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Novel implantation technique for gain media in silicon photonics

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Silicon photonics represents a technological solution to the industrial and societal challenge of increasing internet speeds and capacity, without burdening the financial and power dependencies of networked systems [1]. A key example of this is traditional copper wiring used in datacentres both increasing cost and decreasing communication speeds, which a combined fibre optic and silicon photonic system could dramatically outperform [2]. These challenges are growing and the need for valid solutions increasingly apparent, however silicon photonics still lacks key developmental components in this upcoming revolution in data communications architecture. One such component is integrated gain media brought about due to the fundamental limitations of silicon (indirect bandgap, low doping solubilities of optically active ions, etc.). We present a novel CMOS compatible surface processing route, termed ultrafast laser plasma implantation (ULPI) [3], to deliver significant increases in the solubility of rare earth elements in a silicon platform, thus serving as a possible solution to dramatically increase gain in future devices. Tellurite glass targets doped with Er^{3+}-ion or Tm^{3+} are ablated with a femtosecond laser and implanted into single crystalline silicon substrates heated to 570°C. Through controlled cooling, it has been found that slow cooling leads to crystallisation of III-V particles. Their formation is described through the initial reduction of the ZnO and TeO_2 from the target material and subsequent crystal growth, as identified through thermochemical calculations. These, as well as rare earth doped silicate crystallites are characterised through photoluminescence (PL) spectroscopy and structural analysis is conducted with scanning and transmission electron microscopy, as shown in Figure 1. Fast cooling has been found to inhibit crystallisation and maintain an amorphous structuring of the implanted layer, with a very well defined interface to the pristine Si substrate, unique to the ULPI process. This process can be further optimised to inhibit the formation of any particulates in the film, forming a highly-dense rare earth doped region within a silicon photonics platform to serve as a gain medium. Furthermore, shadow masking can be employed to deploy these regions with micro-scale dimensionality, ideal for silicon photonics.

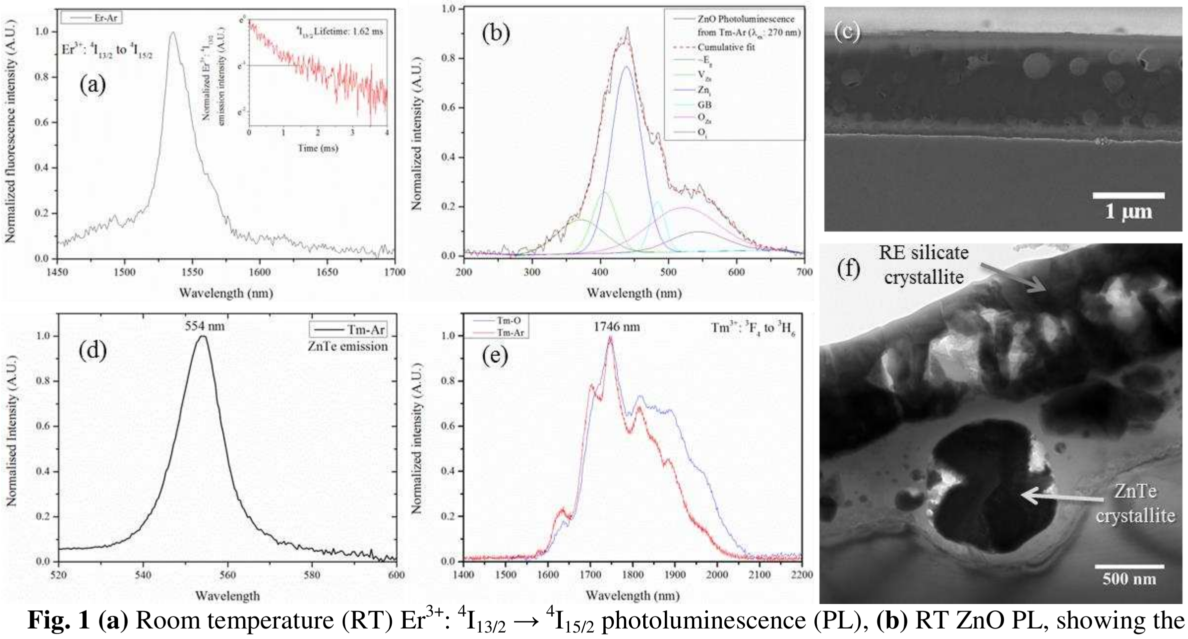

Fig. 1 (a) Room temperature (RT) Er^{3+}: $^4I_{13/2} \rightarrow {}^4I_{15/2}$ photoluminescence (PL), **(b)** RT ZnO PL, showing the deconvolution of the lineshape based on the defect states, **(c)** Cross-sectional SEM image of fast-cooled Er:TZN implanted Si, **(d)** RT ZnTe PL, **(e)** RT Tm^{3+}: $^3F_4 \rightarrow {}^3H_6$ of samples fabricated in an O or Ar atmosphere, **(f)** Cross-sectional TEM image of slow-cooled Tm:TZN implanted Si

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