Full Face Erosion Planar Cathodes as a Low Cost "Cylindrical Rotatable" R&D Tool

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ABSTRACT

The industrial field of magnetron sputtering has seen a rapid transition from large area planar to large area rotatable cathodes. However, most R&D labs have continued with equipment that would require a large investment in order to implement relevant rotatable cathode technology. In many cases the downsizing on cathode diameter, and cathode length, has large implications in the relevance of the research itself. In addition the R&D lab find it very difficult to justify the large target consumable bill associated with the rotatable cathode targets. In order to facilitate suitable and relevant research, which could be applied to rotatable technology, this paper will present the use of circular magnetron sources with rotating plasma, which can simulate some of the benefits of the rotatable cylindrical cathode technology (such as a clean target, and the ability to maintain clean anode in a dual cathode sputtering). The paper presents the development of one of these tools. The sputtering of ITO target has been chosen as a comparative example between the planar and cylindrical target technology.

INTRODUCTION

Since the introduction of rotatable cylindrical magnetron technology by Mckelvey in 1984 [1], there has been a continuous migration in the industry from planar to rotatable cylindrical cathodes. The two main benefits of rotatable cathodes are the longer production campaigns, and the target cleanliness. The longer production campaigns are the product of more target material being available for the sputtering process and, as a result of the rotation, the target use tends to be high, usually above 70 %. This is achievable with relatively simple magnetic arrays. Planar targets, by contrast, require a complex magnetic field in order to enhance the target use above 25-30 %. The target use yield for planar targets is usually below 50 %. The cleanliness of a rotatable target has the added benefit in relation to coating defects, as particles are generated due to microarcing on a clean target [2]. By contrast, it is very unusual to have redeposition areas on planar cathodes below 10 % of the target surface.

The main drawbacks of rotatable targets are material availability, quality and price. In all those aspects, planar cathodes perform better. As the industrial applications move towards rotatables, then the availability of R&D tools to serve the rotatable development market would become very expensive. In addition, the R&D rotatable target inventory would become so expensive that it could, in many cases, be simply prohibitive. The alternative R&D planar target work, when applied to rotatable processes, can sometimes become very removed from the reality, This can result in the research not being conclusive enough to take the step into production.

The R&D market is dominated by small planar circular targets. Making their research meaningful to the rotatable target, whilst at the same time affordable, is the main reason behind the development of full face erosion (FFE) circular cathodes.

As an example of a challenging material, in terms of properties, the ITO represents the materials in which planar and rotatable results are difficult to compare. Therefore a study on the comparative data, obtained by rotatable cathodes and FFE, would be required to decide upon its relevance as a technological R&D proposal.

The concept for this comparison was based on the fact that in both types of equipment there would be a relative movement of the plasma, with respect to the target (see Figure 1). In the Rotatable cylindrical cathode the plasma would be static whilst the target would rotate. In the Full face Erosion (FFE) cathodes the target would be static while the plasma would be rotating. Therefore in both types there would always be material exposed periodically to plasma and no-plasma.

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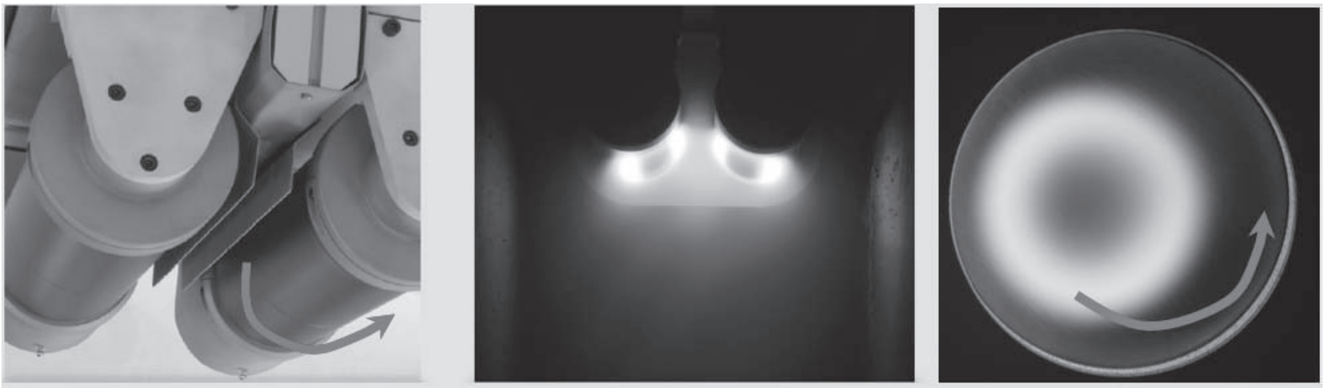

