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Separating nanocluster Si formation and Er activation in nanocluster-Si sensitized Er luminescence

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Er^{3+} ion shows a stable and efficient luminescence at 1.54mm due to its $^4I_{13/2} \rightarrow {}^4I_{15/2}$ intra-4f transition. As this corresponds to the low-loss window of silica-based optical fibers, Er-based light sources have become a mainstay of the long-distance telecom. In most telecom applications, Er^{3+} ions are excited via resonant optical pumping. However, if nanocluster-Si (nc-Si) are co-doped with Er^{3+}, Er^{3+} can be excited via energy transfer from excited electrical carriers in the nc-Si as well. This combines the broad, strong absorption band of nc-Si with narrow, stable emission spectra of Er^{3+} to allow top-pumping with off-resonant, low-cost broadband light sources as well as electrical pumping. A widely used method to achieve nc-Si sensitization of Er^{3+} is high-temperature annealing of Er-doped, non-stoichiometric amorphous thin film with excess Si (e.g.,silicon-rich silicon oxide(SRSO)) to precipitate nc-Si and optically activate Er^{3+} at the same time. Unfortunately, such precipitation and growth of nc-Si into Er-doped oxide matrix can lead to Er^{3+} clustering away from nc-Si at anneal temperatures much lower than ~1000 °C that is necessary for full optical activation of Er^{3+}in SiO_2. Recently, silicon-rich silicon nitride (SRSN) was reported to be a promising alternative to SRSO that can overcome this problem of Er clustering. But as nc-Si formation and optical activation Er^{3+} remain linked in Er-doped SRSN, it is not clear which mechanism is responsible for the observed improvement. In this paper, we report on investigating the effect of separating the nc-Si formation and Er^{3+} activation by using hetero-multilayers that consist of nm-thin SRSO or SRSN sensitizing layers with Er-doped SiO_2 or Si_3N_4 luminescing layers.