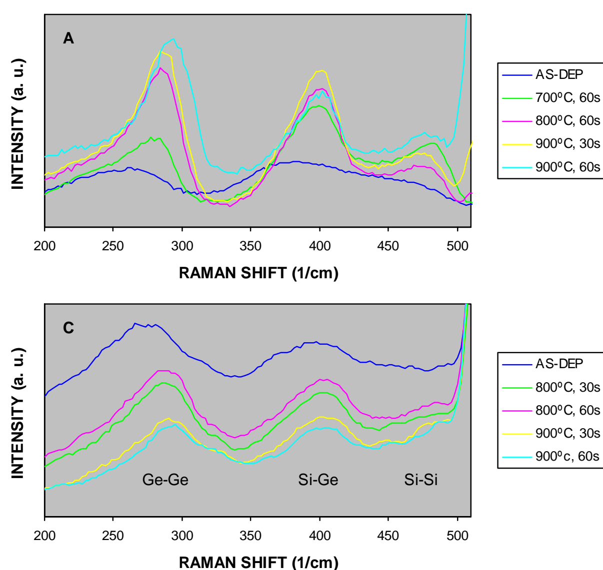

Figure 2. Raman spectra of samples A and C (different nanoparticle size).

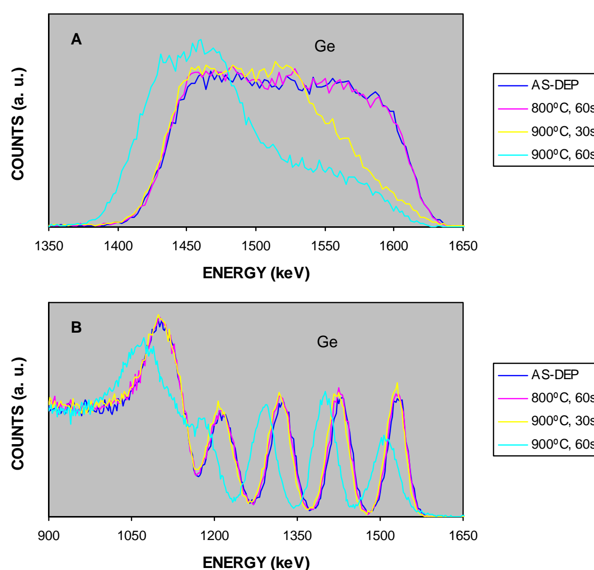

Figure 3. Ge signal of the RBS spectra of samples A and B (different oxide thickness).

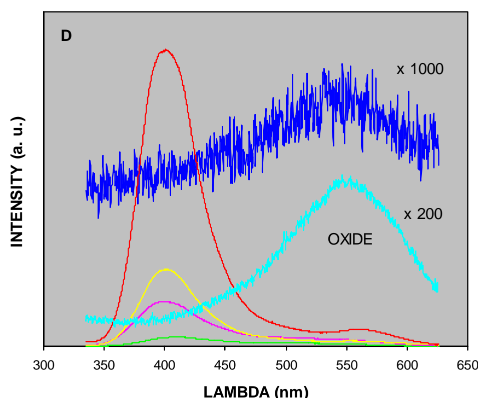

Figure 4. Luminescence spectra of sample D and spectrum of the annealed oxide.

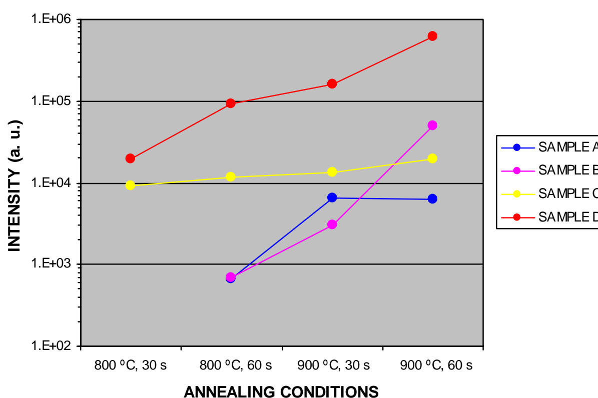

Figure 5. Intensity of the luminescence emission at 400 nm measured in samples A, B, C and D.