General absence of electron accumulation at stoichiometric indium-containing semiconductor surfaces

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During recent years electron accumulation was assigned to many different indium containing semiconductor materials: it almost looked like a universal property [1]. Typically, in technologically usable samples it seems to be a persistently existing effect. But still, the question rises, whether this is an intrinsic or extrinsic semiconductor material property, meaning whether the effect is coming from the material itself or from changes in composition, complete decomposition, or due to oxidation at surfaces.

Therefore, we prepared different indium containing semiconductor samples, i.e. InN, AlInN, and In_2O_3, just by cleavage without any annealing step. This process typically leads to stoichiometric surfaces, at least for a certain time of experimental investigation. After the investigation we also aged the sample in order to see changes. The investigations of the electronic states were performed by cross-sectional scanning tunneling spectroscopy, probing occupied and unoccupied states at the same time.

For all materials—as long as their surfaces stay stoichiometric—we find no intrinsic electron accumulation at all non-polar surface, i.e. the ones without intrisic polarization field. For InN [2,3] we can exclude intrisic electron accumulation at both non-polar surfaces, the *a*- and the *m*-plane, for InAlN [4] at the *m*-plane, and for In_2O_3 at the (111) surface. The electronic structure of these surfaces are all different from each other: InN show no electronic surface state within the fundamental bulk bandgap, for InAlN at least one (depending on the In/Al ratio probaly more) state shifts into the fundamental bulk band gap, and In_2O_3 has different intrisic surface states within it. So the absence of electron accumulation is further independent of the intrinsic electronic properties of the material. Nevertheless, by aging In_2O_3 under ambiant conditions we receive a completely different image: the surface shows metallic behavior, as also surface electron accumulation does. This leads to the assumption that indium containing materials tend to easyly change their surface conditions by decomposition or oxidation, leading to an extrisic interpretation of the typically observed electron accumulation.

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