ELECTRICAL CONDUCTIVITY OF InAs FILMS PREPARED AT DIFFERENT TEMPERATURES

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The paper reports on the investigations on the structure and conductivity behaviour of InAs films under different deposition conditions like substrate temperature, film temperature, thickness, post-deposition annealing treatment etc. The observed results are explained in terms of the structure and the various conduction mechanisms operative in the region.

1. INTRODUCTION

Studies on the properties of vacuum evaporated InAs films are very limited [1 - 7] because of the tendency of the material to dissociate at its melting point, which makes it difficult to obtain stoichiometric films. Different authors have used different techniques to obtain InAs films, viz. coevaporation [1, 2], sputtering [3, 5], thermal evaporation [8] etc. In the present paper, the authors have employed the ‘flash evaporation’ technique for InAs film formation and studied its composition, structure and electrical conductivity.

2. EXPERIMENTAL

The ‘flash evaporation’ technique was chosen for the following reasons: This method is simpler in operation than the ‘three temperature’ method in the sense that critical control of the individual evaporants can be avoided. Moreover, in order to maintain the required As vapour pressure over the surface of the film, the rate of evaporation must be quite high; as a result of which a large amount of arsenic is deposited on the cold parts of the apparatus. Also, in the case of the ‘three temperature’ method, in which the two components are evaporated from different boats, one has to maintain the substrate at a relatively high temperature in order to reevaporate the surplus As incident on the substrate. Such a method, evidently, cannot be used for the formation of amorphous layers because this requires the substrate to be maintained at relatively low temperatures. In the ‘sputtering’ method, as the vacuum conditions in the system are not of a high order, the films obtained in such
an atmosphere might not be pure. In the ‘flash evaporation’ method, the above disadvantages can be avoided by evaporating the material in very small granules (150 to 200 Mesh) by allowing it to drop into a heated boat maintained at a sufficiently high temperature. Since the granules evaporate separately, each contributing less than one mono-atomic layer on the substrate, it is reasonable to expect homogeneous layers of the compound in stoichiometric proportions.

The films were prepared on gold seal glass, mica and NaCl substrates in a vacuum of $\sim 6.7 \times 10^{-4}$ Pa at different substrate temperatures ($323-673$ K). Film thickness varied from 100 nm to 300 nm. The distance from source to substrate was maintained at 25 cm to obtain uniformly thick films. The deposition rate was 20 nm/min.

Thick silver electrodes were used as contact material for making the electrical connections. Measurements were made on 0.3 cm $\times$ 1.5 cm bridge type and 1 cm $\times$ 1 cm van der Pauw type samples on glass and mica substrates. The four-probe method was used for resistivity measurements. Structural analysis was done on mica and NaCl substrates by a Philips Transmission Electron Microscope model EM 300 operated at 80 KV. Chemical composition was estimated by the polarographic method. Annealing was done in a vacuum of $6.7 \times 10^{-4}$ Pa. The heating rate was maintained at 2 K/min for all films.

3. RESULTS AND DISCUSSION

InAs films deposited at and around room temperature ($\sim 303$ K) were found to be amorphous as suggested by the electron diffraction patterns and micrographs reported in our earlier publication [9]; while the electron diffraction patterns were diffuse, the electron micrographs showed a random network of small grains. Diffraction patterns of the films formed at $T_s = 473$ K (fig. 1a, plate I, p. 720a) showed sharp diffraction rings indicating the structure to be polycrystalline. The corresponding micrograph (fig. 1b, plate I, p. 720a) shows significantly big grain size. The films formed at $T_s = 573$ K (fig. 2a, plate I, p. 720a) showed epitaxial growth as evidenced by the spot-like pattern which corresponds to the zinc-blende cubic structure with the lattice parameter 6.04 Å. The electron micrograph of this film (fig. 2b, plate I, p. 720a) shows considerably big grain size of the material.

a) Composition:

The composition analysis of the films was done by polarography. The composition was found to be approximately the same as that of the starting material ($% \text{In} = 39.47; \% \text{As} = 60.53$).

b) Electrical conductivity and annealing behaviour:

The electrical conductivities of as-deposited films formed at different temperatures for different thicknesses ranged from $3 \times 10^{-2}$ Ohm$^{-1}$ cm$^{-1}$ (100 nm, $T_s = 373$ K).