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

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Er³⁺ ion shows a stable and efficient luminescence at 1.54 mm due to its ⁴I₁₃/₂ → ⁴I₁₅/₂ 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, Er³⁺ ions are excited via resonant optical pumping. However, if nanocluster-Si (nc-Si) are co-doped with Er³⁺, Er³⁺ 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 Er³⁺ 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 Er³⁺ 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 Er³⁺ at the same time. Unfortunately, such precipitation and growth of nc-Si into Er-doped oxide matrix can lead to Er³⁺ clustering away from nc-Si at anneal temperatures much lower than ~1000 °C that is necessary for full optical activation of Er³⁺ in SiO₂. 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 Er³⁺ 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 Er³⁺ activation by using hetero-multilayers that consist of nm-thin SRSO or SRSN sensitizing layers with Er-doped SiO₂ or Si₃N₄ luminescing layers.