研究简报

白色有机薄膜电致发光

张步新, 朱文清, 赵伟明, 蒋雪茵, 张志林, 许少鸿
(上海大学 嘉定校区材料系, 上海 201800)

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1987年柯达公司C. W. Tang发表的有机薄膜电致发光[1]因其在平板显示技术中的巨大应用前景而成为当前研究的热点。白色发光因是实现全彩色平板显示的重要方案之一, 而倍受人们的关注。目前已有一些有关白光的报道, J. Kido[2,3]利用多层结构及三种染料掺杂的polymer实现白光, S. R. Forrest[4]利用叠层实现白光, Y. Sato[5]用了一种新的掺杂剂得到白光, M. Granstrom[6]和Y. Yang[7]报道了polymer的白色发射。在这篇文章中, 将报道一种利用锁定层中掺杂染料来实现白色有机电致发光的器件, 其最高亮度达8635cd/m^2, 最大效率为1.39lm/W, 色度x=0.31, y=0.32。

图1给出了实验中所用材料的分子结构图。选择NPB(二胺衍生物)作为白色发光中的蓝色发射体, Rubrene作为白光中的橙色发射体。

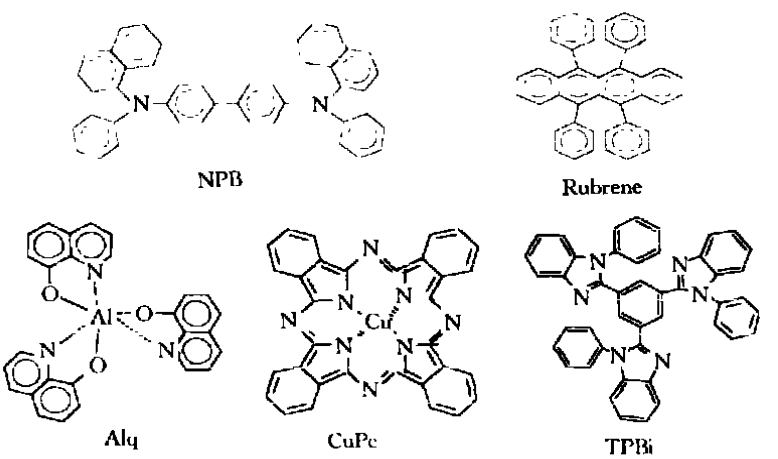

图1 所用有机材料的分子结构

Fig.1 The molecular structure of organic materials used in experiment.

首先研究了NPB-Rubrene体系的光致发光。图2为不同Rubrene浓度的NPB-Rubrene光致发光。由图可见, 随着Rubrene掺杂浓度的增加, 橙色发光增强而蓝色减弱, 表明能量传递确实存在。纳秒时间分辨光谱也证明了这点(另文发表)。对不同浓度掺杂的光谱的色度计算列于表1。

表1 不同Rubrene浓度掺入NPB时的光致发光色度

Table 1 PL CIE coordinates of NPB doped by Rubrene with different concentration.

	0.4%	0.8%	2.6%	12%
x	0.22	0.27	0.34	0.44
y	0.19	0.26	0.35	0.44

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作者简介: 张步新(1966-), 男, 浙江人, 无机材料专业硕士学位, 现正在读发光材料器件与物理方向博士学位。

由表可见, 改变 Rubrene 的掺杂浓度可以调节此 Host-guest 体系的色度, 当 Rubrene 掺杂浓度为 2.6%时, 色度为($x=0.34$, $y=0.35$), 也就是得到白光。

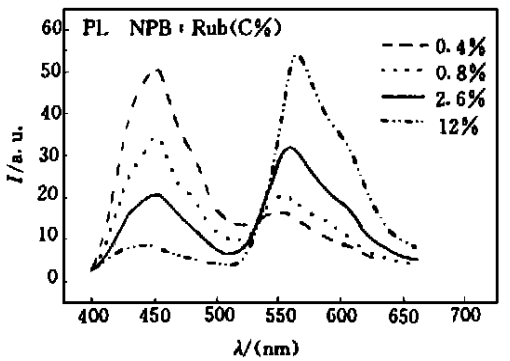

图 2　不同 Rubrene 浓度掺入 NPB 时的光致发光光谱

Fig. 2　PL spectra of NPB doped by Rubrene with different concentration.

