Luminescence of Silicon Nanocrystals

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Miniaturization of features in microelectronic devices has proceeded exponentially for several decades [1], yet is expected soon to be limited by technological challenges as well as intrinsic physical limitations. A possible solution to such problems is to replace electrical signals with photons transported through optical interconnections.

Silicon is group IV semiconductor known to be with indirect bandgap. Despite the large variety of devices based on Silicon, it is not a suitable material for a light emission source. In fact, if excitons are created, their recombination occurs on non-radiative sites. Since the discovery of photoluminescence of nanostructured silicon in 1990 [2], a lot of effort has been employed to develop an efficient source of light and to understand the mechanisms of electro- and photo-luminescence.

Nanostructured Silicon could be obtained by few different techniques Plasma Enhanced Chemical Vapor Deposition [3], Pulsed Laser Deposition [4], ion implantation [5], etc. For industrial applications a rigid and chemically stable system has to be made. Therefore, the best configuration is Silicon nanocrystals (Si-nc) embedded in silicon dioxide (SiO_2).

In this work we present our results on photo- (PL) and electro-luminescence (EL) of Si-nc embedded in SiO_2. Ion implantation has been used to create an excess of Silicon in SiO_2 layer thermally grown on silicon wafer. The technique permits to control the depth of distribution of the emitting centers, the excess of Silicon thus giving control to the size of the formed crystals. The later is directly related to the emitted wave length. Double implantation at two different energies with similar fluences has been employed to obtain relatively uniform distribution and density of the silicon ions through the thickness of the SiO_2 layer. The fluences have been chosen to form a layer of Si-nc with high density to increase the number of the emitting center. The mean size has been evaluated to be of ~ 3nm [7]. Thermal annealing in 95% Nitrogen + 5% Hydrogen has been made to give sufficient thermal energy to the ions to diffuse in the matrix and form the nanocrystals. The best results for electroluminescence have been obtained for electrical devices with top golden semitransparent contact and bottom silver contact.

EL measurements, shown in Figure 1, have been taken at a single luminescent spot (see Figure 2). Three peaks are present. The first peak, at 647 nm, is attributed mainly to non-bringing oxygen hole center (NBOHC) defects in the oxide [8]; the second and third peaks, at 804 nm and 879 nm, are attributed to the presence of the Si-nc, as the peaks positions coincide with the PL peak situated in the range ~ 750–950 nm, and for these peaks the intensity increases with the applied voltage. In samples without Si-nc, no peaks with these positions have been observed [9].

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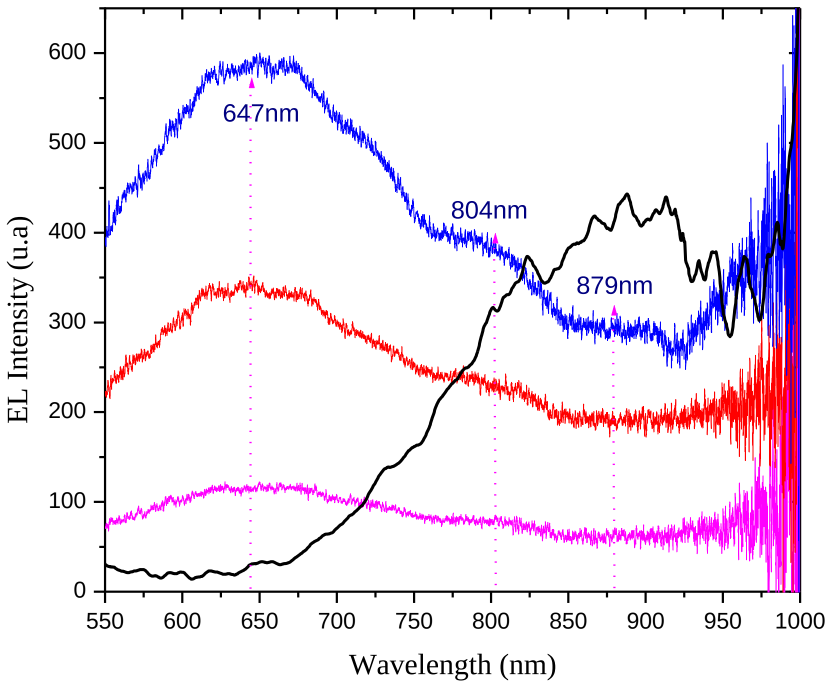

Figure 1. Micro-EL and PL spectra for Si-nc. Blue line: EL at 17V; Red line: EL at 14V; Pink line: EL at 10V; Black line: normalised PL [6].

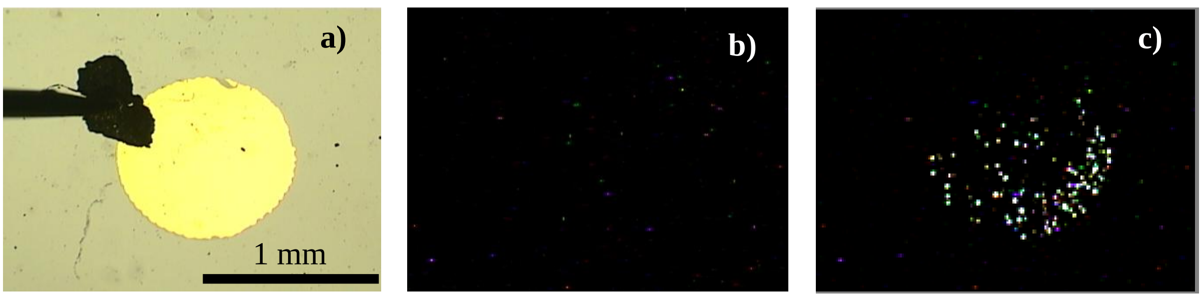

Figure 2. EL points under reverse voltage : (a) image of the electrode; (b) reference at 0V; (c) EL at -18V, -2.7 A/cm^2