Roll-to-roll deposition of ITO film on a flexible glass substrate

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ABSTRACT
Roll-to-roll deposition of ITO film on a flexible glass roll, 50µm thick, 300mm wide and 10m long, was made successfully by magnetron sputtering at elevated substrate temperature. The ITO film on the flexible glass showed a sheet resistance of 7.5 ΩSq at 190 nm, and a resistivity is calculated as 143 µΩcm. SEM observation and XRD analysis suggested good crystallinity of ITO coating.

1. INTRODUCTION
Flexible glasses are very thin glasses below 100 µm, and flexible enough to be wound in a roll. Some of the glass manufactures have started the fabrications of such flexible glasses for cutting edge products including touch screen panels and display devices like OLEDs and LCDs.[1,2] And the success of roll-to-roll deposition of ITO film on the flexible glass was reported at the 55th Annual SVC Technical Conference in May 2012. [3]
Flexible glasses have attractive features as substrates for plasma process as reported in reference 1. They have low thermal expansion coefficient as low as 3.8x10^-6/°C which enables fine patterning required for display applications. The strain point is 650°C, so they have enough heat resistance for TFT fabrications. Their barrier properties are excellent, water vapor transmission rate (WVTR) below 7x10^-7g/m^2/day, which is good enough for the applications of OLEDs. The surface roughness (Ra) is around 0.1-0.2nm without polishing and the transmittance is 92% at 550nm. In addition, such excellent substrates can be supplied as in a roll.

Therefore, the interests in a roll to roll deposition on flexible glasses are growing. However, there are issues coming from the fact that the flexible glass is a glass. Even though they have flexibility to be wound into a roll, they are still easy to break, and there are difficulties for handling of the flexible glasses. From such situation, we attempted to make a roll-to-roll sputter deposition of ITO on a flexible glass roll. This paper describes the result of our trial of the roll-to-roll ITO coating on the flexible glass. Also described are the properties of ITO film on the flexible glass.

2. EXPERIMENTAL

2.1 Deposition
The flexible glass roll for deposition was supplied from Nippon Electric Glass Co., Ltd. The size of the flexible glass is 50µm thick, 300mm wide and 10m long and it was connected with the plastic lead film for easier setting to the roll-to-roll coating machine and wound around a 6-inch core together with the protective plastic film.

For the deposition, series W35 multi-functional sputter roll coater for R&D was used (Fig. 1). The system features compact size, small footprint and easy maintenance, which are realized by its unique structure; a film winding system supported by the front and rear walls of the chamber and two side doors equipped with process sources i.e. sputter cathodes.[4] The system had been originally developed for the handling of 350mm wide plastic web, so we made minor modifications on it to enable handling of a flexible glass roll.

At the deposition, after removing the protective film, the flexible glass is transported via
roll-to-roll web handling system, and ITO deposition is made from a DC magnetron sputtering source on a temperature controlled deposition drum, and then the glass substrate is rewound into a roll with the protective film on a 3-inch core. The system has a capability to control the deposition drum from 40 to 300°C. We intend to demonstrate one of the advantages of the flexible glass, so that we chose 300°C, maximum temperature. By this setting, we estimate that the substrate temperature during the deposition is not less than 250°C.

As a target, a 10wt% SnO₂-doped ITO target was used and it is sputtered by plasma generated by 30kHz pulsed DC power in the range of 1kW to 3kW in Ar and O₂ gas. In the experiment, we intended to obtain a coating with low sheet resistance below 10ΩSq, and proper conditions were chosen to obtain such coating.

2.2 Characterization

After the deposition, electrical properties of the ITO films were measured by a Hall effect measurement system “ResiTest8330™” from TOYO Corporation. As for optical properties, total light transmittances were measured by a haze meter “NDH 5000™” from Nippon Denshoku Industries Co., Ltd. The morphology of the ITO coating was observed by SEM and the film thickness is determined by the cross-sectional observation.

Crystalline was detected by a X-ray diffraction system “Smart Lab™” from Rigaku Corporation, which was operated by thin-film method.

3. RESULTS

3.1 Roll to roll deposition of ITO on flexible glass

A successful roll to roll deposition of ITO on 300mm wide 50um flexible glass was carried out without any fractures or damages of the substrate. The deposition was made by heating up the main drum up to 300°C, which was not possible for usual film substrate, but no visible wrinkles or thermal damage was not observed though the process. Fig. 2 shows the outlook of the roll of the 50um thick flexible glass up to 10m with ITO wound around a 6-inch diameter core.

3.2 Properties of ITO film deposited on flexible glass roll

ITO film on the flexible glass showed a sheet resistance as low as 7.5ΩSq. The thickness of the coating was measured as 190nm, and a resistivity and a carrier concentration were calculated as 143μΩcm and 1.17 × 10²¹cm⁻³. The mobility was
measured as 37.3 cm²/Vs. These electrical properties of ITO coating was superior to the one obtained on plastic films. The resistivity was about 50% of one on the plastic film roll. The biggest factor for this improvement was the enhanced carrier density, which was probably due to the good crystallinity of the coating promoted by high temperature of the main drum. Furthermore, there was no crack on the ITO coating.

The optical transmittance was measured as 83%. A yellowish appearance often found in ITO coatings deposited at low temperature was not seen.

SEM image of the ITO film on the flexible glass is shown in Fig. 3. The thickness of ITO for the calculation of the electronic properties was measured from this image. Both the surface condition of the ITO film and the image in cross-section show that the ITO film was well crystallized. That is why the light transmittance and the electrical properties of that are excellent. However the surface morphology with apparent crystalline structure may not be good for some applications as OLEDs, so we need an optimization of the condition of ITO deposition.

Fig.4 shows X-ray Diffraction diagram of the ITO film on the flexible glass. It is also apparent that the ITO film was well crystallized because the typical crystalline ITO peaks appear in this figure. All these results prove that the flexible glass has been sufficiently heated up with heat radiation from the main drum during the ITO deposition.

4. SUMMARY

Successful roll to roll deposition on a flexible glass roll has been demonstrated using a compact sputter roll coater with some modifications.

ITO film of 190nm was deposited on the 50μm thick, 300mm wide and 10m long flexible glass, and indicated the sheet resistance of 7.5ΩSq and the resistivity of 143μΩcm. The transmittance of the ITO film on the flexible glass totally was approximately 83%. The crystallization of ITO coating was confirmed by a SEM observation and a XRD analysis.
REFERENCES