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

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Introduction

- Roll-to-roll production has been wide-spread by using plastic films like PET.
- We already can see some flexible devices like amorphous Si solar cells in the market.
- Some of the glass manufacturers have started fabrications of flexible glasses.

Motivation of our initial attempt of roll-to-roll vacuum coating on the flexible glass
Flexible glass

- Provided by Nippon Electric Glass Co., Ltd.
- Thickness is below 100 µm
- Wound around 6-inch core with a protective plastic film
- Dimensional stability:
  \[3.8 \times 10^{-6} / ^\circ\text{C} \text{ (30 - 380 } ^\circ\text{C)}\]
- Barrier property:
  \[\text{WVTR} < 7 \times 10^{-7} \text{ g/m}^2\text{day}\]
  \[(85 ^\circ\text{C}, 85 \text{ %RH)}\]
- Surface roughness (Ra):
  \[0.1 - 0.2 \text{ nm (without polishing)}\]
- 50µm glass can be rolled at a radius of 40mm.
  (It depends on the breaking stress of glass)

T. Murata et. al.; "Ultra thin glass roll for flexible AMOLED display", 11th International Display Workshops Proceedings, 2011
ITO Deposition System (W35 type Sputter Roll Coater)

- Compact & small footprint
  - Box Shaped Chamber, 1-Chamber 1-Zone
  - Large Doors at Both Side with Process Units
  - Good access to Film Roll & Rollers
  - Good access to Deposition Shield for Cleaning and Replacement
ITO Deposition System (W35 type Sputter Roll Coater)

- A variety of deposition source
  - DC sputtering cathode
  - Dual magnetron sputtering cathode
  - Ion source for pretreatment
- A 400-mm diameter main drum and 3-inch guide rollers
- Temperature of the main drum can be varied in the range of 40 - 300°C
- An available film size is 350mm wide, 100µm thick and 200m long
- Excellent handling performance of plastic films (PET, PEN, PI…) and metal foils (Al, Cu, SUS…)
Goal for the experiment

Goal for the experiment: < 10 ΩSq ITO coating on a 50µm glass

How about handling of a flexible glass with a protective film?

We successfully achieved ITO coating on a 50µm-thick, 300mm-wide and 10m-long flexible glass without fracture!
# Experimental procedure of ITO coating

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td><strong>Deposition</strong></td>
<td>KOBELCO W35-350S type sputter roll coater</td>
</tr>
<tr>
<td><strong>Substrate</strong></td>
<td>A 50µm thick, 300mm wide and 10m long glass with a protective plastic film</td>
</tr>
<tr>
<td><strong>Sputtering</strong></td>
<td>A 10wt% SnO₂-doped ITO target (120mm x 500mm)</td>
</tr>
<tr>
<td><strong>Cathode</strong></td>
<td>30kHz-pulsed DC 1000 W – 3000 W</td>
</tr>
<tr>
<td><strong>Process</strong></td>
<td>Optimized amount of Ar &amp; O₂ (0.3 – 0.4 Pa)</td>
</tr>
<tr>
<td><strong>Main drum</strong></td>
<td>300 °C during ITO deposition</td>
</tr>
<tr>
<td><strong>Rate</strong></td>
<td>12.7 – 38.0 nm m / min</td>
</tr>
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Electrical property of ITO film

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<tr>
<th>Substrate Thickness (µm)</th>
<th>ITO Thickness (nm)</th>
<th>Sheet resistance (ΩSq)</th>
<th>Resistivity (µΩcm)</th>
<th>Carrier concentration (cm⁻³)</th>
<th>Carrier mobility (cm²/Vs)</th>
<th>Total light transmittance (%)</th>
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<tbody>
<tr>
<td>50</td>
<td>190</td>
<td>7.5</td>
<td>143</td>
<td>1.17 x 10²¹</td>
<td>37.3</td>
<td>83.2</td>
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X-ray Diffraction diagram and SEM image

Typical peaks of the crystallized ITO film were observed by XRD diagram.

The ITO thickness was measured as approx. 190 nm.
Summary

- The roll-to-roll deposition of ITO film on a flexible glass roll, 50 µm thick, 300 mm wide and 10 m long, was made successfully by magnetron sputtering.
- Temperature of the main drum was elevated at 300 °C during the deposition.
- Properties of the ITO film on the flexible glass are:

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- Good crystallinity of ITO film was obtained as deposition.
Future work

- Availability of thicker glasses
- Highly stable handling of flexible glasses
- ITO films on longer flexible glasses
  ⇒ Necessary for cooperation with glass company
- Lower ITO resistivity and smoother ITO surface
  ⇒ Necessary for optimization of deposition process
- Another kind of coatings
  ⇒ Metals or other oxides like AZO, IGZO, etc.
Contact info for inquiries

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Thank you for your attention!