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Investigation of the chemical bonding states on the pre-cleaned GaAs using $(NH_4)_2S_x$ Solution

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The surface of III-V semiconductor materials such as GaAs is known to be plagued by high surface state density that causes the pinning of surface Fermi level within the band gap of material. Sulfur-passivation with $(NH_4)_2Sx$ solution has been revealed to solve these surface problems of GaAs, and to induce the improvement of the electrical property.

In this study, X-ray photoelectron spectroscopy was employed to investigate a chemical bonding state of the different cleaning procedure and sulfur-treated GaAs. Wet cleaning and successive sulfidation of GaAs with $(NH_4)_2Sx$ solution were carried out in air or in an atmosphere controlled glove box with nitrogen, respectively. A cleaved GaAs surface was used as a reference for Ga-As bond to decompose the various bonding states in photoelectron spectra of Ga and As. The photoelectron spectra of bare GaAs before surface treatment were shown Ga-Ga, Ga-As, Ga-O bonds in Ga 2p3 peak and As-Ga, As-As, As-O bonds in As 3d peak. The wet cleaned GaAs treated by HCl-->DIW was revealed to contain oxide and/or elemental forms of As and/or Ga(Fig 1). Successive sulfidation with $(NH_4)_2S_x$ solution brought about large degree of surface oxides and elemental forms, and the occurrence of As-S and/or Ga-S bonds(Fig 2). The different wet cleaned by H_3PO_4-->DIW-->HCl-->DIW was revealed a larger quantity of As-As bond than HCl-->DIW procedure(Fig. 3).

The formation of passivation layer with sulfur was shown to be mainly dependent on the surface state of wet cleaned GaAs before the sulfidation and especially on the presence of elemental form of As and Ga. The amount of sulfur bonds with As and Ga was determined by the quantity of elemental form of As and Ga generated during the surface preparation for the sulfidation.

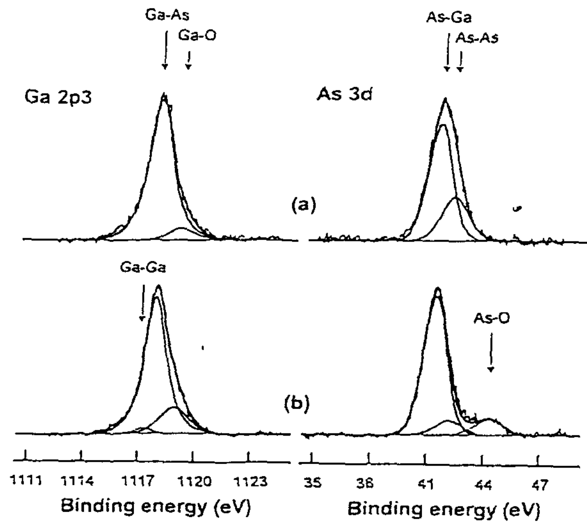

Fig. 1. The Ga 2p3 and As 3d photoelectron spectra of etched GaAs by HCl-->DIW treatment (a)in a glove box and (b)in air.

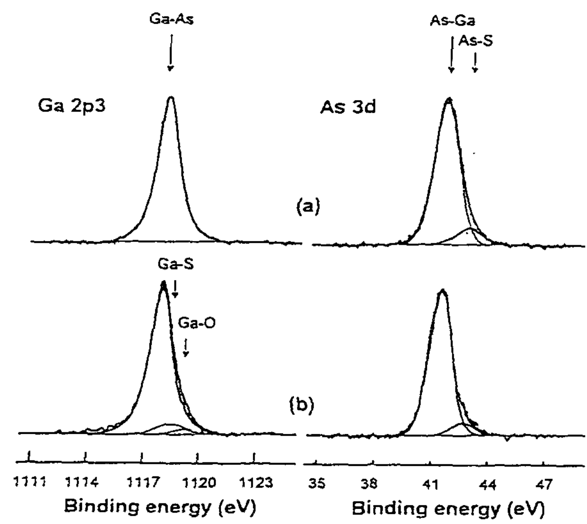

Fig. 2. The Ga 2p3 and As 3d photoelectron spectra of sulfur-passivated GaAs by HCl-->DIW -->$(NH_4)_2S_x$-->DIW treatment (a)in a glove box and (b)in air.

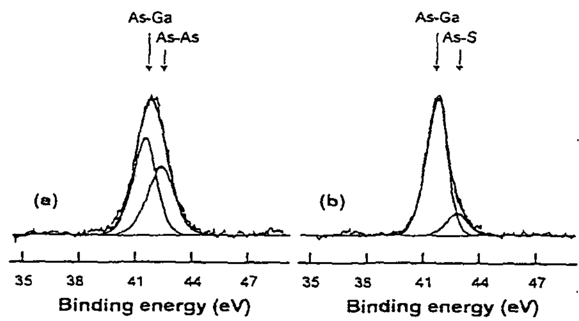

Fig. 3. The As 3d phtoelectron spectra of GaAs obtained after (a)H_3PO_4-->DIW-->HCl-->DIW and (b)H_3PO_4-->DIW-->Hcl -->DIW-->$(NH_4)_2S_x$-->DIW treatments in a glove box.