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Mid-refractive index GeSi photonics for Telecommunication applications

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We discuss a mid-refractive index contrast (MiDex) GeSi-based photonics for future dense wavelength division multiplexing (WDM) system. We show that MiDex Ge-rich $Si_{1-x}Ge_x$ can be used as both a passive low loss waveguide (Fig. 1(a)) and a virtual substrate (Fig. 1(b)) to facilitate epitaxial growth of Ge-based active devices at low temperature (≤ 450°C). In other words, the Ge concentration x of the $Si_{1-x}Ge_x$ layer is designed to be low enough to avoid significant $Si_{1-x}Ge_x$ indirect-gap absorption at the working wavelength of the Ge-based active devices. At the same time, the x concentration of $Si_{1-x}Ge_x$ layer needs to be high enough to ensure a sufficiently small lattice mismatch with the Ge devices, so that dislocations are not introduced from strain relaxation of the Ge-device stack. A sketch of the layer stack and different photonic devices are shown in Fig. 1(b).

Moreover, refractive index contrast between Ge-rich $Si_{1-x}Ge_x$ waveguide and the $Si_{1-y}Ge_y$ (y < x) lower cladding layer is small enough to overcome the polarization dependent loss and detrimental fabrication tolerance of WDM system based on the widely-investigated high refractive index contrast optics (HiDex) of Si on SiO_2 waveguide. Furthermore, from experiment and simulation the index contrast between Ge-rich $Si_{1-x}Ge_x$ waveguide and the cladding layer is still high enough to ensure compactness of important on-chip photonic components including passive waveguide and GeSi-based array waveguide grating (AWG). Last but not least, we experimentally prove that Ge-rich $Si_{1-x}Ge_x$ layer can act as a virtual substrates to facilitate a low temperature high quality epitaxial growth of Ge-based active components using XRD measurement (Fig. 1 (c)). Our studies show that MiDex GeSi-based photonics could uniquely provide both passive and active functionalities necessary for future dense WDM system, which potentially could not be obtained using the widely-developed HiDex systems.

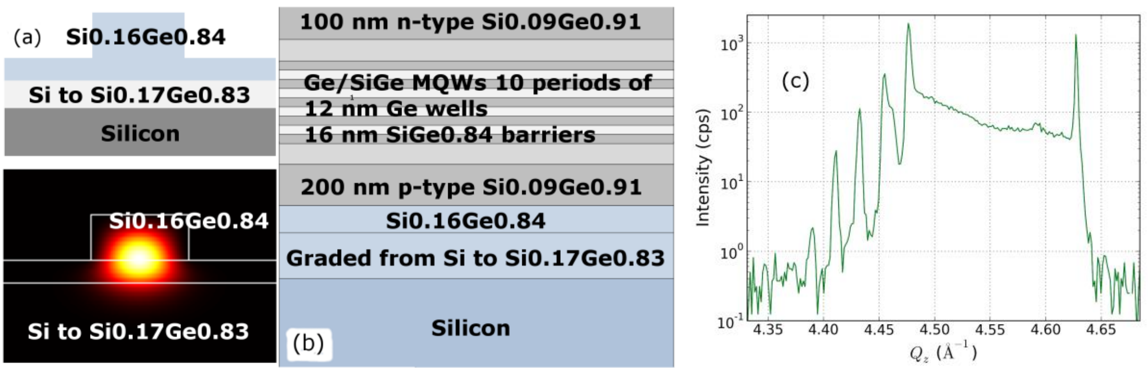

Figure 1. (a) Schematic views of the fabricated 2-µm-wide, 1.5-µm-high, and 1-µm-etched $Si_{0.16}Ge_{0.84}$ rib waveguides. In the lower inset, film mode matching simulation showing the single mode condition of the transverse-electric polarised guided light. (b) Schematic diagram of the Ge/SiGe MQWs and SiGe waveguide stacks grown on a Si substrate via a graded buffer. The MQW stack is coherent with respect to the almost fully relaxed 91% p-type contact. (c) X-ray diffraction ω-2θ scan through the (004) reflection.