Figure 1: On the cylindrical rotatable targets (left) the plasma (centre) would be typically static while the target would rotate. In the Full Face Erosion cathodes (right) the target would be static while the plasma would be rotating.

EXPERIMENTAL

The main components of the experimental coating deposition setup (see Figure 2) were:

- Process chamber
- Ion source
- Ion source Power Supply
- Full Face Erosion cathode
- Magnetron power supply
- Process Controller
- Gas delivery

The process chamber was essentially a stainless steel cube vessel with dimensions of 36 cm 36 cm x 36 cm. The chamber was pumped to high vacuum by means of a mechanical pump and a Turbomolecular pump with 250 L/s effective pumping speed.

The ion source used was a Gencoa's IMC75, which is an Anode Layer Inverted Magnetron Ion Source (ALIMIS). The ion source Power Supply was Gencoa's iM300, which includes feedback control features enabling simultaneous control of ion current (ion density) and voltage (ion energy). The Process Controller was a Speedflo, although only open loop control was used in the experiments related to this paper The gas delivery was split between the main process chamber injection and the IMC75 ion source internal injection.

The magnetron sputter source was a 3" circular full face erosion source from Gencoa (FFE75). The power supply used for this source was an ENI RPG50 allowing DC, and DC-Puled modes, to be used. Both ceramic sintered (unspecified supplier) and plasma sprayed (SOLERAS) ITO 90:10 targets were used along with a power density of 2 W/cm^2.

Gases where injected via Mass Flow Controllers (MFCs), MKS1179A type. Ar (5N0) and O_2 (4N5) were used. In the case of the Oxygen a 10 sccm range MFC was used in conjunction with Ar 50 sccm range MFCs. For the FFE75 ITO depositions a 5.2 mTorr pressure was used. All depositions were carried out at room temperature. Substrate were microscope glass slides (26 mm x 76 mm x 1 mm). Samples were rotated at 6 rpm.

The FFE75 magnetic pack was rotated between 7 to 100 rpm (depending on the experiment). Before deposition, ion cleaning pre-treatment using the IMC75 was applied. The voltage was 1500V, and the current 30 mA. In some experiments additional ion bombardment was applied during the sputtering deposition (IMC75 at 1.1 kV and 45 mA). As the deposition system lacked in-vacuum heating, some post annealing in atmosphere at 200ºC was carried out. This was done to compare with the results of in-vacuum deposition obtained with heated substrates using rotatable targets (these were observed at room temperature, 150ºC and 300ºC [3]).

