Chemical-Dynamic Polishing of Indium Antimonide: Kinetics, Mechanism, and Surface Nanostructure Control

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Indium antimonide (InSb) is a key material in infrared photodetectors, thermal imaging systems, and highly sensitive optoelectronic devices. Achieving high-performance InSb-based devices requires precise surface preparation, particularly through chemical-dynamic polishing (CDP). This study investigates the influence of iodine concentration in hydroiodic acid (I_2 in HI) on the CDP rate of InSb, elucidates the dissolution mechanism, and identifies optimal etchant compositions for achieving smooth, nanostructured surfaces.

Experimental results reveal that the dissolution of InSb in I_2 + HI solutions is diffusion-limited, governed by the transport of fresh etchant to the surface. Electrochemical measurements show that the self-dissolution potential of InSb increases from 0.041 V to 0.060 V with rising iodine concentration, while the potential for indium remains constant at –0.52 V. Antimony exhibits a positive self-dissolution potential, increasing from 0.318 V to 0.341 V. These findings suggest that Sb dissolution predominates in the overall InSb etching process, indicating that the formation and removal of antimony or its compounds dictate the dissolution kinetics. Two key insights were derived:

1. Etchant Composition Optimization: The polishing rate is minimized (16.4 $\mu m \cdot min^{-1}$) at low I_2 concentrations, with minimal variation in InSb dissolution potential. This composition is associated with a redox potential of ~0.04 V and yields a controlled, uniform etch.

2. Surface Smoothing via Additives: The incorporation of ethylene glycol (EG) into the etchant significantly improves surface quality, reducing the root-mean-square roughness from 1.1 nm to 0.8 nm (measured by AFM). EG also decreases the polishing rate by an order of magnitude, likely by complexing with surface antimony species and suppressing excessive dissolution.

This work provides a deeper understanding of InSb surface processing and presents practical strategies for achieving ultra-smooth surfaces with tunable nanorelief. Such control is critical for the fabrication of next-generation optoelectronic and infrared sensing devices.

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