基于光致发光的研究, 将 NPB 与 Rubrene 形成一个 Host-guest 体系而使用一个锁定层, 使得发光区域限制在 NPB 区。制成 ITO/CuPc/NPB : Rubrene/TPBi/Alq/Mg : Ag 结构器件, 其中 CuPc 为缓冲层, TPBi 为空穴锁定层, Alq 为电子传输层。和光致发光的结果完全不同, 得到一个强的蓝光和一个弱的橙光, 尽管加大 Rubrene 的浓度直到 12%, 仍然是蓝光强橙光弱, 因此不能合成白光。这可能是电场作用下 NPB-Rubrene 间的能量传递有所削弱。

另外一种结构, 将 Rubrene 掺杂到 TPBi 中, 即 ITO/CuPc/NPB/TPBi : Rubrene/Alq/Mg : Ag。在这种器件中, 色度很容易用 Rubrene 的浓度去调整。将这两种器件的结构示于图 3(a)和 3(b)。

3(b)结构器件的电致发光光谱及电流-亮度关系示于图 4 和图 5。

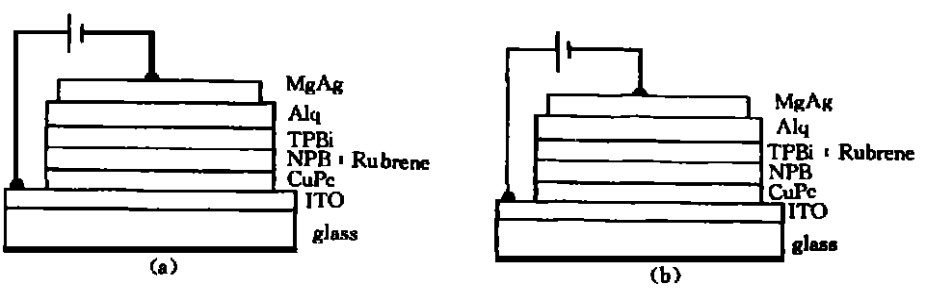

图 3　两种器件的结构

Fig. 3　The schemes of two type devices.

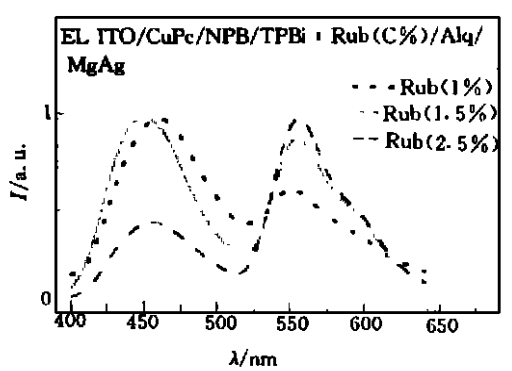

图 4　不同 Rubrene 浓度掺入锁定层的器件电致发光光谱

Fig. 4　EL spectra of the devices with blocking layer doped by different concentration of Rubrene.

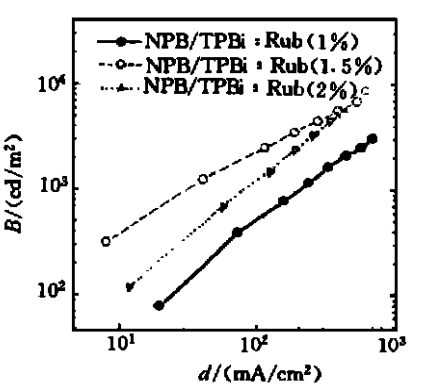

图 5　亮度-电流密度关系

Fig. 5　Dependence of brightness-current density.

