

Electrochemical Formation of Nanoporous InP

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There is considerable interest in the electrochemical formation of porosity in semiconductors. Much of the work has focused on silicon but investigations of pore formation in III-V compounds such as GaAs^{1,2} and InP^{3,4} have also been reported. It has been suggested that controlled modulation of the pore diameter and pore growth direction in such structures could lead to photonic band gap applications. However, only limited investigations of the mechanism of pore initiation and growth in III-V semiconductors have been reported. In this paper we review our recent work on the formation of porous InP during anodization in KOH electrolytes^{5,6}.

When the potential of an InP electrode in a KOH solution (2 – 5 mol dm⁻³) is swept in the anodic direction, a current peak is obtained after which the current decreases to a low value. Cross-sectional TEM of electrodes subjected to a potential sweep past this peak shows a porous sub-surface region of fairly uniform thickness separated from the surface by a thin non-porous region, ~40 nm in thickness (Fig. 1). Careful TEM examination shows evidence of channels through this non-porous layer but these appear to be sparsely distributed. Further evidence of the presence of such channels has been obtained by atomic force microscopy (AFM) of the surface. We suggest that electrochemical etch processes leading to generation of the porous layer occur at the advancing tips of electrolyte-filled pores in a network which is connected to the bulk electrolyte via the limited number of channels through the otherwise dense near-surface layer. Consequently, these channels have a critical role in the evolution of the porous region.

Porous InP structures can be formed both under potentiodynamic and potentiostatic conditions. Remarkably, however, porous InP layers are not formed in KOH solutions more dilute than 1.5 mol dm⁻³.

At the earlier stages of porous layer formation, TEM clearly shows individual porous domains that appear triangular in cross-section (Fig. 2) and square in plan view. The cross-sections also show that the domains are separated from the surface by a ~40 nm thick, dense InP layer. It is concluded that the porous domains have a square-based pyramidal shape and that each one develops from an individual surface pit which forms a channel through this near-surface layer. We suggest that the pyramidal structure arises as a result of preferential pore propagation along the <100> directions. It is clear that pores propagating in this way with uniform instantaneous speed will reach, at a given time, points on the surface of a square-based pyramid.

AFM measurements show that the density of surface pits increases with time. Each of these pits acts as a source for a pyramidal porous domain, and these domains eventually form a continuous porous layer. When the domains grow, the current density increases correspondingly. Eventually

domains meet, the interface between the porous and bulk InP becomes relatively flat and its total effective surface area decreases resulting in a decrease in the current density. Numerical modelling of this process will be briefly described.

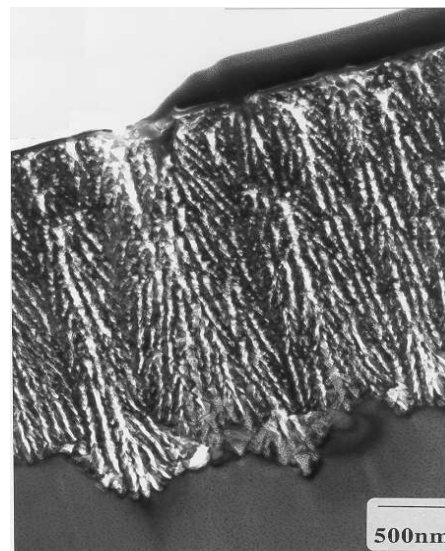


Fig. 1 Bright field TEM of InP cross section after a potential sweep from 0.0 to 0.8 V (SCE) in 2 mol dm⁻³ KOH in the dark.

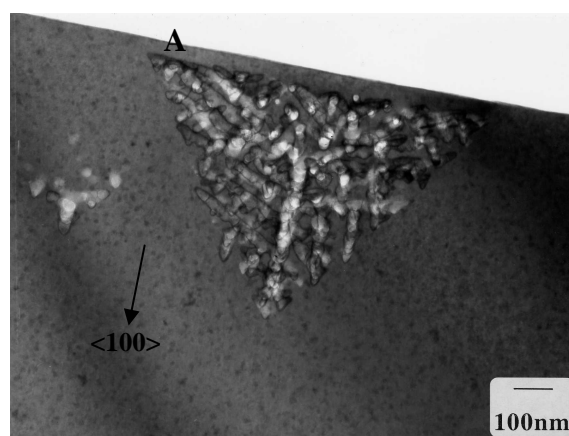


Fig. 2 Bright field TEM of a cross section of an InP electrode after a potential sweep from 0.0 to 0.44 V (SCE) in 5 mol dm⁻³ KOH. The plane of the micrograph is (110). A single porous domain is clearly visible.

References

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