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Electron energy-loss studies of InSb(100)

T S Jones†, M R Ashton†, N V Richardson† and C F McConville‡
† Surface Science Research Centre, The University of Liverpool, PO Box 147, Liverpool L69 3BX, UK
‡ Royal Signals and Radar Establishment, St Andrews Road, Malvern, Worcestershire, WR14 3PS, UK

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Abstract. The undoped InSb(100) surface (n-type, $\sim 1 \times 10^{14}\,cm^{-3}$) has been studied using high-resolution electron energy-loss spectroscopy (HREELS). After exposure to formic acid at room temperature, the formate species (HCOO) is identified, using HREELS, at the InSb surface.

High-resolution electron energy-loss spectroscopy (HREELS) has been used to study the clean, undoped, InSb(100) surface (n-type, $\sim 1 \times 10^{14}\,cm^{-3}$) and the same surface after exposure to formic acid (HCOOH) at room temperature.

The InSb sample consisted of a 1 cm^2 slice of a 500 μm bulk material (MCP Ltd) grown in the (100) orientation. After mechanical polishing, solvent cleaning and chemical etching, the sample was cleaned in UHV by Ar^+ bombardment (500 eV, 1–2 μA ion current, 45 min) and gentle annealing (maximum temperature 525 K, 15 min). After two or three cycles, the LEED showed a relatively sharp (4×1) pattern, with additional faint streaks/spots between the (4×1) features. This surface structure has been described as a (4×1), or a (4×2) with one-dimensional disorder [1].

On the clean reconstructed surface, specular HREELS reveals the coupled surface phonon/plasmon polaritons at 21 and 55 meV [2]. The 21 meV loss is predominantly the Fuchs–Kliewer phonon mode and the higher-energy feature the surface plasmon. The plasmon has a much greater frequency than expected for such low bulk dopant levels [3]. Although shifts from the bulk plasmon frequency can occur because of surface segregation [4], we prefer to interpret the high plasmon frequency as arising from lattice damage in the surface region as a result of the Ar^+ bombardment. It is known that such bombardment causes preferential sputtering of the group V elements in III–V semiconductors. In our case, this would lead to a surface enriched in indium, consistent with an increase in the free-carrier concentration and a higher plasmon frequency at the surface.

Specular HREELS studies of the InSb(100) surface, after exposure to $\sim$1000 L HCOOH at room temperature, are dominated by the plasmon loss of the clean surface at 55 meV. Additional, higher-frequency losses at 167, 190 and 360 meV are also observed and these are assigned as the symmetric O–C–O vibration (ν_s(COO)), the asymmetric O–C–O vibration (ν_a(COO)) and the symmetric C–H stretching vibration (ν(C–H)) of an adsorbed formate group (HCOO). By carrying out off-specular HREELS studies, the dipole-active plasmon loss can be made considerably weaker in intensity and a number of additional adsorbate-derived vibrational features are observed, indicative of the presence of a surface HCOO species [2]. Since the surface plasmon frequency lies below the adsorbate vibrational modes the so-called surface dipole selection rule is not expected to apply as rigorously as in the case of adsorption on metals. On transition metals, the absence of the ν_a(COO) mode in specular scattering is used in the determination of adsorbate orientation [5]. For adsorption on InSb the observation of this mode in specular scattering may well be the result of the reduced screening.

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