Compound clusters in silicon dioxide obtained by N⁺, C⁺ and B⁺ high-dose ion implantation: nature of the blue cathodoluminescence emission and relationship with the embedded phases

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Abstract: SiOₓ films on Si substrates have been implanted at 800°C by N⁺[C⁺. N⁺[B⁺ and N⁺[C⁺[B⁺] ions at two different doses, and subsequently thermal annealed. Cathodoluminescence measurements of the samples have shown three bands at 3.45, 2.7, and 2.1 eV. The 2.7 eV band, observed in all the samples and more intensely in N⁺-annealed samples, is due to oxygen deficiency centers, while the 3.45 eV one, only present in N⁺ and N⁺[C⁺[B⁺] samples, seems to be related to BN or B associated centers. Insetra spectra of the implanted films showed Si-O-B and N-O bonds in samples containing B, as well as a contribution about 1200 cm⁻¹ assigned to a ternary compound in the N⁺[C⁺[B⁺] implant. No modes different than those of Si-O bond have been found in samples without B.

Experiments:

- Substrates: 1000A thick thermal silicon oxide grown on (100) n-type Si wafers, at 1300°C in pure O₂ flow
- Energies: 15, 25 and 35 keV, respectively
- Doses: 3.7x10¹⁶ cm⁻² (low dose samples)
- Process temp.: 1300°C
- Annealing: 1000°C, 3 hours, in pure N₂ flow

Cathodoluminescence (CL):

- Performed in a JEOL 8600-LMU with a QM11 monochromator.
- The spectra was acquired with acceleration voltages ranging from 5 to 10 kV and beam currents from 5 to 40 nA.

N⁺ shows in all cases a main band centered at 480 nm (2.7 eV), thus related to the nature of the impurity or the phases formed during the implantation process. A similar band has been associated with transitions from the lowest triplet state to the singlet state in oxygen deficient centers (ODCAs).

- In low dose implantation, intensity of this band is higher for annealed N⁺ implanted samples.
- High dose implantation, intensity of this band is similar for the different samples, as can be observed in N⁺ and N⁺[C⁺[B⁺] samples.

Two other contributions can be observed in the spectra:

- A shoulder at 550 nm (2.1 eV), whose origin is not clear.
- A peak at 2.45 eV, a common feature to all the samples for the decrease of the Si-O-Si main band, placed at 1080 cm⁻¹, as a consequence of silicon-oxygen bond breaking.

Conclusions:

- SiOₓ, N⁺ and N⁺[C⁺[B⁺ implanted SiOₓ layers show three main luminescence features:
  - A main emission band at 480 nm associated to oxygen deficiency centers caused by the breaking of Si-O-Si bonds during the implant process.
  - A second contribution at 370 nm that has been mostly observed in N⁺ implanted samples and has been related to oxygen-canters emission.
  - Presence of Si O₃: bands at 480 nm, which origin is unknown.

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