From Deposition to Encapsulation:
Roll-to-roll manufacturing of organic light emitting devices for lighting

Program: DOE EERE SETP CSP subprogram award number DE-E00008723
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Objectives

- Develop R2R process integrating VTE and OVPD growth with film thickness variation <10% on translating substrates
- Fabricate a WOLED with 50 lm/W, CRI >85 by R2R
- Demonstrates 100nm bilayer growth by VTE and OVPD with film thickness variation <10%
- Fabricate 1 cm² WOLED in R2R system with 3000 nits, 15% EQE, and CRI > 80.
- Encapsulate the WOLED with 50 lm/W, CRI >85, L=1000 nits, and T=500 hr, in the R2R tool.
- Develop market forecast and cost models for the volume manufacture of OLED lighting
- Develop roadmap for rapid insertion of R2R manufacturing of WOLED lighting fixtures into the commercial sector

Milestones

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Description</th>
<th>Completion Dates</th>
<th>Percent Complete</th>
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</thead>
<tbody>
<tr>
<td>Task 1.1</td>
<td>Develop R2R process integrating VTE and OVPD growth with film thickness variation &lt;10% on translating substrates</td>
<td>9/30/19</td>
<td>100%</td>
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<tr>
<td>Task 1.2</td>
<td>Fabricate a WOLED with 50 lm/W, CRI &gt;85 by R2R</td>
<td>3/31/20</td>
<td>50%</td>
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<tr>
<td>Go/NoGo</td>
<td>Demonstrates 100nm bilayer growth by VTE and OVPD with film thickness variation &lt;10%</td>
<td>3/31/20</td>
<td>100%</td>
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<tr>
<td>Go/NoGo</td>
<td>Fabricate 1 cm² WOLED in R2R system with 3000 nits, 15% EQE, and CRI &gt; 80.</td>
<td>3/31/20</td>
<td>50%</td>
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<td>Task 1.3</td>
<td>Encapsulate the WOLED with 50 lm/W, CRI &gt;85, L=1000 nits, and T=500 hr, in the R2R tool.</td>
<td>3/31/21</td>
<td>15%</td>
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<td>Task 2</td>
<td>Develop market forecast and cost models for the volume manufacture of OLED lighting</td>
<td>6/30/20</td>
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<td>Task 3</td>
<td>Develop roadmap for rapid insertion of R2R manufacturing of WOLED lighting fixtures into the commercial sector</td>
<td>3/31/21</td>
<td>0%</td>
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Technology: OVPD

- In OVPD, the molecular species are thermally evaporated into a stream of inert carrier gas in a hot walled reactor held at low pressure and transported in equilibrium towards a cooled substrate.
- OVPD is particularly suited to low cost volume manufacturing due to its very high deposition rate without sacrificing film quality.
- Growth during translation within the OVPD system shows high film thickness uniformity, smooth surface morphology, and no systematic dependence on the translation speed.

R&D Approaches

- R2R film growth on translating substrates integrates multiple deposition techniques of different processing parameters.
- Interconnected deposition chamber with different pressures; 6-source OVPD: exciton blocking and active emitting layers deposition with accurate doping control; 6-source VTE: metal contacts, charge transport and charge generation layers; in-situ masked patterning; adjustable web translation speed.
- Flexible encapsulation of WOLED without air exposure using 3M Ultra Barrier® or equivalent non-permeable package material.

Preliminary Results

- OLEDs with the emission layers fabricated at different deposition rates from 2 to 50 A/s by OVPD show similar max EQE = 2010 %.
- As the emission layer deposition rate increases, OLEDs show increased efficiency roll-off at high current densities.
- From the PI fitting based on the space charge limited current model and the triplet-polaron quenching rate equation, higher emission layer deposition rate yields higher quenching rate, potentially due to the inhomogeneity in host matrix.