GRS for ITO processes

Use of rotatable magnetrons for low damage ITO layers

There is a strong market demand for deposition of transparent conducting oxides directly onto sensitive substrates such as organic devices to simplify the device structure and improve performance. The organic nature of the substrate material prevents the use of an elevated temperature during deposition and plasma damage reduces the device performance. Hence the need to create an ITO layer at room temperature and without process plasma damage. The typical organic material of interest for devices such as OLED's is an aluminium (III) bis (2-methyl-8-quninolinato)-4-phenylphenolate (BAlq) layer. It has been shown that bombardment of high-energy particles, such as ions and electrons, to the organic layer leads to serious degradation of the performance [1]. Current methods to solve the problem rely upon less efficient means such as magnetically confined face-to-face sputtering from planar targets or electrically biased grids between the source and substrates. In order to achieve a more efficient production means, Gencoa have configured rotatable magnetrons with a combined magnetic and electrical trap to strongly reduce the sputter target voltage and collect electrons efficiently from the plasma. This combined action allows the deposition of ITO layers at room temperature with superior properties to layers deposited at 300ºC.

Rotatable magnetrons & active anode

Gencoa have developed a means to efficiently collect plasma electrons from a rotatable magnetron discharge by a combined magnetic and electric field, see figure 1 [2]. A magnetic field 'bottle' is formed between the two targets into which the electrons are confined with the positive electric bias of the anode drawing the electrons. This method provides an ideal means to collect 100% of the plasma electrons. It also enhances long term stability of rotatable magnetron sputtering, and allows reactive sputtering of dielectric materials with pulsed DC as opposed to AC power.

ITO Low voltage sputtering & electron collection

Deposition of the highest quality sputtered ITO layers are usually performed at low target voltages (the order of 220V) in combination with elevated substrate temperatures (300°C). The importance of a low sputter voltage is related to a reduction of negative oxygen ion bombardment of the growing film. As the target voltage is reduced, the energy of the oxygen ion bombardment is reduced, which reduces the damage imposed upon the growing film structure and hence increases the electrical conductivity of the layer [3]. A low voltage is achieved by very high strength magnetic fields over the target surface. For a planar magnetron, this high field strength strongly reduces the target yield (<20%), resulting in a higher cost process. By dynamic movement of the magnetic field over the planar target, target usage can be improved, but typically only in the 40-50% range. The moving of the field introduces a modulation of the plasma properties which can be seen as a layer property modulation, so is not an ideal solution.

