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Blue-cathodoluminescent layers synthesis by high-dose N^+, C^+ and B^+ SiO_2 implantation

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Abstract

Thermal silicon oxide layers have been implanted at 600 °C with $N^+ + C^+$, $N^+ + B^+$ and $N^+ + C^+ + B^+$ ions. Two different implantation doses have been chosen in order to introduce peak concentrations at the projected range comparable to the SiO_2 density. Some pieces of the samples have been annealed in conventional furnace at 1200 °C for 3 h. After annealing, cathodoluminescence measurements show in all cases a main broad band centered at 460 nm (2.7 eV). High doses of C implantation give rise to an intensity attenuation. Phases formed in the oxides have been investigated by Fourier transform infrared spectroscopy before and after annealing. The spectra suggest that N incorporates as BN and probably as a ternary BCN phase in the triply implanted samples, while C seems to bond mainly with B. Boron is also bonded to O in B–O–Si configuration. Depth structure and quantitative composition of the films were deduced from fittings of the spectroscopic ellipsometry measurements.

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Keywords: Ion implantation; Silicon oxide; BCN; Luminescence

1. Introduction

The efforts to obtain visible luminescent Si-based structures for optoelectronic applications have led to several fields of research, among them are porous Si [1], a variety of deposition techniques, and ion implantation in SiO_2 and subsequent thermal annealing to aggregate small clusters of the implanted elements inside the oxide matrix. The good stability of the SiO_2 matrix and well-controlled Si oxidation process, besides the compatibility of the implantation process with the microelectronics technology, have revealed ion

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implantation as one of the most promising approaches for achieving luminescent devices compatible with Si technology. A limited number of elements, like Si^+, Sn^+, C^+ or Ge^+, have been considered up to now for the implant process [2]; however, a wide spectrum of candidates can be investigated for this aim, in order to tailor the composition and the structural properties of the SiO_2 matrix in the desired way. In this work, we have implanted high doses of N^+, C^+ and/or B^+ combined in such a way that one produced doublly and triply implanted samples. An added advantage of these implants is that they can also improve the mechanical properties of the SiO_2 films, according to the attractive properties of BCN compounds in hard coating applications [3], and those predicted for CN [4].

2. Experimental

Thermal silicon oxide, about 1900 Å thick was grown on both sides of polished silicon wafers at 1200 °C in a conventional furnace. Samples were subjected to double and/or triple implantations in a modified extrion system: $N^+ + C^+$, $N^+ + B^+$ and $N^+ + C^+ + B^+$ ions. N^+, C^+ and B^+ implantation energies were 27, 23 and 19 KeV, respectively, in order to achieve a projected range of 750 Å. An as-oxidized wafer was preserved for reference. Doses were chosen to get peak concentrations of the implanted species of 10% of the SiO_2 density in a first series of samples, and 50% in a second one ($D_1 = 4.7 \times 10^{16}$ and $D_2 = 2.35 \times 10^{17}$ at/cm^2, as obtained from SRIM simulations [5]), henceforth referred to as low-dose and high-dose implanted samples. All the implantations were carried out at 600 °C. Afterwards, wafers were cleaved and one piece of each sample was furnace annealed at 1200 °C for 3 h under nitrogen flow.

Cathodoluminescence (CL) measurements were performed in a JEOL 820 SEM (scanning electron microscope) with a GATAN mono CL 2 system. The excitation was carried out with acceleration voltages ranging from 5 to 10 KV and beam currents from 5 to 40 nA.

A Bruker IFS-66v spectrometer was used for Fourier transform infrared (FTIR) analysis of the samples using resolution of 6 cm^{-1}. Spectroscopic ellipsometry (SE) measurements were acquired between 1.5 and 4.5 eV by an Uvisel model Jobin Yvon spectrometer.

3. Results and discussion

The CL spectra measured on annealed samples show three main features: a broad and intense band centered at 460 nm (2.7 eV), and two other weaker structures at 360 nm (3.45 eV) and 580 nm (2.1 eV). The main band at 2.7 eV is similar for the three implantations, though its intensity shows strong variations from each other after annealing. The highest intensities are obtained for B + N implanted samples while the lowest ones are achieved for N + C and N + C + B implanted samples. The band at 3.45 eV is observed in BN samples. Finally, the band at 2.1 eV appears as a shoulder in the low-energy tail of the 2.7 eV band for all the samples. In Fig. 1, representative spectra of the high-dose implanted and annealed samples are shown. We will focus our discussion on 2.7 and 3.45 eV bands. The band at 2.7 eV is observed for the three implants, which suggests that it is not related to any of the implants. This band has been reported in oxygen deficient silica [6] and in Si^+ implanted SiO_2 [1]. It is associated with transitions

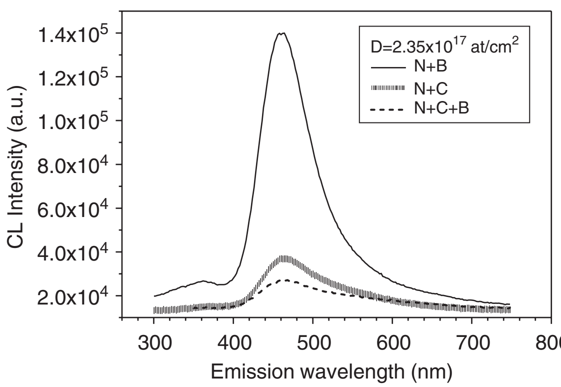

Fig. 1. CL spectra of samples implanted with 2.35×10^{17} at/cm^2 after annealing, with $V = 10$ KV and $I = 5$ nA.