

Silicon Light Emitter Fabrication and Characterization

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Silicon Light Emitter Fabrication

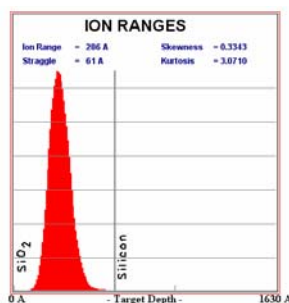
The fabrication of a silicon light emitter has been undertaken with the use of Erbium ion-implantation into silicon dioxide and silicon-rich-oxide (SRO) films. This research was motivated by the recent announcement from ST Microelectronics regarding efficient light emission from Erbium-doped silicon oxide films.¹ Our initial studies have been performed with gate oxides of 630Å with Erbium Ion-Implantation of $1E15 \text{ cm}^{-2}$ at 50 KeV to place the peak of the ion distribution near the center of the oxide film. This distribution was verified with SIMS analysis. The oxide films were grown thermally, ion-implanted, and annealed at temperatures from 850-1050C for times varying from 30-60 minutes.

Fabrication Sequence for Erbium-doped MOS Capacitor Structures

- 1.0 P-type 20 ohm-cm silicon wafers
- 2.0 RCA chemical cleaning
- 3.0 630Å thermal oxide @1000C for 75 min
- 4.0 Erbium implantation $1E15 \text{ cm}^{-2}$ @ 50 KeV
- 5.0 RCA chemical cleaning
- 6.0 Activation Anneal @ 850-1050C (Custom Furnace)
- 7.0 Ready for photo and cathodo luminescence studies
- 8.0 Polysilicon Deposition @ 900C*
- 9.0 N⁺ Doping in POCl₃ Furnace*
- 10.0 2000Å thermal oxide*
- 11.0 Photolithography (contact window mask)*
- 12.0 Aluminum Deposition*
- 13.0 Photolithography (contact window)*
- 14.0 Metal Sinter*

* Processes remain to be completed after photomask design

Er Ion Implantation Simulation



Ion Type = Er
Ion Energy = 50 keV
Ion Angle = 0

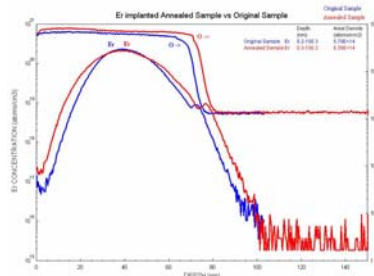
$$N(x) = N_p e^{-\frac{(x-R_p)^2}{2\Delta R_p^2}}$$

$$N_p = \frac{\Phi}{\sqrt{2\pi\Delta R_p^2}} = 6.5 \times 10^{20} \text{ ions/cm}^3$$

$$\Phi = 1 \times 10^{15} \text{ ions/cm}^2, R_p = 286 \text{ Å}, \Delta R_p = 61 \text{ Å}$$

- Erbium ions are located in the center of the SiO₂ film with a peak concentration of $6.5E20 \text{ ions/cm}^3$.

SIMS Analysis Result



- Anneal condition: 900C in N₂ gas for 60 minutes.
- Verify the distribution of Er ions.

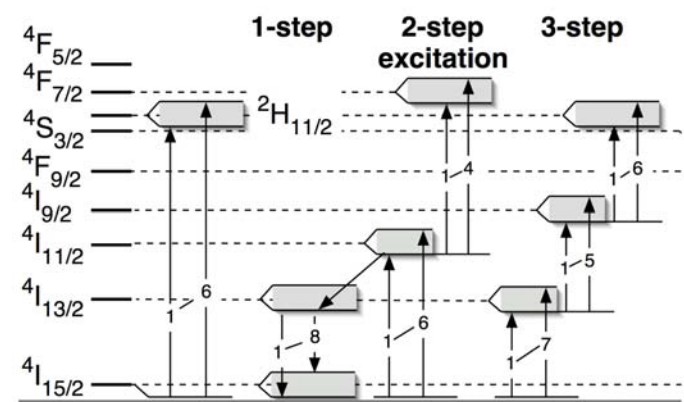
Conclusions

- Since the photoluminescence appears to be weak with silicon dioxide films, we will perform experiments with co-implantation of Erbium and Silicon to enable efficient transfer of energy to the Erbium center.
- In addition, we are in process of designing photographic masks to study electrical excitation of the Erbium centers by Fowler-Nordheim tunneling from a semi-transparent, conductive, gate electrode.
- We will need to perform experiments with different film thickness, ion-implantation parameters, and annealing conditions.

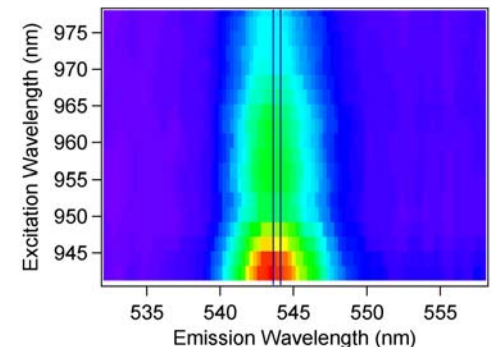
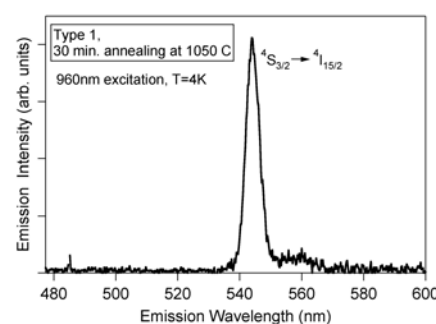
Optical Characterization

In order to characterize the Er-emission efficiency in the layers we excite the ion directly. Several excitation schemes can be used to excite the Erbium ions in the SiO₂ layer. However, the photoluminescence from the layers studied so far is very weak and therefore the choice is determined by minimal background and maximum detector sensitivity. The best results are achieved for the green up-conversion emission excited at around 980nm (2-step excitation). So far only for type 1 samples significant luminescence was found

Energy Level Scheme and Excitation Processes

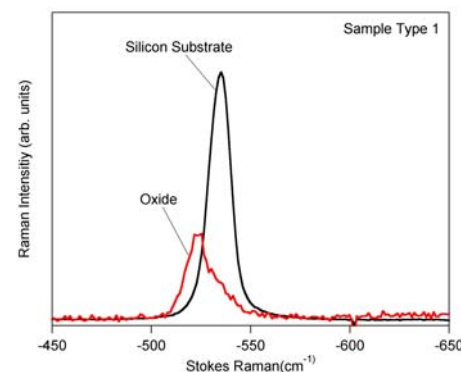


Site-selective Photoluminescence



- Emission spectrum almost independent of excitation energy

Micro Raman Spectroscopy



- Determination of the damage caused by ion implantation
- Localization of the oxide layers

Conclusions

- Photoluminescence from the thin layers is very weak, suggesting strong non-radiative decay
- Annealing to 1050C appears to be optimum, so far
- Improvement of the annealing procedure required
- Up-conversion emission shows no discrete sites suggesting strong inhomogeneous broadening

¹ Maria Eloisa Castagna, Salvatore Coffa, Liliana Caristia, A. Messina. "Quantum Dot Materials and Devices for Light Emission in Silicon", ST Microelectronics, ESSDERC 2002.