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Cleaning influence on p-GaN surfaces for photocathodes with negative electron affinity

Introduction

- p-type GaN, grown on sapphire, is able to produce a negative electron affinity (NEA) surface when cesium is applied on it
- To achieve an atomically clean surface, a wet chemical cleaning and a vacuum thermal cleaning were investigated
- Ar^+ sputtering is possible to remove remaining carbon and oxygen from the surface

Fig. 1: preparation chamber of p-GaN:Cs

Methods

- A PHI 5600 spectrometer (average pressure of 4×10^{-9} Torr and Al Ka line (hv =1486.6 eV) from non-monochromatized x-ray source was used to analyze the surface after each treatment step
- SEM images were done on a Zeiss Nvision 40 FIB/SEM with an electron beam energy of 20 kV

Results

1) Wet chemical cleaning

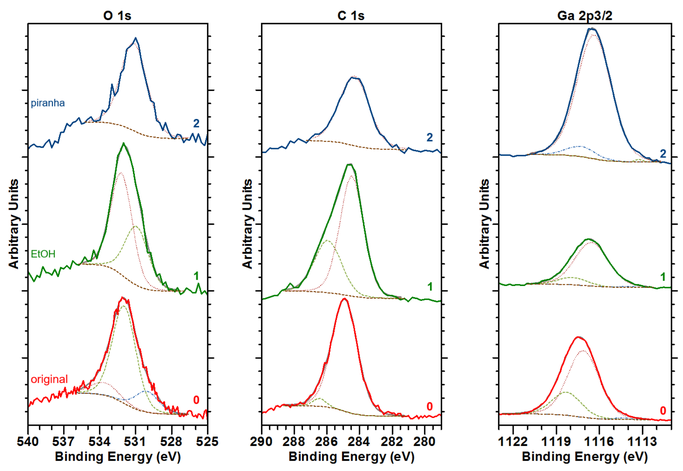

Figure 2: XPS spectra of the p-GaN surface 0) original p-GaN surface, 1) cleaned with EtOH and 2) piranha solution

Table 1: comparison of XPS results of the p-GaN surface

Sample	O 1s (eV)	At-%	C 1s (eV)	At-%
Original p-GaN	530.08	0.72	282.91	8.97
	531.96	3.33	286.45	0.32
	533.63	0.51		
Ethanol	530.92	1.82	284.47	8.89
	532.18	2.82	285.94	4.36
Piranha	531.14	2.13	284.31	3.55

→ Piranha cleaning results in lowest C and O concentration → Ga signal is more intensive

→ EtOH solvent residues remain on surface → Ga signal is less intense

2) Thermal cleaning and Ar^+ sputtering

- Several temperatures were applied to remove the carbon and oxygen

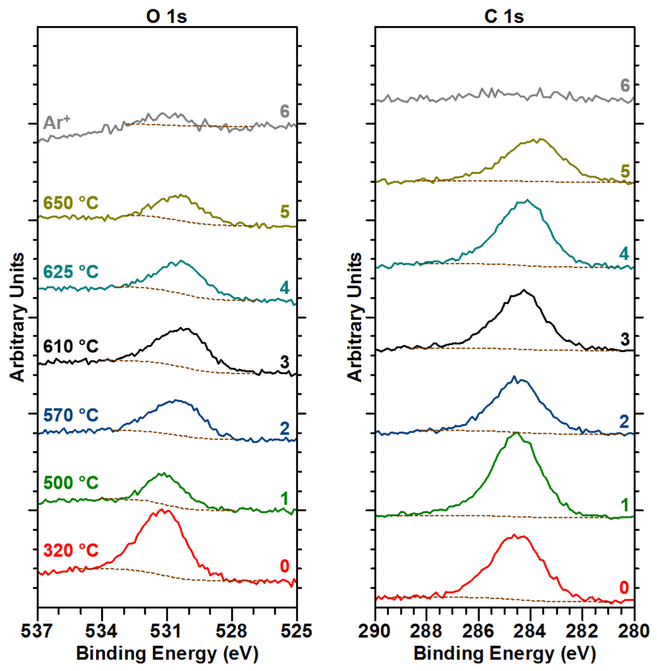

Figure 3: XPS spectra of the p-GaN surface after applying several temperatures and argon ion irradiation

