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Surface Characterisation and Preparation of Copper Photocathodes

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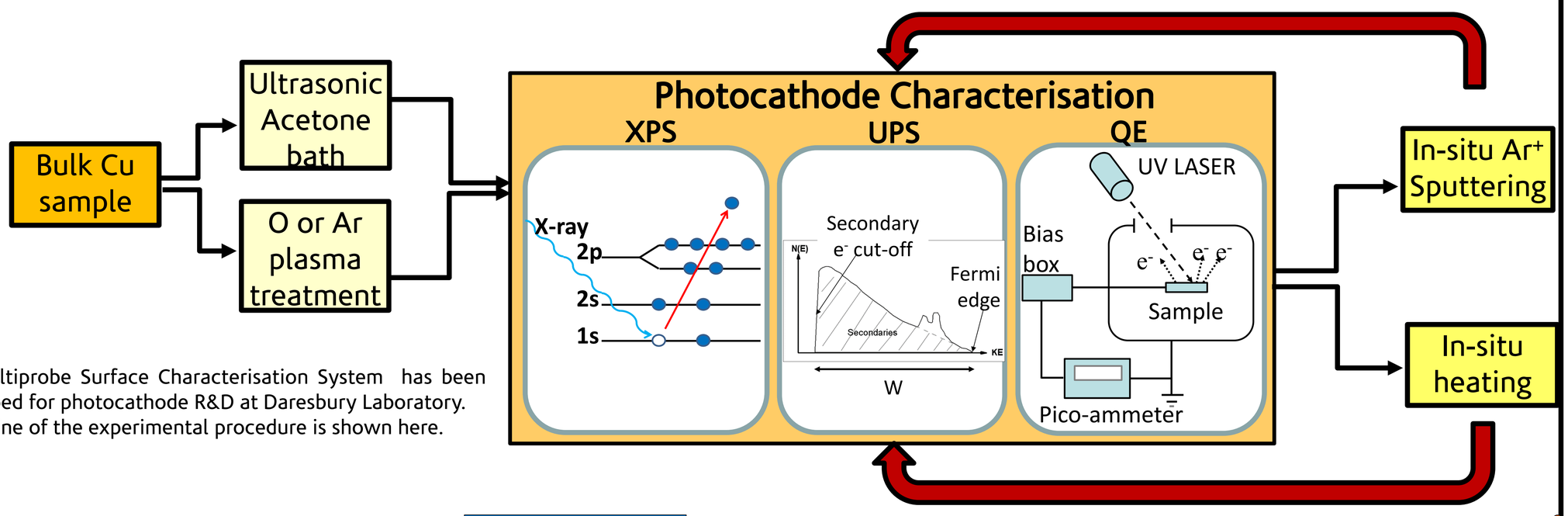
Abstract

The aim of this study was to investigate the preparation procedures of copper photocathodes for use in the CLARA accelerator (Compact Linear Accelerator for Research and Applications); the Free Electron Laser test facility at Daresbury Laboratory.
Each sample was cut from oxygen free copper and taken through four different preparation procedures.

A comparison of the surface composition, work function and quantum efficiency for each procedure is presented below.

Experimental Setup



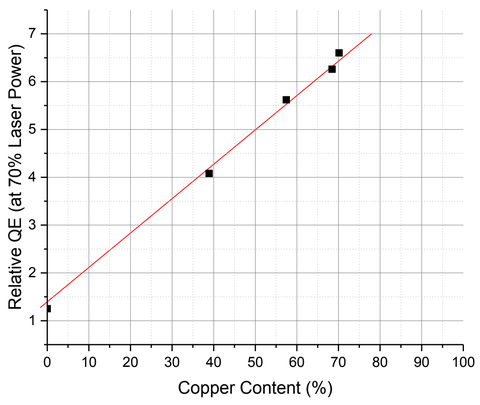
The Multiprobe Surface Characterisation System has been developed for photocathode R&D at Daresbury Laboratory. An outline of the experimental procedure is shown here.

Results

01_copper

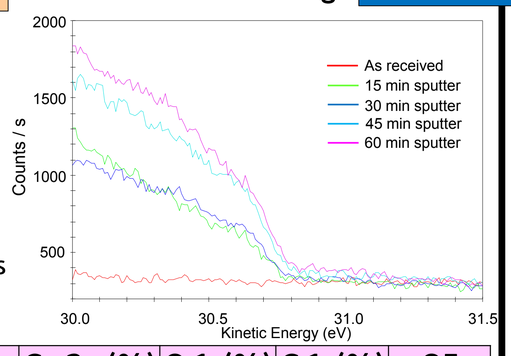
- Ultrasonic acetone bath
- 15 minute Ar^+ sputtering at 2 keV

Rel. QE as a function of Copper Content at 70% Laser Power



The QE is shown to increase with reduction of surface contaminants. Though the oxide was reduced down to trace levels, carbon persisted. The thick carbonaceous layer, though reducing with each cycle of sputtering is perhaps also mixing into the surface.