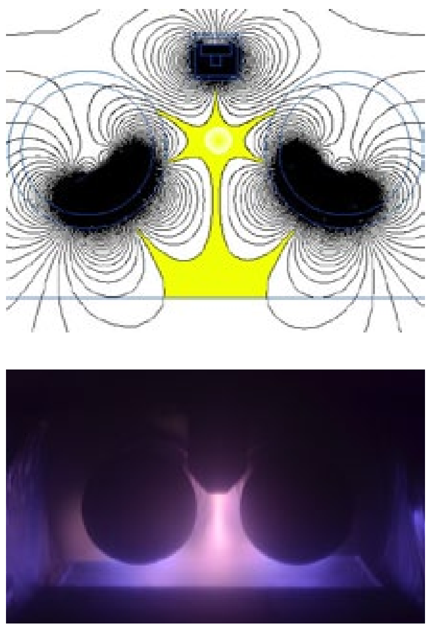

Figure 1

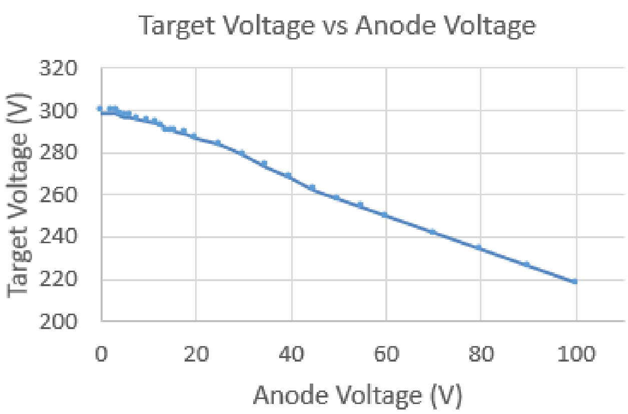

Figure 2

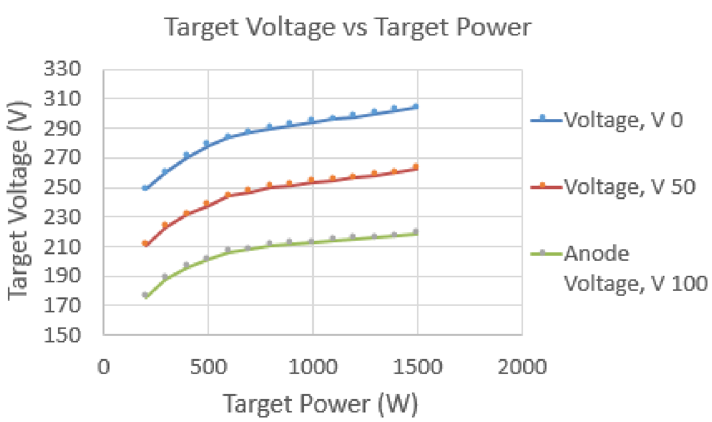

Figure 3

Rotatable magnetrons with their target motion naturally improves the target use to the >80% level. This motion also reduces ITO target nodule formation, which is a problem for most planar magnetron sputtering situations. However, a downside of using a rotatable magnetron is the lack of a dark space shield to confine the plasma close to the target and collect the plasma electrons as they leave the plasma trap. Preventing plasma bombardment of the ITO layer and in particular oxygen ion damage is a very important consideration

Sputter voltage reduction for rotatable magnetrons via active anodes

A method to confine the plasma close to the rotatable magnetrons is possible by using the afore mentioned combined magnetic and electrical field to direct the electron flow to the rear of the target and away from the substrate area (see figure 1).The variation of the positive bias voltage on the anode has a profound effect on the target voltage potential – any increase in the anode potential has a corresponding 'like for like' decrease in target potential, see figures 2 and 3. Measurements have been made on a Gencoa dual GRS rotatable magnetron system with an ITO target OD of 90mm and 350mm length. The magnetic field strength over the target is 700 Gauss and the plasma characteristics and ITO layer performance has been compared with respect to the applied anode positive potential.

Without any anode present, the target discharge voltage is 360 Volts at the equivalent 1.2 kW DC power on each target. When the special magnetic linking to the anode is introduced, the magnetic bottling reduces the voltage to 300V via the lower impedance of the overall magnetic trap. By then increasing the positive bias potential on the anode the target voltage potential is shifted to 218 volts at the 1.2 kW power level. A higher potential than +100V would presumably reduce the voltage below 200 Volts. In addition, as these targets are small in terms of diameter and length, both the magnetic field strength and plasma volume are lower than is achieved with a 152mm OD production-sized target. From previous experiments with a 152mm OD ITO dual target of the same 350mm length at 1200W power, the target voltage with an active anode fitted at 0V potential, is 260 volts. Hence the target voltage in this situation will be shifted below 200 volts with 70 volts positive anode bias. It is expected that this reduced target voltage will be highly beneficial to reduce damage of organic substrates. The additional effect of collecting all the electrons from the discharge will likewise protect the organic device performance.

ITO material properties with the active anode

Experiments to determine the effect of the active anode on the ITO layer properties show that good layer properties can now be achieved at room temperature. Figure 4 shows benefits of introducing the anode effect. The measurements are the average resistivity taken from 130nm ITO layers deposited 'statically' in front of the targets, with optimized oxygen gas conditions.

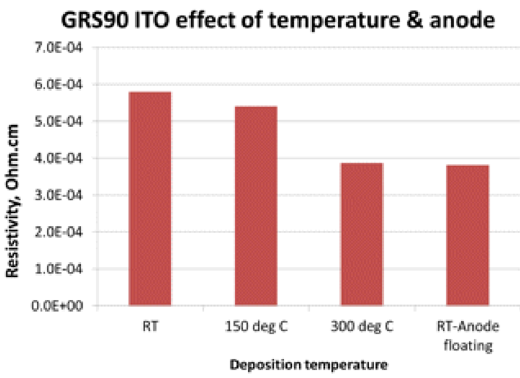

Figure 4

There are a large number of possible process combinations available in order to fully optimize the active anode for ITO layer production (variables are magnetic tilt angle & strength, target power level, mode and pulse frequency & active anode bias level). Initial data in this small scale test shows that films deposited at room temperature can have equivalent properties of layers deposited at 300°C. By optimizing the other variables, room temperature layers should be superior to the higher temperature production of ITO.

Installing a low temperature ITO process with active anodes

In order to upgrade an existing single or dual rotatable installation, both an active anode and new target magnetic bar(s) are required. In addition, the active anode needs to be connected to the floating output of the target power supplies earth return (this is the floating arrangement). Alternatively, a separate power supply is used to bias the active anode to higher voltages. The suitability of the existing magnetron power supplies would also need to be assessed (not all power supplies allow this type of floating output anode return). Tuning of the new process parameters would then be required in terms of the optimum oxygen flow and the best relative tilt angle of the magnetics. Please contact Gencoa for assistance with all these aspects.

[1] Y. Onai, T. Uchida, Y. Kasahara, K. Ichikawa and Y. Hoshi, Thin Solid Films 516, No. 17, 5911-5915 (2008).[2] Gencoa patent, GB2454964 EP2186108 WO2009022184 [3] S.Ishibashi, Y. Higuchi, Y.Ota, K.Nakamura, J.Vac.Sci.Technol. A8 (1990) P 1403

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