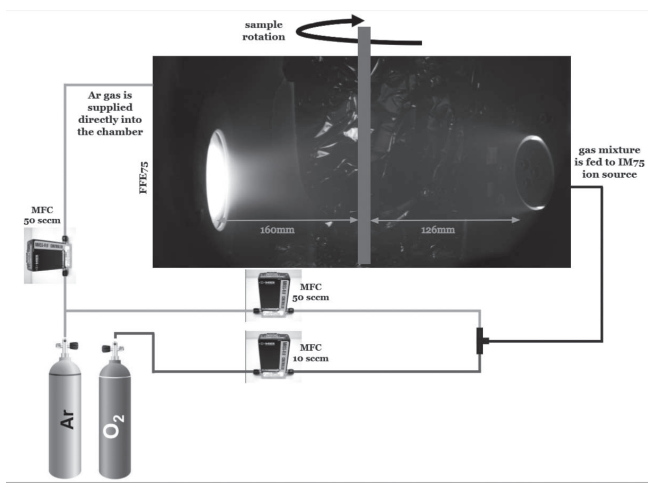

Figure 2: Experimental deposition setup using the FFE75 magnetron sputtering cathode and the IMC75 ion source. The samples rotated in front of both the ion source and the cathode. The current setup enabled the possibility of a near-simultaneous deposition and additional ion bombardment. Typically the ion bombardment was used for the purpose of ion cleaning the surface prior to surface deposition. The system also used a shutter so the ITO target surface could be cleaned before deposition. The ion source could operate with Ar, O_2 or a mixture of both gases.

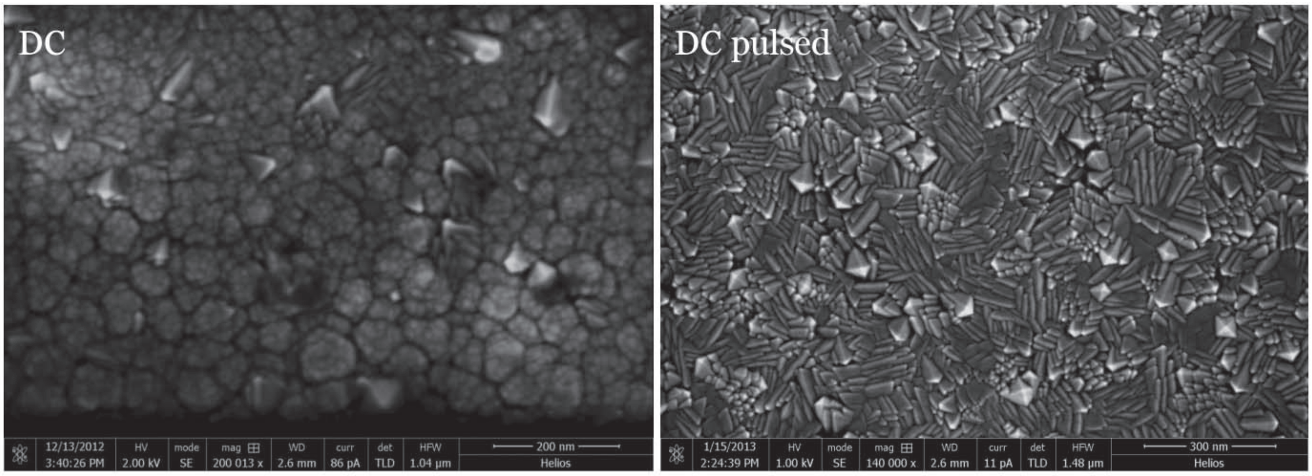

Figure 3: Top surface SEM of Rotatable ITO deposited at 150 ºC using DC (left x 200k magnification) and DC-pulsed (right x 140k magnification). The ability to produce a more orderly crystal structure is evident on the DC-pulsed, as extra energy is given to the growing substrate. The DC deposition present some large crystal among a more disordered basic structure.

A Nagy SD600 4-point probe was used to determine the sheet resistance. Inficon 12.4 mm 6MHz Gold coated crystal sensors were used to determine coating deposition thickness. A Heraeus Noblelight UV-VIS-DTN 6/50 lamp and Ocean Optics USB2000 were used on a device in order to measure light transmission of coated glass slides. An average of 50 spectra was used. The difference in transmission, with respect to an uncoated substrate, was used as the reported value of the coating transmission i.e. the uncoated transmission is assumed to be the 100 % transmission value at any particular wavelength.