UPS Scan of Cu Fermi Edge



The cleaner the surface, the sharper the Fermi edge becomes thus enabling more accurate calculations of the ϕ.

	Cu 2p (%)	O 1s(%)	C 1s(%)	QE
As received	0.00	22.39	77.61	1.25
15 min sputter	38.92	7.55	53.52	4.08
30 min sputter	57.47	5.63	36.90	5.62
45 min sputter	68.47	0.00	31.53	6.26
60 min sputter	70.16	0.00	29.84	**6.60**

A Comparison of the Rel. QE yields for Cu samples

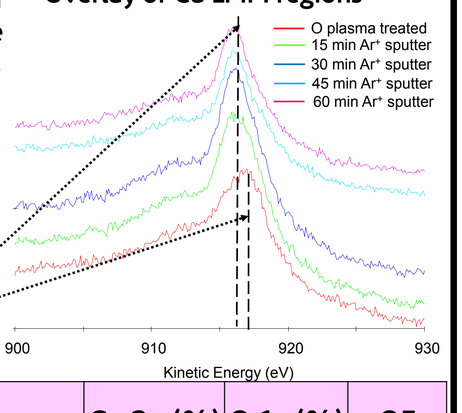
	Cu 2p (%)	O 1s(%)	C 1s(%)	QE
01_copper	70.16	0.00	29.841	**6.60**
02_copper	69.83	30.17	0.00	**1.21**
03_copper	100.00	0.00	0.00	**5.01**
04_copper	75.16	8.21	16.63	**9.34**

02_copper

- Ex-situ O plasma treatment
- 15 minute Ar^+ sputtering at 2 keV

To circumnavigate the issue of the adventitious carbon layer, oxygen plasma treatment was employed. Oxygen ions react with the surface hydrocarbons which are pumped away, and ultimately a CuO layer is formed on the sample.
Sputter etching the O plasma treated Cu produced a shift in the chemical state, from CuO to Cu_2O. This is evidenced in the spectra for the Cu auger regions.

Overlay of Cu LMM regions

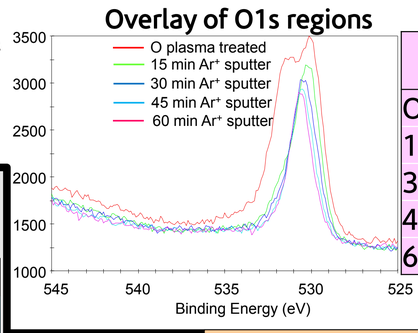


For 60 min Ar^+ sputter: Cu LMM = 916.1 eV

For O plasma treated: Cu LMM = 917.1 eV

Sputter etching the O plasma sample for 1 hour was insufficient to remove the thick Cu_2O layer.

Overlay of O1s regions



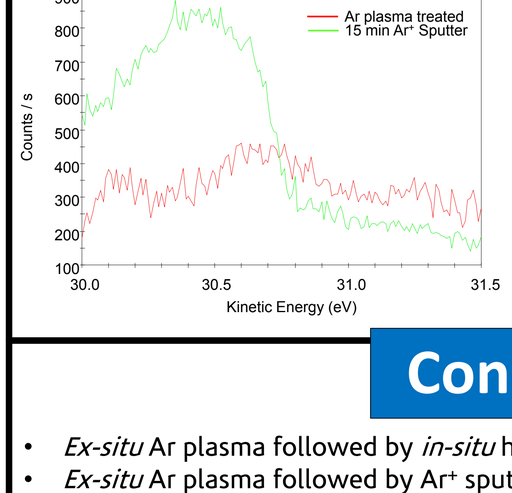
	Cu 2p (%)	O 1s (%)	QE
O plasma	55.44	44.56	1.07
15 min sputter	63.67	36.33	1.03
30 min sputter	69.83	30.17	**1.21**
45 min sputter	74.70	25.27	1.08
60 min sputter	72.27	27.73	1.10

03_copper

- *Ex-situ* Ar plasma treatment
- 15 minute Ar^+ sputtering at 2 keV

In place of O plasma, Ar plasma was used to reduce hydrocarbon contaminants. XPS data would suggest that as well as reducing carbon contamination, Ar plasma also reduces CuO (as received surface) to Cu metal. Ar plasma followed by a single sputter cycle is sufficient to reduce oxygen and carbon contamination to trace levels, producing the cleanest Cu metal surface of the 4 preparation methods described.

