Surface x-ray diffraction of Sb/InAs(001) surface phases

Brad P. Tinkham[1)], Wolfgang Braun[1)], Klaus H. Ploog[1)], Masamitu Takahasi[2)], and Jun'ichiro. Miziki[2)]

[1)]Paul Drude Institute for Solid State Electronics, Berlin, Germany. [2)] JAEA

Abstract: The (2x4) Sb/InAs(001) was measured and the reconstruction appears to have a similar structure to that of the α2 InAs(001) (2x4) reconstruction. We have also measured the InAs(001) surface structure *in situ* and as a function of temperature to arrive at a complete picture of the InAs(001) (2x4) surface as a function of arsenic chemical potential.

Keywords: In sit surface x-ray diffraction, narrow-bandgap semiconductors

The performance of InAs-channel high-electron mobility transistors (HEMTs) is strongly linked to the interface structure of the AlSb/InAs/AlSb quantum well. A 2D electron gas (2DEG) is present at the InAs/AlSb interface and depending on how the quantum well structure is prepared, the two-dimensional charge density in the 2DEG can vary by more than an order of magnitude and at high enough charge densities the electron mobility can in turn suffer[1]. It is therefore important to understand the structures of bare InAs (001) and Sb-terminated InAs(001) surface phases in order to identify optimum surface and interface preparation procedures for real devices.

InAs(001) quarter wafers were loaded in the UHV chamber and the oxide layer was desorbed in an As flux. A 100nm InAs buffer layer was grown followed by a several atomic layer thick Sb layer at low temperature. Upon heating, the surface structure was monitored with reflection high-energy electron diffraction (RHEED) and x-ray diffraction. A disordered (1x3) structured appeared followed by a much more ordered (2x4) structure upon further heating. On this Sb-terminated InAs(001) (2x4) surface phase, we proceeded with a complete surface x-ray diffraction structure measurement. Over 200 in-plane reflections, 8 fractional-order crystal truncation rods (CTRs) and 2 integer-order CTRs were measured on this surface. Due to the similarity of this structure with the predicted InAs(2x4) surface, we prepared a high quality InAs(001) (2x4) surface using a similar procedure and performed the same x-ray measurements on this phase just below the InAs(001) (4x2-2x4) transition temperature (400°C) with an As flux of 4×10^{-5} Pa. We proceeded to measure the in-plane structure of this surface at over a

range of temperatures to monitor the InAs(001) α2 (2x4) to InAs(001) β2 (2x4) structural transition.

The structural analysis of the different (2x4) surface phases is currently underway. Although the measured Sb-terminated (2x4) phase was less ordered than the pure InAs(001) (2x4) surface, it was clearly more ordered that the Sb-terminated InAs(001) (1x3) phase that is usually present during transistor device growth. Initial analysis for the data measured on the bare InAs(001) (2x4) surface at variable temperature agrees with STM measurements[2]; namely that for temperatures ranging from the (4x2)/(2x4)-transition down to the arsenic adsorption temperature, a mixture of α2 and β2 phases is present.

Using surface x-ray diffraction under technologically relevant growth conditions we have identified a Sb/InAs(001) (2x4) phase that is structurally similar to the InAs(001) α2 (2x4). The ongoing structural analysis will determine if this Sb-terminated phase is more similar to the InAs(001) α2 (2x4) or the InAs β2 (2x4) surface reconstruction. It is an important finding that it should be possible during device growth to transition from an InAs layer to AlSb while maintaining a (2x4) surface reconstruction. Our preliminary analysis of the InAs(001) (2x4) reconstruction indicates that for an arsenic overpressure of 4×10^{-5} Pa, both α2 and β2 structures are present in some proportion for all temperatures for which this phase is stable. In a previous surface diffraction study carried out on a quenched InAs(001) (2x4) surface, a pure InAs(001) β2 (2x4) structure was used to model the data[3]. Our results suggest that this model is oversimplified and that a mixture of phases is likely present both for the case of quenched samples as well as samples measured *in situ*.

[1] G. Tuttle, H. Kroemer, and J. H. English, J Appl Phys **67,** 3032 (1990).
[2] H. Yamaguchi and Y. Horikoshi, Phys Rev B **51,** 9836 (1995).
[3] M. Göthelid, Y. Garreau, M. Sauvage-Simkin, R. Pinchaux, A. Cricenti, and G. Le Lay, Phys Rev B **59,** 15285 (1999).

Publication plan

3 original papers

Appropriate Journals: Physical Review B, Surface Science, Applied Physics Letters

Timeframe for publication: 18 months