Rotatable ITO deposition was carried out using Gencoa's DLIM magnetics. Targets were cylindrical 450 mm long x 150 mm diameter ITO ceramic sintered targets (UMICORE) on a stainless steel backing tube. The targets were mounted on a large vacuum deposition equipment (Gencoa), with internal dimensions of 600 mm ID x 4000 mm length. The targets were installed using side mounted SCI MM endblocks. An effective pumping speed of approximately 2000 L/s turbo pumping was used for pumping. The experimental results using the above configuration have been previously presented elsewhere [3]. SEM images were performed at the Nanoinvestigation Centre at Liverpool (NiCaL).

RESULTS AND DISCUSSION

Results for the sintered ITO cylindrical rotatable targets have already been presented elsewhere [3]. The experimental setup allowed heated substrate deposition. In the experiments the influence of the power mode in the coating crystallisation was clearly visible. Figure 2 shows depositions on DC and DC-pulsed at 150ºC. The structure in DC presents some crystals among a more disordered structure. The DC-Pulsed surface presents a large grain highly ordered crystal structure. When

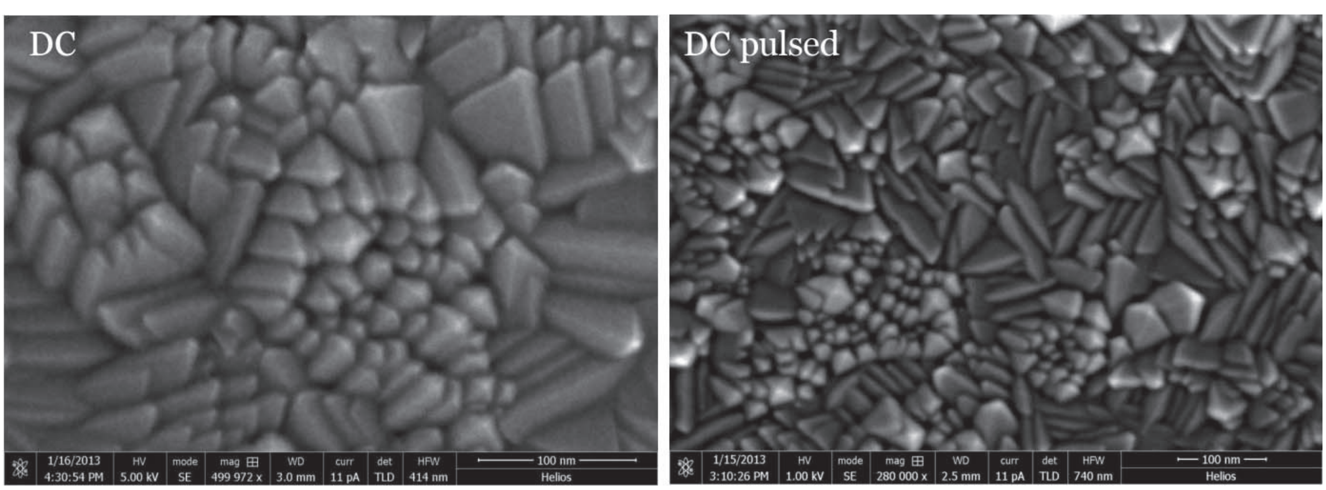

Figure 4: Top surface SEM of Rotatable ITO deposited at 300ºC using DC (left x 500k magnification) and DC-pulsed (right x 280k magnification). At this level of temperature, both DC and DC-pulsed give similar highly ordered crystal growth.

comparing the structures obtained at 300ºC (see Figure 4) the DC deposition was able to produce a highly ordered large grain crystal structure. The DC-pulsed surface did not present any improvement on that front when the deposition temperature was 300ºC.

Overall results obtained using cylindrical rotatable targets have been consistently inferior to those obtained using planar targets. A large production volume is still performed using planar cathodes (see Figure 5).

