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Sensitization of Er3+ Emission in Er- and Yb-doped Si Thin Films by Laser Ablation

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Rare-earth (RE) doping of Si and Si-related materials [1-4] has attracted much attention for the development of Si-based optoelectronic devices initiated by the report on the photoluminescence (PL) centered at around 1540 nm of Er^{3+} ($^4I_{13/2} \rightarrow {}^4I_{15/2}$) in Si [1]. Ytterbium (Yb) is known as a sensitizer for Er^{3+} emission at 1540 nm in Er-doped materials [2]. Since the energy level of the Yb^{3+}-$^2F_{5/2}$ state is close to that of the Er^{3+}-$^4I_{11/2}$ state, optical transitions between them are expected to raise the excitation efficiency of the Er^{3+}. Therefore, much attention has been given to Er, Yb-codoped Si and Si-related materials for Si-based optoelectronic device application. Kozanecki et al. presented that the codoping of Yb leads to the enhancement of Er^{3+}-related PL at 1540 nm in the Er-doped SiO_2 films [2]. However, there are few studies on Er and Yb codoping of Si matrix. Here, we investigated the synthesis of Er- and Yb-doped Si (Si:Er,Yb) thin films by laser ablation. Laser ablation technique is simple and useful for doping the RE elements into the host materials [3]. The Si:Er,Yb films with approximately 200 nm thick were synthesized on Si(100) substrates at room temperature by using a Q-switched YAG (QW-YAG) laser with fourth harmonics (266 nm and 1 J/cm^2). The Er and Yb doping levels in the films were in the range of 10^{18} to 10^{20} cm^{-3}. The intensity of the Er^{3+}-PL at 1540 nm from the Si:Er,Yb films was two orders of magnitude higher than that from the Er-doped Si films. This result indicates that the Yb^{3+} acts as the efficient sensitizer of the Er^{3+} emission. The details of the sensitization effect of Yb on the Er^{3+} emission will be presented based on the PL and PL excitation spectra as well as the temperature dependence of the Er^{3+}-PL.

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Keywords
rare-earth doping
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