Initial growth of tin on silicon and germanium surfaces

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The integration of Sn into Si and SiGe technology offers a great potential for future applications. With increasing Sn content in GeSn alloys, the carrier mobility is enhanced [1]. Moreover, Sn may offer a precise control of the electronic band structure for Si photonics [2], and GeSn films are very promising as stressors for the fabrication of tensile strained Ge layers.

We have investigated the adsorption and initial growth of Sn on Si(001), on Ge(001), and on compressively strained pseudomorphic Ge layers grown on Si(001). The evolution of surface reconstruction and morphology during Sn deposition was monitored *in situ* with low-energy electron diffraction (LEED) and microscopy (LEEM). Room-temperature (RT) Sn deposition, followed by annealing between 570°C and 680°C, is compared to Sn growth at elevated temperatures.

On Si(001) substrates, RT deposition of Sn leads to different surface reconstructions after annealing. Depending on Sn coverage, *c*(4×4), (1×*n*), (2×*n*), *c*(8×4), and finally a (5×1) reconstructions were observed in the range of up to 1.5 monolayers (ML) Sn. Many of these reconstructions undergo a reversible phase transition at about 535°C, either into a (2×1) or into a (1×1) structure. The surface phase diagram is depicted in Fig. 1. It is in good agreement with earlier work by Ueda *et al.* [3]. Unlike these authors, however, we do not observe a (2×6) reconstruction near 0.4 ML. Instead, we found a varying *n* in the range from 4 to 5. The situation is different, when Sn is grown on Si(001) at elevated temperatures. In the investigated range from 470°C to 580°C, (1×*n*) and (2×*n*) periodicities with very large *n* evolve immediately after the start of the deposition. With increasing coverage, *n* is reduced continuously down to *n*=5. This points to a missing-row arrangement of Sn-Si and, progressively, Sn-Sn dimers. Upon further Sn growth, all LEED superstructure spots vanish and, finally, the high-coverage (5×1) phase evolves. For Sn deposits in excess of 1.5 ML, the growth of pyramidal islands is observed with LEEM. A three-dimensional reciprocal-space analysis with LEED reveals the {113} orientation of the side facets of these Stranski-Krastanov islands, in agreement with earlier STM work [4].

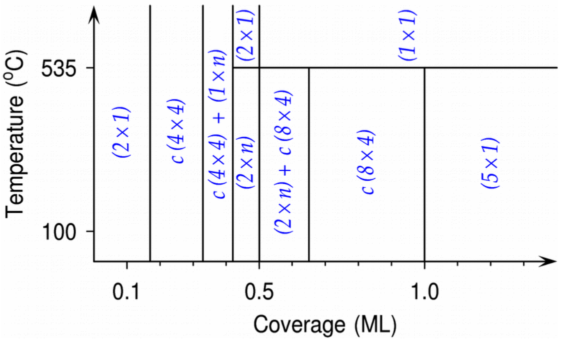

Fig. 1: Phase diagram for Sn/Si(001).

On strained pseudomorphic Ge films on Si(001), the structural evolution upon Sn deposition is very similar. The only notable difference is that at low coverage a (2×*n*) periodicity prevails from the beginning, which originates from the Ge wetting layer [5].

For Sn on bulk Ge(001) substrates, the development of the surface reconstruction is also similar to that on Si(001). However, though we observe a (1×*n*) periodicity, our data does not provide clear evidence for other reconstructions, such as *c*(8×4). Nevertheless, *n* shows the same trend with coverage as for Sn/Si(001): it starts at very large values and is reduced continuously to *n*=6.4. Compared to the larger-lattice-mismatch systems Sn/Si(001) and Sn/Ge/Si(001), where finally *n*=5 is reached, this finding points to strain as driving force for these reconstructions.

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