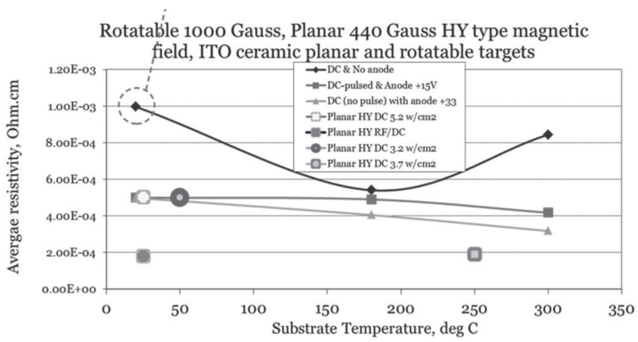

Figure 5: Comparative data of ITO deposition using industrial cylindrical rotatable and industrial planar cathodes (static arrays). Traditionally the results using rotatable targets have yielded higher resistivity values for the deposited ITO, both at low temperature and at high temperature. The highlighted result would be compared with the FFE deposited film (see Figure 6).

The room temperature tests, using rotatable cylindrical targets, served as a comparison for the room temperature tests carried out using the FFE75 circular cathodes.

Resistivity results for the experiments using the FFE75 sintered target can be seen in Figure 6. One of the main factors influencing the properties of ITO is the target voltage. Typically the FFE target voltage would increase with the rotating speed. Therefore, the best results were obtained from the lower speed condition. Also at room temperature the best results, in terms of conductivity, were obtained for DC rather than DC-pulsed. In general, for the sintered target, a narrow zone of optimal properties could be found, and the ion-source additional bombardment had a detrimental effect of resistivity. Resistivity increased with the ion bombardment (see Figure 6).

In regards to coating transmission, it was generally considered that Pulsed-DC offered better transmission than DC, with the exception of the singularity when the oxygen partial pressure is increased. The combination of resistivity and transmission data would limit the best ITO properties to a narrow band of deposition conditions.

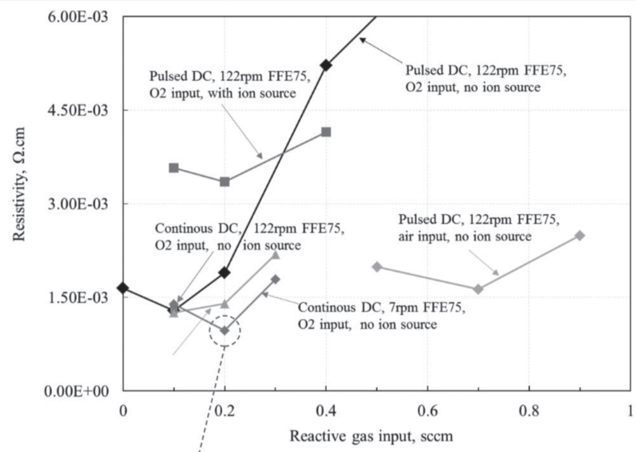

Figure 6: Resistivity data for a FFE75 using a sintered ceramic ITO target. All depositions were carried out at room temperature. Different plasma rotation speeds and power modes were used. The highlighted result using DC, 7 rpm plasma rotation and 0.2 sccm O_2 was the same as the one obtained when using an industrial rotatable target deposition at room temperature.

However, the plasma sprayed ITO target offered some interesting results. Compared to sintered targets, and due to the particular stoichiometric preparation of the target by its manufacturer, a higher amount of O_2 was added during the ITO sputtering (see Figure 7). In addition, the deposition using the sprayed ITO target produced a wider O_2 band zone were the process could be operated. This allowed a better control of the results.

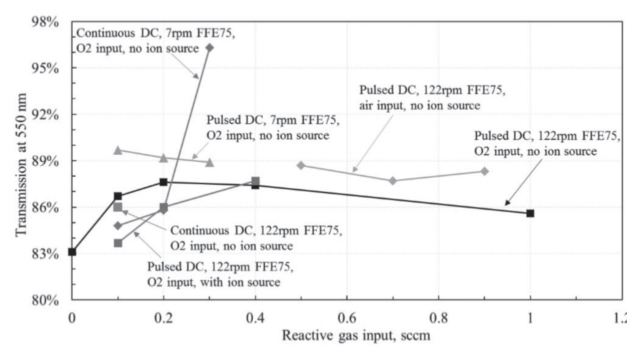

Figure 7: Transmission value at 550nm wavelength for the sintered target FFE75 depositions. The best conductivity value (Figure 5) had a transmission around 86 %. The highest transmission value required a DC, low rpm plasma and high O_2 input.