- Oxygen and carbon remain on the p-GaN surface but could be reduced by thermal cleaning
- Using Ar^+ ions (1.5 keV) lead to a completely removal of C and O

3) Surface morphology

- XPS shows the depletion of nitrogen from the surface after using Ar^+ irradiation

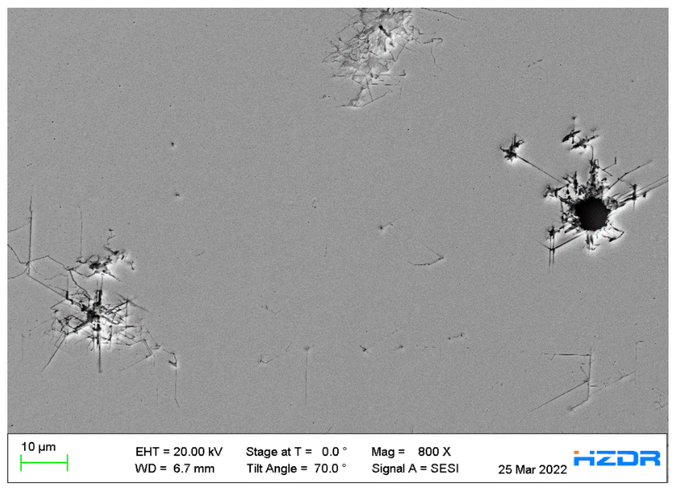

Figure 4: SEM image of p-GaN:Cs photocathode on sapphire, treated at various temperatures, irradiated with Ar^+ and activated with cesium

- SEM image shows irregularities (holes) in the surface, where the original p-GaN is destroyed
- Thermal cleaning at too high T and argon irradiation destroyed the p-GaN surface, and its ability to form a NEA surface

4) activation

- After cesium deposition: O and C show up again
- 724.7 eV: adsorbed cesium on p-GaN 727.6 eV: cesium with a strongly electronegative compound (cesium oxide or cesium carbide)

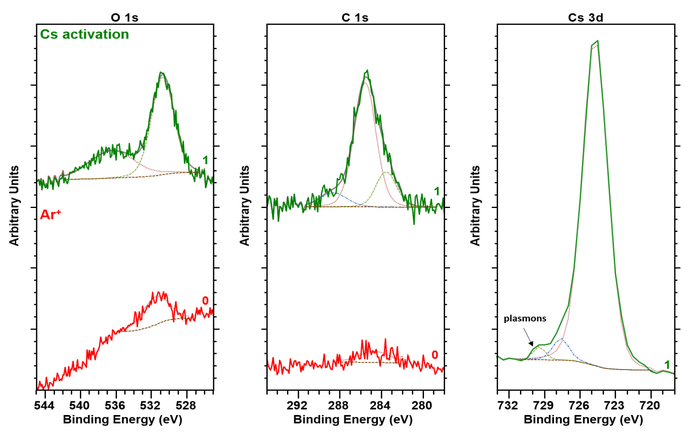

Figure 5: O, C 1s and Cs 3d XPS spectra of the p-GaN surface 0) after Ar^+ sputtering and 1) after cesium activation

Conclusion

- Wet chemical cleaning is good to reduce O and C to a few at-%
- Thermal cleaning cannot remove these contaminations completely
- Ar^+ sputtering leads to the desired effect of removing C and O completely
- **BUT**: excessive thermal cleaning and argon irradiation cause damage, resulting in no NEA photocathode
- Oxygen and carbon impurities are found after cesium activation
- Contaminations might derive from the mechanic transport (and/or from Cs source)

Outlook

- thermal cleaning at 450 °C was applied, followed by Cs activation
- A NEA photocathode surface is achievable although O and C remain on surface

Figure 6: XPS spectra of O, C 1s,Ga 2p and Cs 3d5/2 of p-GaN 0) after thermal cleaning at 450 °C and 1) after Cs activation

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