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Light-emitting nanocomposite films on the base of silicon nitride and silicon oxynitride layers

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Abstract. The silicon nanostructures on the base of SiN_x and SiN_xO_y with room temperature luminescence in visible part of spectrum were obtained. The regimes of deposition and annealing allowed adjusting excess of Si and structure of layers and essentially influenced on their electrical, optical and luminescent properties. The mechanisms of photo and electroluminescence and paths of the Si light source realization are discussed.

The creation of silicon efficient sources of visible light compatible with modern silicon technology has a science and practical significance in connection with perspective of their using for optical interconnection in Very Large Scale Integration (VLSI) and other applications [1–3]. Therefore the search for new Si-based material with room temperature luminescence in visible part of a spectrum is very actual. In this work it was obtained and investigated the luminescent Si nanostructure on the base of thin SiN_x and SiN_xO_y layers. The layers were deposited on different substrates by ion-plasma sputtering of Si target by Ar ions in controlled atmosphere of N_2 and O_2 gases. The regimes of deposition and annealing allowed adjusting excess of Si and essentially influenced on the structure of layers and their electrical, optical and luminescent properties. The layer structure was investigated by TEM and AFM. It was found that layers contain Si nanocrystals with average size about 2–20 nm in dependence of Si excess and the preparation conditions.

The layer with low Si excess show the visible photoluminescence (PL) in wide spectral region ($\lambda = 400-800$ nm). The vacuum annealing ($T = 1100°C, t = 10$ min.) of samples results in sharp increasing of PL especially in PL peak region ($\lambda = 500-600$ nm). The optical properties of layers (transmission and reflection) do not change essentially. In Fig. 1 and Fig. 2 shown the spectra of PL and transmission before and after vacuum annealing.

The electroluminescence (EL) was investigated on cSi-SiN_x-Au structures. The light was observed trough the semi-transparent Au top contact. The conductivity of layers with low Si content was very low before annealing. The annealing activated the carrier injection and conductivity and visible EL appeared at forward polarity of voltage-current characteristic. The quantum efficiency in such layers was not more than 10^{-6}. We associate the PL and EL mechanisms and peculiarity of optical properties of layers with low Si excess with formation in such layers Si nanocrystals with size quantum spectrum. The short time annealing improves the layer structure, passivate the nanocrystal-matrix interface and suppress the non-radiating recombination in such layers.

The different results were obtained on the layers with high Si excess. In such layers was observed the essential decreasing of PL intensity up to PL disappearance and drastic increasing of EL intensity at reverse polarity of voltage-current characteristic (at negative polarity on cSi substrate in pSi-SiN_x-Au structure). The typical EL spectrum for such structure shown in Fig. 3. The quantum efficiency in such layers was reached 10^{-4}. The substrate heating ($T = 200-300°C$) during the layer deposition result to increasing of EL efficiency.

The vacuum annealing influenced noticeably on optical properties, in particular increased the transmission on the whole spectrum, and decreased the EL efficiency. The observed effects are due to significant modifications of a layer structures with increasing of Si excess. The TEM and microdifraction patterns shown that the main part of Si excess are exist as large (10 and more nm) amorphous and crystalline clusters and also in state of supersaturated solid solution in matrices. The annealing results in dissociation of solid solution and partly Si crystallization. We connect the PL suppress with imperfection of layer structure, worsening of condition of quantum confinement in nanocrystals and increasing