Results after post-annealing can also be seen for the sintered and plasma sprayed targets (see Figure 8). In general the post-annealing, when applied to the best low temperature samples of the sintered target, did not improve resistivity values. However post-annealing, in general, improved the resistivity when applied to samples obtained using the plasma sprayed target. The resistivity values of the post-annealing process were less sensitive to the deposition condition, offering an easier degree of control. This factor would have important applications when considering its industrialisation.

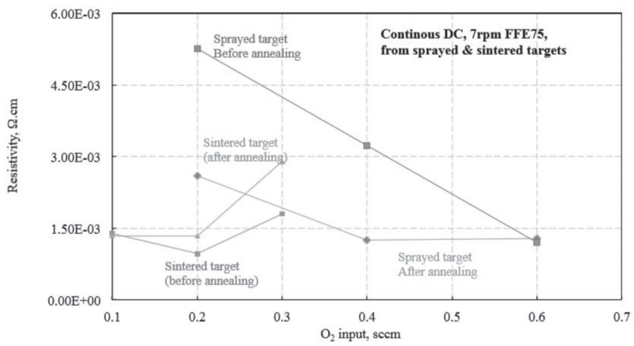

Figure 8: Conductivity values for FFE75 depositions using DC, 7 rpm, for both sintered and sprayed ITO targets. Also the resistivity after annealing was measured. In the case of the sprayed target after annealing at 0.4 sccm O_2 the resistivity values coincided with the 0.2 sccm of the sintered target. It was noticeable how the area of properties, for annealing on the sintered target, offered a wider range of control which from an industrial point of view would be important.

Figure 9 presents the transmission spectra of the referenced cylindrical rotatable target (at 150ºC) and the sintered and plasma sprayed targets. The larger the O_2 flow the better the transmission. Also the post-annealed sample spectra can be seen represented. Transmission improved with post-annealing. In conclusion it could be seen how the transmission values of FFE75 samples were similar to those of the cylindrical rotatable.

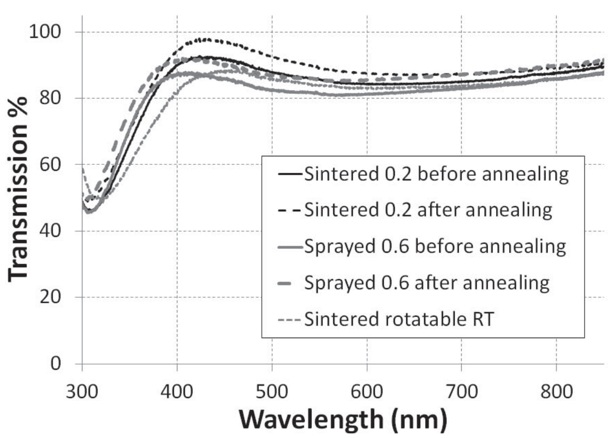

Figure 9: Transmission spectral data for sintered and sprayed ITO FFE75 targets. Results of post-annealing (at 200 C) were compared with sintered rotatable target deposited at 150ºC.

CONCLUSIONS

There is a large gap between the traditional R&D magnetron sputtering product and industrial cylindrical rotatable market. The use of full face erosion (FFE) cathodes offers an R&D alternative to the planar cathode development using cylindrical rotatable cathode technology. FFE technology would present a lower investment cost option for researchers An application to ITO targets using FFE planar cathode has been demonstrated. Low rpms (in the FFE magnetic array) produce similar results to cylindrical rotatable ITO depositions. The FFE research has demonstrated that the Plasma Sprayed ITO target offered a very viable alternative to the traditional sintered ITO target.

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OBITUARY

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