Plasma-Induced Surface Modification of Indium for Improved Bonding

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Bonding plays an important role in advanced microelectronics integration and packaging by bringing together components and devices produced separately. Surface-pretreatments on bonding materials have been consistently found to be crucial to achieving a high-quality bond, despite incomplete understanding of why certain treatments have greater success than others. Our project aims to improve understanding of some of these bonding pre-treatment effects to provide information to enable more efficient development of bonding protocols.

Indium is a critical material for conductive contacts in the fabrication of cryogenic low-temperature electronics and optical detectors for infrared and microwave applications, because In is a superconducting material which retains its ductility and adhesion properties during thermal cycling [1]. Certain pre-bond plasma treatments increase the success of In-In bond adhesion. We have observed that plasma chemistries such as H_2/He, which do not include N_2 as a plasma gas, promote more successful In-In bonding. To understand why, we investigate the effects of atmospheric plasma exposure on In surfaces for several plasma chemistries including He/H_2/N_2, He/H_2 and He/N_2. X-ray photoelectron spectroscopy (XPS) and ultraviolet photoelectron spectroscopy (UPS) are used to characterize In surfaces prior to and after ambient pressure plasma treatment. All plasma treatments decreased the amount of carbon and increased the amount of In-oxide present when compared to an untreated film. N_2-containing plasmas resulted in the appearance of an additional high binding energy peak in the N 1s XPS spectrum (Figure 1). We postulate that this may be due to nitrate species formed on the In native oxide surface. Additional experiments are planned to assess the plausibility of this explanation. In foil was measured prior to and after Ar sputter cleaning for comparison to treated samples.

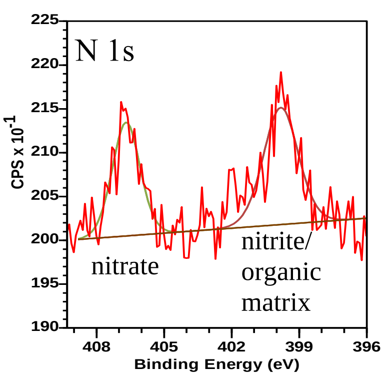

Figure 1. N 1s XPS after He/N_2 plasma.

UPS measurements showed that all plasma chemistry treatments lowered the work function compared to the non-treated control. Greater spatial variation in work function was observed for chemistries with high N_2 versus those with little to no N_2. This finding possibly correlates with poorer bonding for N_2 containing plasmas.

[1] T. J. Lucas, J. P. Biesecker, W. B. Doriese, S. M. Duff, M. S. Durkin, R. A. Lew, J. N. Ullom, M. R. Vissers, D. R. Schmidt, J. Low Temp. Phys. **216**, 67 (2024)

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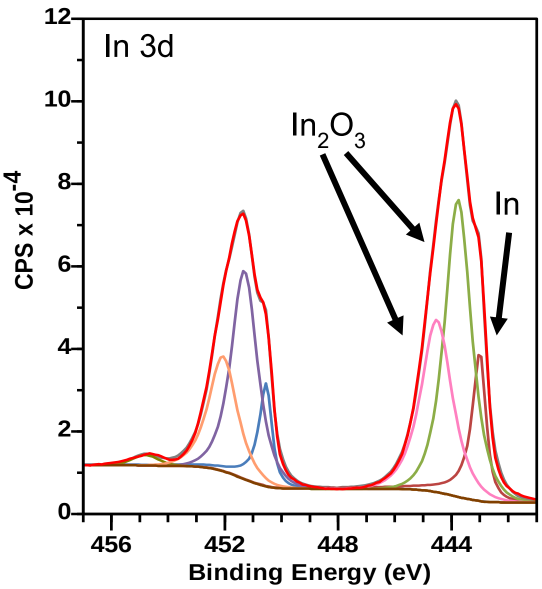

Figure 2. Indium 3d XPS spectrum after He/H_2 plasma.

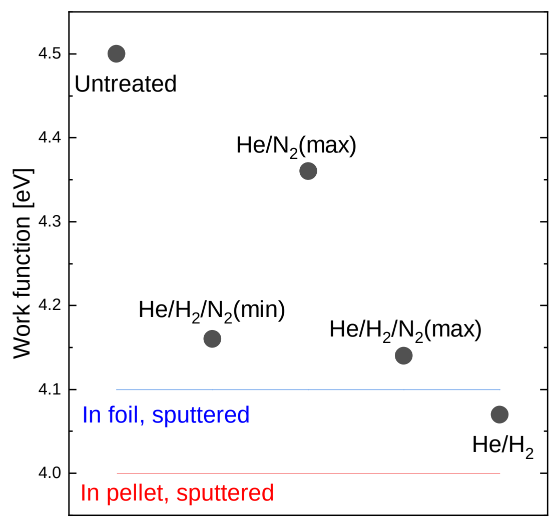

Figure 3. Work function of plasma-treated Indium, untreated control, foil and pellet controls.