Overlay of Cu Fermi Edge

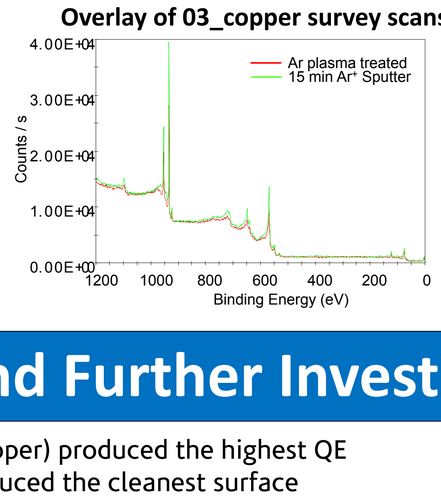


The reduction of oxygen and carbon produced a sharp Fermi edge from which a work function value of 4.27 eV was determined.

	O 1s	Cu 2p	QE
Ar plasma	21.44	78.56	1.00
15 min sputter	0.00	100.00	**5.01**

Upon sputter cleaning the QE improves by a factor of 5. This could be as a result of the reduction in oxygen contamination

Overlay of 03_copper survey scans



04_copper

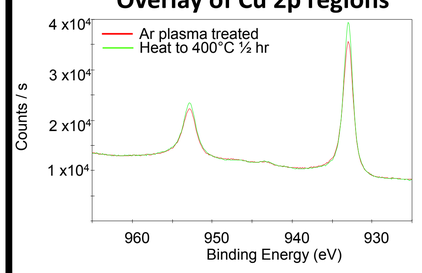
- *Ex-situ* Ar plasma treatment
- Heating to 400°C

This process was used to see if a clean surface was obtainable without Ar^+ sputtering. With respect to QE, a factor of 3 improvement is observed.

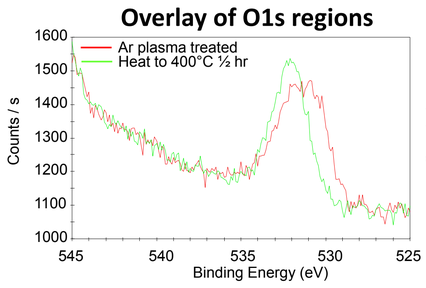
	O 1s	C 1s	Cu 2p	QE
Ar plasma	14.60	0.00	85.40	2.68
Heated 400 °C	8.21	16.63	75.16	**9.34**

Interestingly, XPS scans of Cu 2p, O 1s and C 1s (shown below) show that very little chemical change occurs upon heat treatment. So, what is the cause behind the increased QE? One possible explanation is that heating produces topographical changes to the Cu surface which serve to enhance the extracted photocurrent.

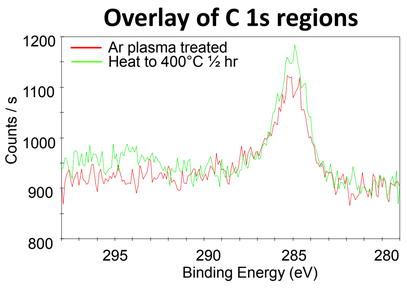
Overlay of Cu 2p regions



Overlay of O1s regions



Overlay of C 1s regions



Conclusions and Further Investigations

- *Ex-situ* Ar plasma followed by *in-situ* heating to 400°C (04_copper) produced the highest QE
- *Ex-situ* Ar plasma followed by Ar^+ sputtering (03_copper) produced the cleanest surface
- With Ar^+ sputter techniques, there seems to be a correlation between surface chemistry and QE
- In the case of 04_copper, the insignificant changes in surface chemistry suggest that heating had produced topographical changes which might account for the factor of 3 increase in QE

- Absolute QE measurements have not been possible due to potential space charge limitation effects and possibility of ion current, therefore further investigations in the QE measurement methodology is required
- Future studies will investigate how the topography of Cu surfaces vary with Ar^+ sputtering, plasma treatment and heating using *in-situ* Atomic Force Microscopy. These same preparation procedures will be employed on other metals such as Nb and compared with Cu

Acknowledgements

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