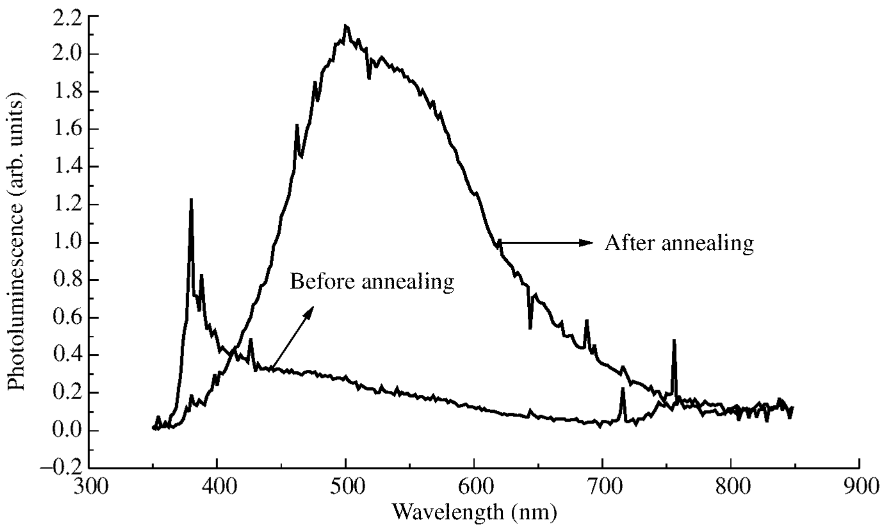

Fig. 1. The photoluminescence spectra before and after vacuum annealing.

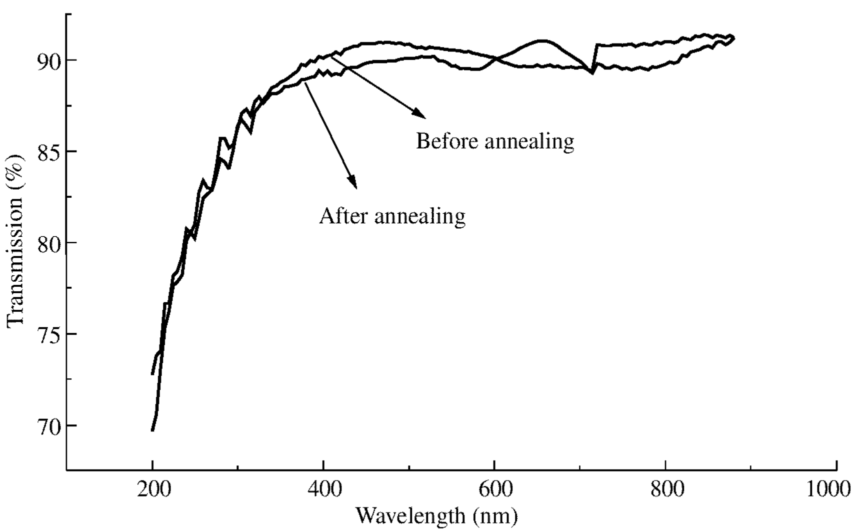

Fig. 2. Spectra of the optical transmission before and after vacuum annealing.

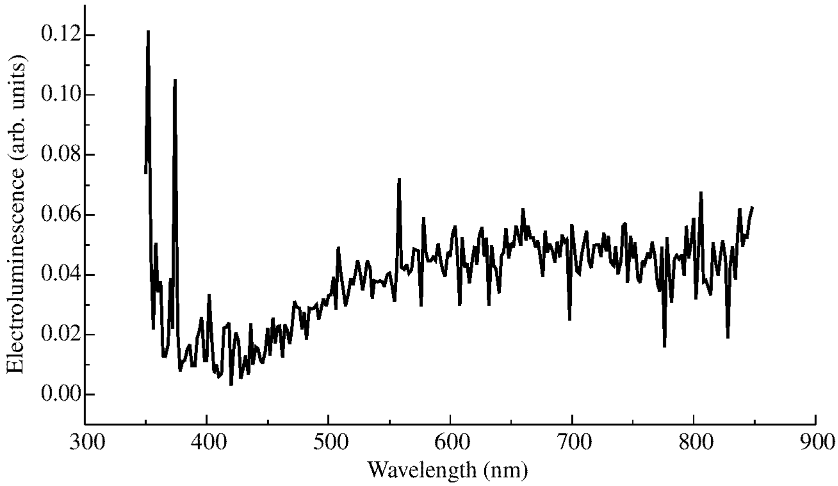

Fig. 3. Spectrum of the electroluminescence.

of the non-radiating recombination. The increasing of EL can be connected with sharp rise of carriers injection and conductivity in such layers, appearance of regions with high local electrical field, avalanche ionization and microplasma formation. The paths of increasing PL and EL quantum efficiency and perspectives of realization Si LED are discussed.

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