Poster

LUMINESCENCENT NANOSTRUCTURES BASED ON SiGe NANOPARTICLES EMBEDDED IN AN OXIDE MATRIX

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The formation of a high density of nanocrystals with uniform size, less than 5 nm, embedded in a dielectric medium is an essential process for the fabrication of electronic and optoelectronic devices which can be easily integrated with the Si-based electronic circuits [1]. In this work, SiGe nanoparticles in an oxide matrix have been obtained by (a) steam thermal oxidation of polycrystalline SiGe layers and (b) by direct deposition by LPCVD of SiGe/SiO_2 multilayers with discontinuous SiGe films. Both approaches are compared in terms of the composition and size of the nanoparticles and the luminescence properties of the structures.

(a) The first process was carried out using 35 nm thick SiGe layers with Ge fraction $x = 0.3$ deposited on thermally oxidized Si substrates using a hot wall LPCVD system and subsequently crystallized by thermal annealing. The polycrystalline SiGe layers were oxidized in steam atmosphere at 650 ºC for several times up to 90 min, which exceeds the time necessary for full oxidation of the SiGe films. The oxidation process was analyzed by FTIR spectroscopy, showing that Ge and Si atoms are oxidized simultaneously and that the grown oxide is a mixture of silicon and germanium oxides. A cross-sectional TEM image of a partially oxidized sample is shown in figure 1-a, where a top layer of amorphous oxide and a remaining polycrystalline SiGe layer are observed. After oxidation for 80 minutes, the SiGe layer is fully oxidized, see figure 1-b. SiGe nanocrystals embedded in the amorphous oxide are present. EDX spectra indicate that these nanoparticles are Ge-rich, compared to the as-deposited SiGe layer composition. Cathodoluminescence spectra, measured at room temperature, of samples oxidized for different times are shown in figure 2. A strong increase of the intensity of the main emission band at 3.1 eV takes place as the oxidation proceeds, which is associated to the presence of Ge-rich nanoparticles [2].

(b) The second method consists of the direct deposition by LPCVD of a SiGe/SiO_2 multilayer structure, where the SiGe layers are discontinuous to give rise to nanoparticles. The temperature was fixed at 390 ºC throughout the process. SiGe was deposited using a Si_2H_6 flow of 5.5 sccm, a GeH_4 flow of 4.5 sccm. The deposition time was just above the incubation time for SiGe deposition on SiO_2 in this system, which is estimated to be around 20 minutes, to ensure that the SiGe layers are discontinuous. SiO_2 was deposited during 15 minutes using a Si_2H_6/O_2 flow ratio of 0.2. Figure 3-a shows a cross-section TEM image of an as-deposited sample. The oxide appears in the image with bright contrast. A distribution of SiGe agglomerates with a Ge fraction measured by EDX of $x = 0.3$ and a diameter of around 3 nm can be observed. Annealing the sample at 725 ºC for 72 hours induced the formation of nanocrystals embedded in the amorphous oxide, see figure 3-b. Figure 4 shows the cathodoluminescence spectra of the as-deposited and annealed samples. The as-deposited sample presents a broad spectrum with subbands at 2.7 eV and 1.9 eV, being the first one the dominant emission. The spectrum of the crystallized layer is broadened and the intensity of the 2.7 eV band is decreased. This 2.7 eV band has been related to bulk SiO_2, in particular to oxygen deficient centers [3]. This is consistent with the dominant presence of this band in the as-deposited layer, since the quenching of these centers during the crystallization process could take place. No emission associated to the presence of nanoparticles is found.

From the point of view of the application of these structures in the fabrication of luminescent devices, the first approach seems to be the more appropriate one, since the emission is intense and with a narrow spectrum. However, the second approach is much more attractive from the technological point of view, since the structure can be fabricated in a single run process at low temperature. These structures are currently being improved in order to get light emission due to the nanoparticles.

References:

[1] G. Taraschi *et al.*, J. Appl. Phys., 93 (2003) 9988.
[2] T. V. Torchynska *et al.*, Microelectronics Journal 34 (2003) 541.
[3] A. N. Trukhin *et al.*, J. Non Cryst. Solids, 331 (2003) 91.

