Visible-range photocurrent of silicon nanocrystals in a MOS structure

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Since the discovery of the visible luminescence of porous silicon [1], there is a great interest to fabricate optoelectronic silicon devices. Thanks to the quantum confinement, silicon nanostructures can exhibit high conversion efficiency compared with bulk Si [2, 3]. Some techniques have been developed to obtain silicon nanostructures as silicon nanocrystals (Si-ncs), synthesized by ion implantation [4], by precipitation in non-stoechiometric oxide [5, 6] or by chemical-vapour deposition (CVD) [7]. The introduction of silicon nanocrystals as a floating gate in a metal-oxide-semiconductor (MOS) device allows to obtain charging effects and efficient memory properties, widely studied since several years. Recent studies have shown the possibility of using silicon nanocrystals in MOS or MIS (metal-insulator-semiconductor) structures for photodetection [8, 9] and photovoltaics [10]. These structures are attractive because of low bias needed compared with conventional photomultiplier tubes and avalanches photodiodes.

In this work, we report spectral photocurrent of a MOS structure with silicon nanocrystals. It is fabricated as following. A 10 nm non-stoechiometric oxide layer SiO_x is deposited by low-pressure-chemical-vapour deposition (LPCVD). After deposition, a first annealing step in nitrogen was performed at 1000 °C for 3.5 min in order to induce the separation between the Si and the SiO_2 phases and the formation of Si nanocrystals. A second annealing step in oxygen atmosphere at 1000 °C for 5 min was performed to slightly shrink the size of clusters and repair eventual defects in the oxide layer, like oxygen vacancies. Finally a 50 nm n^+ polysilicon was deposited by LPCVD. Transmission electron microscopy analysis shows that Si-ncs are 5 nm from the substrate/SiO_x interface, and their size varies from 2 to 5 nm. The SiO_x layer is about 18 nm thick, i.e. above the targeted, due to the oxidizing annealing step. An semi-transparent contact of 100 × 100 μm^2 was formed on the top of the polysilicon and was used as an hard mask for etching polysilicon, SiO_x and substrate by reactive ion etching (RIE).

Photocurrent spectra display different behaviours at forward and reverse biases. At the forward biases, the photocurrent is weak. However, at the reverse biases, a peak appears at 1.9 eV (650 nm). We believe that this peak corresponds to the band gap of Si-ncs, since photoluminescence study of Si-ncs also reported similar results. This work will present photocurrent results of these devices and also a detail analysis.

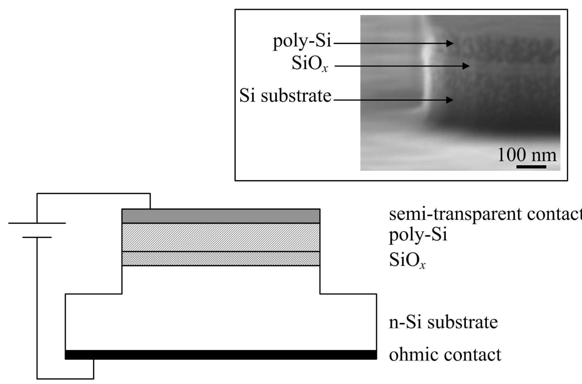

Fig. 1 Schematic illustrating the studied structures. The inset shows a SEM micrograph of a structure after plasma etch.

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