Plasma-Enhanced Chemical Vapor Deposition of Er-doped Amorphous Silicon Thin Films

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Rare earth doping of Si is known to result in the formation of luminescent centers and is considered as a possible way to manufacture Si-based optoelectronic devices. Among the various rare earth elements, Er is of special interest since its atomic transition at 1.54μm matches the absorption minimum of SiO_2, a highly desirable feature both for signal transmission through glass fiber cables and optical on-chip communication [1]. Erbium luminescence depends strongly on the nanostructure of the silicon matrix [2-3] and on the co-doping elements, such as oxygen [4] and fluorine [5]. The addition of oxygen or fluorine to Er-doped silicon matrix enhances the Er luminescence intensity and reduces the thermal quenching of the luminescence. In particular, the addition of fluorine to Er-doped silicon matrix improves the light intensity output of erbium by 100 times, compared to erbium in oxide silicon. The larger electronegativity of fluorine compared to oxygen leads to a stronger ligand field surrounding the Er^{3+} ion.

In this contribution, we report on plasma enhanced chemical vapor deposition with incorporated erbium metal sputtering facility to deposit erbium doped amorphous silicon. a-Si:Er,H,F growth is performed at low temperature (200°C) from SiF_4-H_2-Ar plasmas and sputtering of a pure target of metallic erbium. Both the sputtering and PECVD processes have been investigated, through the parametric study of the effect of pressure, RF power, bias potential, and electrode geometry on sputtering rate and Er incorporation yield in silicon thin films. Figure 1 shows the dependence of Er sputtering rate as a function of the bias potential, V_{bias}, at the sputtering electrode. The extrapolation of the straight line gives the lowest bias potential value to have Er-sputtering.

An important aspect that characterizes the present study is the definition of the correlation between growth chemistry and kinetics and material structure and properties of Er-doped amorphous silicon thin films. This correlation is established through the in situ real time monitoring of the process kinetics by Laser Reflectance Interferometry (LRI) and the structural and optical characterization of the thin films by various techniques such as Spectroscopic Ellipsometry (SE), Rutherford Backscattering Spectroscopy (RBS), Atomic Force Microscopy (AFM), Secondary Ion Mass Spectroscopy (SIMS) and Photoluminescence (PL) measurements.

A particular emphasis is given to Spectroscopic Ellipsometry that is used to establish the interplay between nanostructure and optical properties of a-Si:Er thin films [6-7]. In particular, the Er ionic character affects Er photoluminescence. SE is found to be very sensitive to Er ionic character discerning the optical response of metallic Er from Er^{3+} ions in silicon matrix. Figure 2 shows a comparison between refractive index and extinction coefficient of metallic Er and Er^{3+} ions in silicon matrix. The singularities at 1.55eV and 2.29eV in SE spectra of Er^{3+} ions correspond to the $^4I_{15/2}\rightarrow{}^4I_{9/2}$ and $^4I_{15/2}\rightarrow{}^2H_{11/2}$ absorption transitions, respectively. In metallic Er, electric dipole transitions are not allowed.

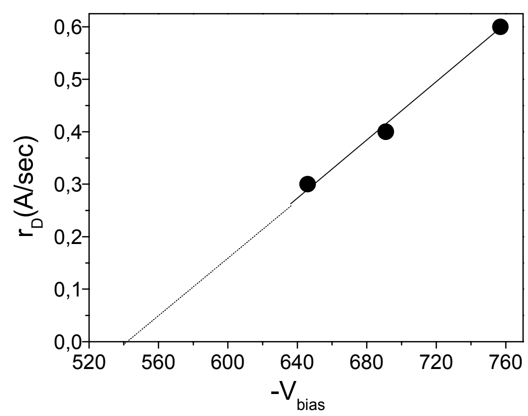

Figure 1. Dependence of Er sputtering rate on self-bias potential

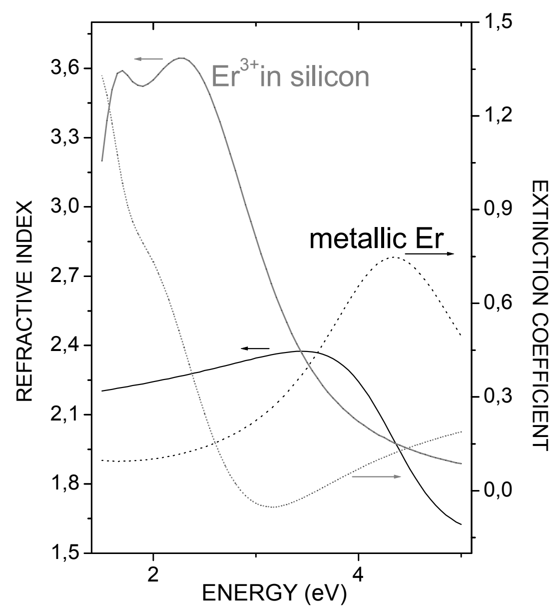

Figure 2. Comparison between refractive index (continuous line) and extinction coefficient (dashed line) of metallic Er and Er^{3+} ions in silicon matrix

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