Morphology and Chemistry of S-treated GaAs(001) Surfaces

S. Heun,[1] M. Rudolf,[2] M. Lazzarino,[2] G. Biasiol,[2] B. Bonanni,[2] L. Gregoratti,[1] A. Barinov,[1] B. Kaulich,[1] and L. Sorba[2,3]

[1] *Sincrotrone Trieste, Basovizza, 34012 Trieste, Italy*

[2] *Laboratorio TASC-INFM, Basovizza, 34012 Trieste, Italy*

[3] *Università di Modena e Reggio Emilia, Via Campi 213/A, 41100 Modena, Italy*

Introduction

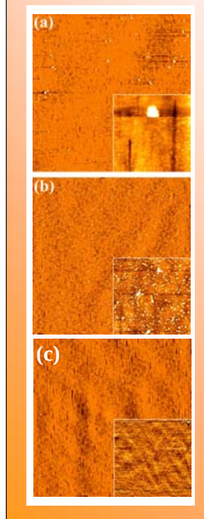
- Problem: GaAs has high surface state density.
- Consequence: Fermi level pinning near midgap.
- Solution: surface passivation by S-treatment.
- But: how homogeneous is the S-passivation?
- Our approach: AFM and SPEM measurements.
- SPEM = scanning photoemission microscope.

Sample preparation:
- 1 µm GaAs buffer, grown by HM-MBE at TASC on GaAs(001).
- 1 min in 1% HF/H_2O.
- 30 sec water rinse.
- 5 min in $(NH_4)_2S_x$ at 65-70°C.

sample A

sample B rinsed by flowing DI water.

- blown dry with N_2.
- annealed in UHV for 10 min at 350°C.



AFM images:

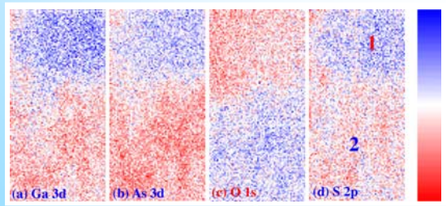
all images 50 µm x 50 µm
insets 2 µm x 2 µm

(a), (b): two different regions of **sample A**

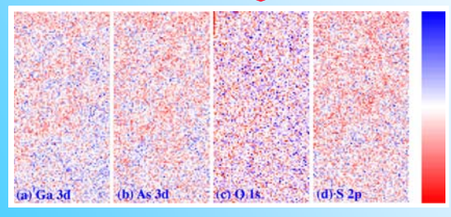
white spots = particles on the surface
passivation related
particles inhomogeneously distributed

(c): **sample B**

no particles
homogeneous surface

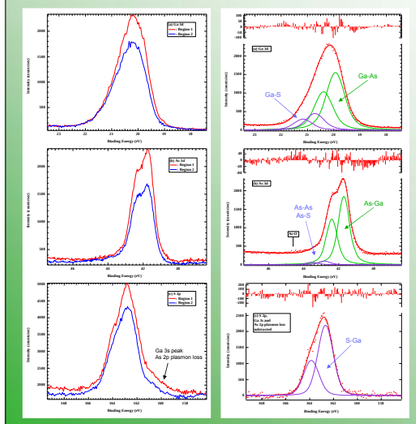


SPEM images of sample A
all images 6.4 µm x 12.8 µm
upper and lower half of sampled area different
Region 1: higher intensity at Ga 3d, As 3d, and S 2p
Region 2: higher intensity at O 1s
contrast inversion, chemical contrast



SPEM images of sample B
all images 19.2 µm x 38.4 µm
laterally homogeneous emission from all core levels

AFM and SPEM images consistent, but:
- different length scales
- different contrast mechanisms



Core level spectra of Regions 1 and 2 of sample A

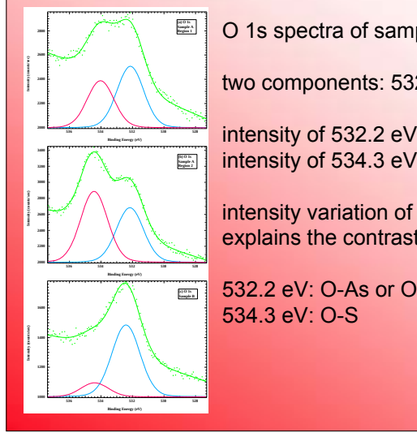
Peak shape and position approximately equal for Regions 1 and 2

No distinct differences in chemical composition

Peak intensities from Region 2 are 75% lower

Attenuation

- Spectra from sample B are virtually identical to the spectra from A
- S 2p / Ga 3d =1.5 for A and 1.1 for B [Ga 3d / As 3d = 1.2 for A,B]
- From position of Ga 3d and As 3d: CBM - $E_F \leq 0.2$ eV



O 1s spectra of samples A (Reg. 1 and 2) and B

two components: 532.2 eV and 534.3 eV

intensity of 532.2 eV component nearly constant
intensity of 534.3 eV component changes strongly

intensity variation of 534.3 eV component explains the contrast observed in SPEM image

532.2 eV: O-As or O-Ga
534.3 eV: O-S

Conclusions

- After the S-treatment, the surface of the GaAs substrate is covered by a S layer. The S bonds mainly to Ga.
- Sample A (w/o water rinse): inhomogeneous distribution of particles observed by AFM.
- SPEM: inhomogeneous distribution of O-S bonds.
- Water rinse removes the particles and reduces the amount of S at the surface.
- The particles are made of SO_x.
- Sample B (with water rinse): homogeneous surface.