The Correlation between Glass Transition Point of Dopant and Device Life of OEL

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1. Introduction
For Organic electroluminescent (OEL) devices, dopant is very important component for the device’s efficiency and for its luminescent color. Therefore, various fluorescent dyes have been investigated as dopant [1-5]. We have been developing Coumarin for OEL dopant [5-11] because of its high fluorescence quantum yield and easy functional group modification properties. By combining electron-withdrawing and donor properties of functional group introduced at appropriate position, fluorescent wavelength of Coumarin can be controlled in the range between around 450nm (blue region) to 650nm (red region). Improvement of various properties such as durability can also be expected. In this paper, we report the correlation between glass transition point (Tg) of green dopants that we developed and device life of OEL.

Fig. 1. Structure of Coumarin

2. Method
Coumarin’s structure is in Fig.1. Substituent is applicable mainly to three positions, A, B and C. Dopants, which we investigate in this paper were shown in Fig. 2. Basic properties of these dopants were shown at the Table 1. λ max and Fmax (maximum wavelength of absorption and fluorescence, respectively) were measured in CH2Cl2 solvent. General route to prepare these dopants were able to classified into three groups,

Fig. 2. Structure of dopants

shown in Scheme 1. Structure of OEL
device and molecular structure using this time were shown in Fig. 3. In devices, all materials were deposited by vacuum thermal evaporation on the patterned pre-cleaned indium-tin oxide(ITO)-coated glass substrate. Dopig concentration was about 1%. The active area of devices was 3x3 mm². And measurement of device characteristics was continuously carried out in vacuum.

<table>
<thead>
<tr>
<th>Dye</th>
<th>λ max nm</th>
<th>Fmax nm</th>
<th>m.p. °C</th>
<th>Tg °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>479</td>
<td>508</td>
<td>229</td>
<td>100</td>
</tr>
<tr>
<td>1b</td>
<td>487</td>
<td>514</td>
<td>326</td>
<td>129</td>
</tr>
<tr>
<td>1c</td>
<td>450</td>
<td>515</td>
<td>230</td>
<td>106</td>
</tr>
<tr>
<td>1d</td>
<td>491</td>
<td>518</td>
<td>242</td>
<td>151</td>
</tr>
<tr>
<td>1e</td>
<td>442</td>
<td>508</td>
<td>375</td>
<td>181</td>
</tr>
</tbody>
</table>

Table 1. Basic properties of dopants

![Scheme 1. General synthetic route of dopants](image)

Scheme 1. General synthetic route of dopants

3. Results and Discussion

Some characteristics of these devices were summarized at table 2. All characteristics were measured at driven 11 mA/cm² except for device life. The period of decreasing luminance life into half by constant current from initial luminance, 4000 cd/m² was taken as the device life. The life of one device used dopant 1e was extrapolated and was estimated. All devices were showed almost the same luminescent color (CIE). Luminance and external quantum efficiency (EQE) were improved almost in order of 1a to 1e.

The correlation between device life and Tg of these dopants was shown in Fig. 4. It was proven that the correlation coefficient showed good value, R=0.78, if there were first order correlation between these data. On the other hand, it is possible to anticipate that the effect of device life-lengthen by rising dopant Tg will be decreased with reduce difference between Tg
Table 2. Some characteristics of devices

<table>
<thead>
<tr>
<th>Dye</th>
<th>Luminance ( \text{cd/m}^2 )</th>
<th>EQE ( % )</th>
<th>CIE ( x )</th>
<th>CIE ( y )</th>
<th>Life ( \text{hr} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>996</td>
<td>2.4</td>
<td>0.28</td>
<td>0.65</td>
<td>75</td>
</tr>
<tr>
<td>1b</td>
<td>990</td>
<td>2.3</td>
<td>0.30</td>
<td>0.65</td>
<td>90</td>
</tr>
<tr>
<td>1c</td>
<td>1220</td>
<td>3.0</td>
<td>0.30</td>
<td>0.63</td>
<td>300</td>
</tr>
<tr>
<td>1d</td>
<td>1397</td>
<td>3.5</td>
<td>0.33</td>
<td>0.61</td>
<td>350</td>
</tr>
<tr>
<td>1e</td>
<td>1619</td>
<td>4.5</td>
<td>0.30</td>
<td>0.62</td>
<td>500</td>
</tr>
</tbody>
</table>

![Graph showing correlation between device life and Tg of dopants](image)

Fig. 4. Correlation between device life and Tg of dopants

of host and dopant. But, it is not possible to discuss more, because of lack of samples in this time. However, it can be sufficiently anticipated that there are any positive correlation between Tg of dopant and device life.

By the way, dopant 1c was showed better device life than the value expected from its Tg, in these data. However, the long life of this dopant was regarded to be caused by a different factor other than its Tg dependence. The cause, we considered is to decrease chemical reactivity by introducing 4(C position in Fig. 1)-substituent.

In case of 1% doping concentration, expected mean intermolecular distance of dopant molecule is about five molecules, when in ideal dispersion state. It is considered that the intermolecular distance of five molecules is a sufficient distance without intermolecular interaction. We do not know with how many molecules the physical factor of Tg appears. However, it is considered that present result clearly shows that under the 1% doping concentration, enough dopant molecules gathered so as to appear the physical factor, Tg.

From the investigation of this time, we found out the relation between Tg of dopant and device life of OEL. And more, it was that the long life could be expected from other factor. The accurate correlation will be proven with the increase in number of samples. Although this investigation was carried out for fluorescent green dopant, the similar result is expected even for red or blue and phosphorescence materials.

References
7. *Japan Pat.* 2001-76876
8. *Japan Pat.* 2001-329257
9. *Japan Pat.* 2001-81090
10. *Japan Pat.* 2001-52869
11. *Japan Pat.* 2001-220577