Figures:

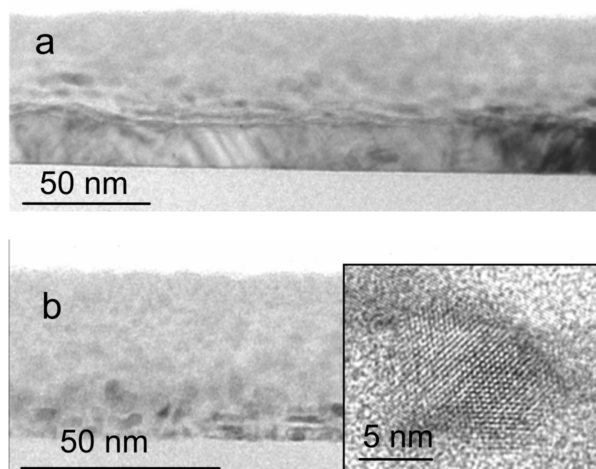

Figure 1. Cross-sectional bright field images of samples oxidized in steam at 650 ºC. (a) Partially oxidized, 30 min. (b) Fully oxidized, 80 min. A detail of a nanoparticle is shown.

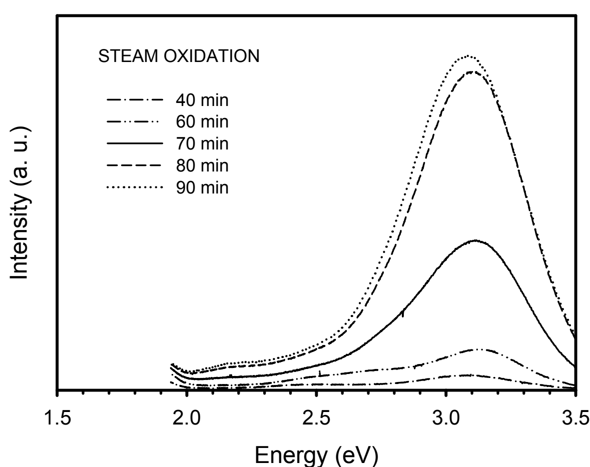

Figure 2. CL spectra of SiGe samples oxidized in steam atmosphere at 650 ºC for several times.

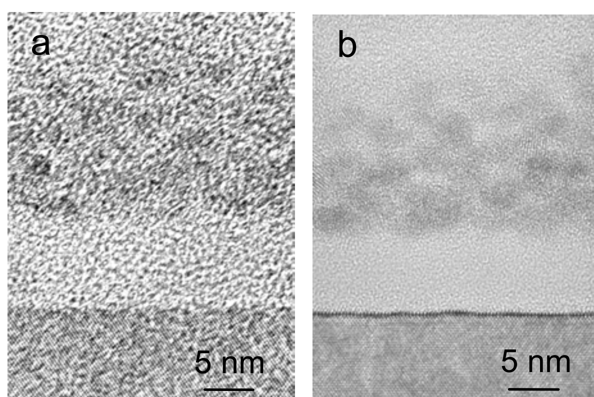

Figure 3. Cross-sectional bright field images of SiGe nanoparticles embedded in SiO_2. a) Sample directly deposited by LPCVD on top of a 20 nm SiO_2 buffer layer. b) The same sample after SiGe crystallization.

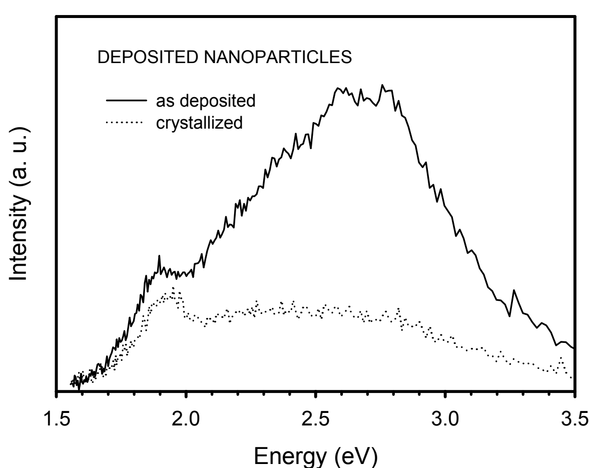

Figure 4 CL spectra of the $SiGe/SiO_2$ structures shown in figure 3. a) As-deposited. b) Crystallized.