Microstructure and light-emission in stain-etched Si_xGe_{1-x} alloys

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The discovery of visible luminescence at room temperature in anodized [1] and stain-etched [2] porous . Si has sparked interest into the possibility of other semiconductor materials exhibiting similar forms of luminescence. The Si_xGe_{1-x} alloy system is a good starting point for these investigations since both are group IV elements and are completely soluble in each other in the solid state across the entire range of compositions. Indeed, previous work [3] on an anodized $Si_{0.85}Ge_{0.15}$ alloy demonstrated that these layers do luminesce with a red-shift in the peak wavelength as compared to anodized silicon.

In the present study, the luminescence and microstructure of stain-etched Si_xGe_{1-x} alloys with $0 \leq x \leq 1$ were examined. Apart from the pure Si and pure Ge, which were in bulk crystalline wafer form, SiGe crystals with all other alloy compositions were grown by molecular beam epitaxy on (100) Si substrates. For the lower Ge contents the epitaxial layers were grown below the critical thickness for strain relaxation. After stain etching in $HF:HNO_3:H_2O$ the alloys were characterized using high resolution transmission electron microscopy (TEM), x-ray photoelectron spectroscopy and photoluminescence. The porosity and chemical composition of the layers were determined by energy dispersive x-ray spectroscopy (EDX) and parallel electron-energy loss spectroscopy (PEELS) using field emission analytical electron microscopy.

Examination of diffraction patterns obtained from the porous Si_xGe_{1-x} layers indicates that the bulk of the porous material is amorphous. High resolution images confirmed the diffraction results, although small crystallite were observed near the porous-substrate interface for lower x values (fig. 1). These crystallite were absent for the stain-etched pure Ge. EDX indicated that the layers had a porosity ranging from 65 to 85%, with some non-uniformity in the alloy layers (see fig. 2 for Si results). In addition, carbon and oxygen were detected in the stained Si layer by PEELS.

X-ray photoelectron spectroscopy measurements also confirm that the stain-etched layers are mostly amorphous. Enrichment in the Ge concentration above the substrate value was observed in the stained Si_xGe_{1-x} alloys. This result was confirmed using PEELS. The Ge content appears to be maximum at the surface of the porous layer and tapers down to the content in the unetched layer. The enrichment is presumably a consequence of the selective removal of Si from the Si_xGe_{1-x} layer during the wet etching process.

Photoluminescence measurements indicate a dramatic reduction in the PL intensity with increase in Ge content of the Si_xGe_{1-x} alloys. No obvious trend was observed in the maximum peak position with Ge content as opposed to the results obtained by Gardelis *et al.*[3] The decrease in intensity can be correlated to the Ge enrichment in the porous layers. Mechanisms of photoluminescence in Si_xGe_{1-x} layers will be discussed in the light of these structural analyses.

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References:

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