Effect of Current Density on Pore Formation in n-InP in KOH

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The anodic formation of porosity in semiconductors has been studied extensively over the previous two decades, in the hope of exploiting the wide range of possible applications that the resulting porous structures may have.[1-3] For the formation of porous InP, Highly acidic electrolytes are typically used[4-5] and pore etching is often carried out at a constant current density. The constant current allows for control of the pore tip velocity (etch rate), control of the pore morphology and for the passage of a prescribed amount of charge through the electrode, resulting in a porous layer of known thickness.[6-7]

We have previously reported the formation of pores in InP anodized in >2 mol dm^{-3} KOH.[8] These pores emerge from pits in the surface,[9] and grow along <111>A crystallographic directions.[10] We have also recently published a model for the formation of crystallographically oriented pores in III-V semiconductors.[11] In our previous reports, porous InP was typically formed either by linear potential sweep (LPS) or at a constant potential. In this report, the formation of porous InP layers in KOH at constant current densities is examined.

It will be shown that, after a short nucleation period, the thickness of the porous layer increases linearly with charge during formation of porous InP at a constant current. Estimates of the porosity are made from this data and it will be shown that this porosity does not vary with thickness.

It will be argued that the porous etching of InP in KOH is closer to a 6- than an 8-electron process. This is demonstrated by comparing the pore tip velocity calculated from layer thickness measurements with that calculated from a simple model of pore density, in which the porous structure is approximated by an array of parallel cylinders distributed uniformly throughout the substrate. The assumptions of the model are informed and supported by a comprehensive range of experimental evidence, including measurements of pore width, layer thickness, porosity, pore density and pit density.

The applied current density will be shown to have a complex influence on mass transport within the porous network. It will be shown that higher current densities during the early stages of pore growth lead to rapid and widespread nucleation of porous domains across the electrode surface (see Fig. 1). This high pit or porous domain density reduces the mass transport workload of the average pit or porous domain. Conversely, a higher current density increases the mass transport workload for a single pit at a given pit density. The result is that porous layer thickness does not vary significantly with current density (see Fig. 1). The greater variation in porous layer thickness for samples anodised at low current densities (see error bars in Fig. 1) is due the greater variation in porous domain size that would be expected for lower pit densities. Despite the lack of layer thickness variation with current density shown in Fig. 1, it will be shown that with careful control of the applied current, porous layers more than twice their typical thickness can be produced.

Preliminary work on the influence of current density on pore morphology will also be presented. It will be shown that at higher current densities (>5 mA cm^{-2}), *i.e.* higher pore tip velocities, pores exhibit rounded cross-sections, with no particular crystallographic facets being revealed on the pore walls. However, at lower current densities (≤5 mA cm^{-2}), *i.e.* lower pore tip velocities, pores appear to have triangular cross-sections. An interpretation of this unusual observation, within the framework of our recently published model for pore formation in III-V semiconductors, will be given.[11]

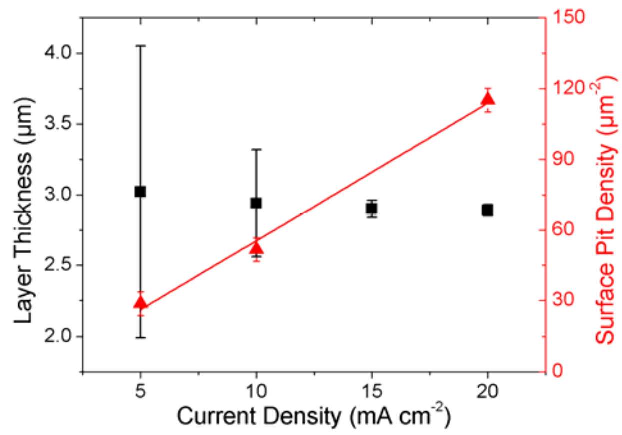

Fig. 1: Plot of both porous layer thickness (■) and surface pit density (-▲-) against current density for InP porous layers formed galvanostatically in 5 mol dm^{-3} KOH at 25°C. The error bars are equivalent to one standard deviation of the corresponding measurements.

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