它们的色度、最大效率 η_{max} 和最大亮度 B_{max} 列于表 2。由表可见，Rubrene 的掺杂浓度为 1.5%时，得到最好的结果。

表 2 不同 Rubrene 浓度掺杂锁定层的器件特性

Table 2 Characteristics of the devices with blocking layer doped with Rubrene.

device	CIE	η_{max}(lm/W)	B_{max}(cd/m²)
TPBi : Rub(1.0%)	$x=0.27, y=0.30$	0.95	3077
TPBi : Rub(1.5%)	$x=0.31, y=0.32$	1.39	8635
TPBi : Rub(2.0%)	$x=0.34, y=0.39$	1.48	5650

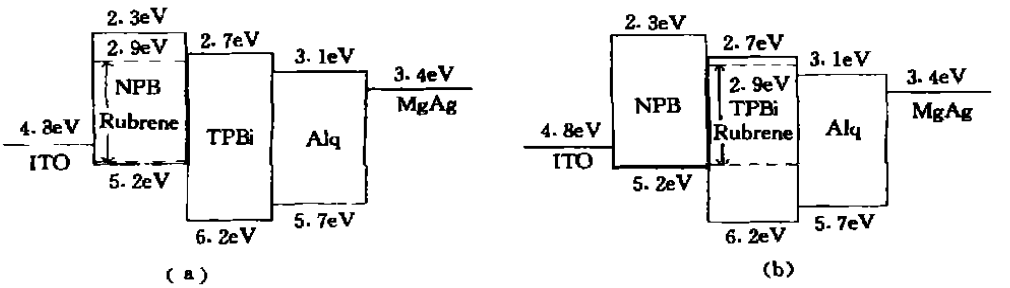

图 6 两种器件的能级图

Fig. 6 Energy levels scheme of two type of devices.

为了比较两种器件的发光机理，将两种结构器件的能级图示于图6(a)和图6(b)。由图可见在6(a)器件中，由于锁定层 TPBi 使 NPB 发光，Rubrene 是依靠能量传递来发光的。但在 6(b)中，Rubrene 和 NPB 分别处在两层中，且 Rubrene 在较低浓度(1.5%)下的发光就能在器件中和 NPB 的蓝光产生白光，这与能量传递很明显的 Rubrene 掺入 NPB 体系形成光致白光输出的 2.6%浓度相比，Rubrene 的发光是载流子直接隧穿复合占主导作用。

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White Emitting Organic Thin Film Electroluminescence

ZHANG Bu- xin, ZHU Wen- qing, ZHAO Wei- ming, JIANG Xue- yin,
ZHANG Zhi- lin, XU Shao- hong
(*Department of Material, Shanghai University Jiading Campus, Shanghai* 201800. *China*)

Abstract

White color emitting organic electroluminescence (EL) device is a convenient means to realize full - color display because the three necessary primary colors could be obtained by color filters from white back light. In this paper a new three- layer device is presented. We used N, N′- bis- (lnaphhyl) - N, N′- diphenyl- 1, 1′- biphenyl- 4, 4′- diamine (NPB) as the hole transport layer, Alq as the electron transport layer, CuPc as the buffer layer, and TPBi as the blocking layer inserted between NPB and Alq. The 5, 6, 11, 12- tetraphenyltetracene (Rubrene) as dopant was doped into the blocking layer.

It was thought initially that if energy transfer existed between the host and dopant in photoluminescence (PL) of NPB doped with Rubrene, white emission might be obtained in a device such as ITO/CuPc/NPB: Rubrene/TPBi/Alq/Mg: Ag. Thus the PL of NPB: Rubrene system excited by NPB absorption band with different dopant concentrations were investigated in advance. There are two bands in the PL spectra, the blue one is emitted by NPB and the yellow one is by Rubrene. The ratio of these two bands can be adjusted by changing the Rubrene concentration. This shows that energy transfer does occur from NPB to Rubrene. Time- resolved spectra of this system, which will be given in another paper, confirm further that the energy transfer exists and is quite effective. White emission can be produced by adjusting the concentration of Rubrene in PL. However, devices of structure ITO/CuPc/NPB: Rubrene/TPBi/Alq/Mg: Ag were made according to these results with TPBi as the blocking layer, white emission can not be obtained by changing the Rubrene concentration.

For another device of structure ITO/CuPc/NPB/TPBi: Rubrene/Alq/Mg : Ag, with a blocking layer TPBi doped by Rubrene concentration 1. 5% inserted between NPB and Alq, white emission can be obtained. The highest luminance and maximum efficiency are 8635cd/m^2 and 1. 39lm/W respectively, CIE coordinate $x = 0.31$, $y = 0.32$. The color of the emitted light can still be optimized by adjusting the relative thickness of the relevant layers and dopant concentration.

The electroluminescence mechanism of two kinds of cells was discussed.

Key words: white displays; organic thin film; electroluminescent devices

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