Structured low density coating studies leading to a novel coating plant design

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Abstract
Using vacuum deposition methods a range of micro-structured coatings of differing metallic elements have been fabricated for use on high power laser experiments in the CLF. Studies were carried out to determine how a range of process conditions affect the coating micro-structure and the studies were used to design a dedicated vacuum coating plant to produce micro-structured coatings.

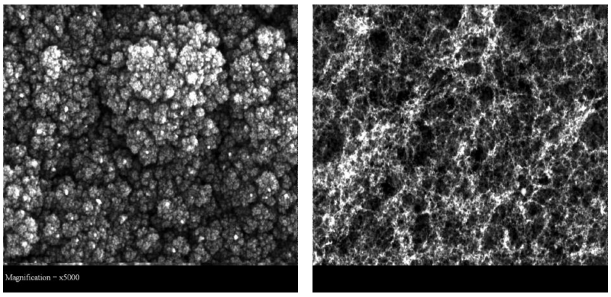
Introduction
There has been a significant amount of interest across the high power laser community in the use of a range of structured materials as laser targets and x-ray backlighters. Experiments have been carried out at the Rutherford Appleton Laboratory using the Astra laser to produce efficient He-α and K-α emission from Ti foils [1] and it was suggested that the efficiency could be improved if the foil had a 'smoked' surface to make it strongly absorbing. Experiments performed on smoked coatings showed an increase in yield of He-α [2] indicating an increased absorbance of the laser energy.

Since the initial success there has been an ongoing programme in the Target Fabrication Laboratory at RAL to produce low density microstructures and to understand the process conditions that affect their structure. An existing photocathode coating plant was utilised for the fabrication of the coatings which had the necessary vacuum and gas connections and initial studies were carried out to determine the main factors that affect the coatings.

Experimental Procedure
The smoked deposits were obtained by evaporating material from a tungsten evaporation source in an argon atmosphere at a pressure of approximately 2mbar. Deposition was performed on a variety of substrates including glass and metals. A range of materials were deposited prescribed by the experimental requirements. Results for both copper and titanium are discussed in this paper.

Evaporation was also carried out at a number of different argon pressures to determine the effect this had on the microstructures and typically the mass evaporated from the source was measured. In addition the deposition rate of the evaporation was varied and samples were taken from different places in the chamber to study the distribution of the deposition in the chamber.

Discussion
For the initial coatings there was a variation in the colour of the coatings that were produced with, for example, some of the titanium deposits being black and some having a blue tint. A range of samples were characterised using a SEM and representative images are shown in figures 1a and 1b. After analysis of many sets of electron micrographs it became apparent that there were two differing structures that had been fabricated. One was a 'cauliflower like' structure that covered the whole surface with no noticeable voids and the other a fibrous deposit with a large number of voids.



Figures 1a and 1b. Smoked titanium coatings showing differing microstructures. (10µm field of view).

Further depositions were carried out that examined the parameters previously mentioned. In these cases a recently purchased SEM in the Target Fabrication Laboratory was utilised to carry out immediate characterisation of the deposits. (This meant that there was less time for the deposits to degrade or oxidise.) The large amount of micrographs that were examined gave good information on the structural morphology of the deposits formed by the deposition condition changes that were made.

Some examples of these effects are shown in the micrographs below: 1) An increase in pore size in the fibrous coating due to an increase in the argon pressure is shown in figures 2a and 2b. 2) A change from a fibrous structure to a cauliflower like structure as deposition rate varied from a fast or slow deposition is shown in figures 3a and 3b. 3) An open irregular network formed when a slow leak of air was introduced into the chamber as shown in figure 4.

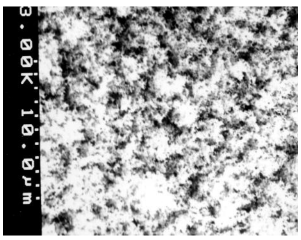


Figure 2a. Copper deposit exhibiting small pore sizes between filaments (formed at laser pressure).

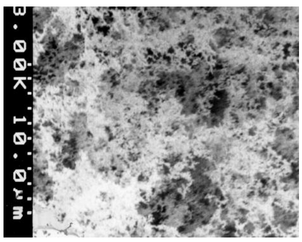


Figure 2b. Copper deposit exhibiting large pore sizes between fibres (formed at higher pressure).

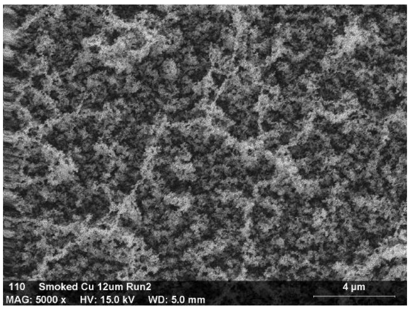


Figure 3a. Copper deposit exhibiting fibrous structure (formed at fast deposition rate).

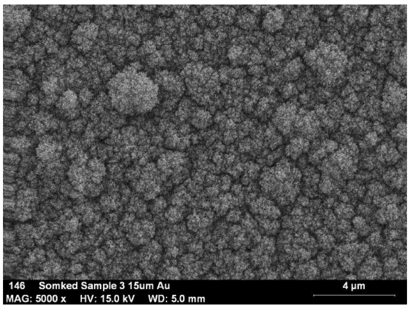


Figure 3b. Copper deposit exhibiting cloud structure (formed at slow deposition rate).

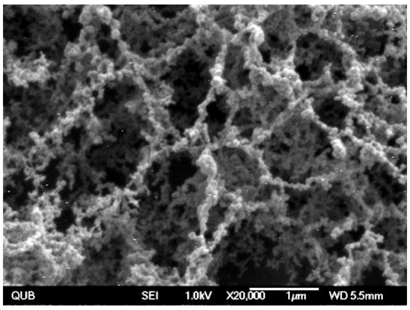


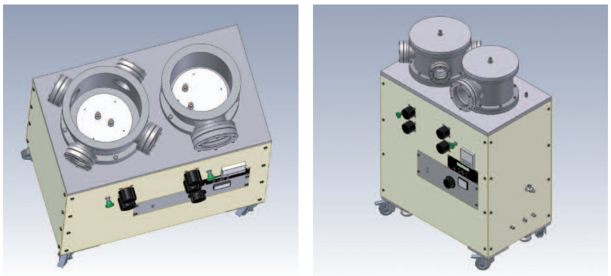
Figure 4. Copper deposit exhibiting open irregular network (formed by introduction of slow air leak).

Deposition Plant Design

Having carried out a study on the main factors affecting coating microstructures a design for a new dedicated coating plant was specified. The new plant is required to have a mass flow controller (to give control over the amount of gas injected into the chamber) and also to have a variable restriction on the pumping line (so that the pressure in the chamber can be controlled).

In the plant used for the initial coating runs the amount of gas that was pumped out of the system was not controllable. This meant that the argon inlet to gas throughput ratio was never constant and this was a possible factor leading to the variable coating structures. A novel idea of having two pumping lines was designed with one line for direct pumping to reach the required vacuum level and a second line being used with a variable (controlled) restriction in the line to give a variation in the pumping speeds that can be used. The restriction in the pumping line allows the gas to be pumped out from the chamber at a high or low flow rate and therefore has an effect on the time the smoked deposit is flowing in the chamber. The chamber was also designed to have gas flow from above the filament and pumped out from the floor of the chamber around a baffle. From these novel designs the plant gives a much greater control over the gas throughput and combined with the mass flow controller should give the control needed to produce specific structures and pore/clump sizes.

In addition to the smoked coatings deposition chamber a second vacuum chamber was designed with the same specifications to enable the production and investigation of smoked 'fluffy' photocathode materials. The design for the plant is shown in figures 5a and 5b and a picture of the completed plant is shown in figure 6.



Figures 5a & 5b. The design for the new plant.

Figure 6. The delivered plant ready to be commissioned.

Delivery was taken of the plant in July and initial commissioning is underway with the first coatings to be used on an Astra experiment in 2007.

References

1. D. Riley *et al.*, *Phys. Rev. E*, **71**, 016406 (2005)
2. F. Y. Khattak *et al.*, *Europhys. Lett.*, **72** (2), pp.242-248 (2005)