Comment on “Surface plasmon coupled electroluminescent emission” [Appl. Phys. Lett. 92, 103304 (2008)]

Zhaoxin Wu, Shixiong Liang, Bo Jiao, Xuanke Zhao, and Xun Hou

Citation: Appl. Phys. Lett. **93**, 266101 (2008); doi: 10.1063/1.3056110
View online: http://dx.doi.org/10.1063/1.3056110
View Table of Contents: http://aip.scitation.org/toc/apl/93/26
Published by the American Institute of Physics

Comment on "Surface plasmon coupled electroluminescent emission" [Appl. Phys. Lett. 92, 103304 (2008)]

Zhaoxin Wu,[a] Shixiong Liang, Bo Jiao, Xuanke Zhao, and Xun Hou
Key Laboratory for Physical Electronics and Devices of the Ministry of Education, School of Electronic and Information Engineering, Xi'an Jiaotong University, Xi'an 710049, People's Republic of China

(Received 12 October 2008; accepted 21 November 2008; published online 29 December 2008)

[DOI: 10.1063/1.3056110]

In a recent letter, Koller *et al.*[1] reported on direct probing surface plasmon (SP) mode of a microcavity organic light emitting diodes (OLEDs) with thin film metal electrodes, by leaky wave extraction with a high refractive index glass prism coupler. The authors also used the method of transfer matrix to calculate the SP mode. However, the characteristic of the SP modes the authors described is not consistent with the role of SP in OLEDs.[2]

SP mode is a guided optical mode that exists at the interface between a dielectric and a metal.[3] The dispersion relationship for the SP mode can be derived from Maxwell's equations by applying the appropriate boundary conditions for a planar interface,

$$k_{spp} = \frac{\omega}{c}\sqrt{\frac{\varepsilon_1\varepsilon_2}{\varepsilon_1+\varepsilon_2}}, \quad (1)$$

where $k_{\rm spp}$ is the wavevector of SP mode, ω is the angular frequency, and ε_1 and ε_2 are the relative permittivities of the dielectric and metal media, respectively. These modes are intrinsic nonradiation, i.e., $k_{\rm spp} > k_1$, where $k_1 = \sqrt{\varepsilon_1}k_0$, with $k_0 = \omega/c$, k_0 is the free space wavevector, ω is the angular frequency of the light, and k_1 is the wavevector in the dielectric material in which the emitter is embedded. So the light given off by the emitter cannot directly couple to the SP modes.

According to the dispersion relationship for the SP mode, there are four SP modes supported by the OLED structure described in the authors' letter. These four SP modes ($k_{\rm SP1}$, $k_{\rm SP2}$, $k_{\rm SP3}$, and $k_{\rm SP4}$) are at the air/Al, tris-(8-hydroxyquinoline)-aluminum (Alq_3)/Al, N,N′-bis(3-methylphenyl)-N,N′-diphenylbenzidine (TPD)/Au, and BK7/Ag interfaces respectively. By Eq. (1), the wavevectors of $k_{\rm SP1}$, $k_{\rm SP2}$, $k_{\rm SP3}$, and $k_{\rm SP4}$ are calculated to be $1.012k_0$, $1.818k_0$, $2.201k_0$, and $1.687k_0$ (the dielectric constants of Al, Ag, Au, organic layer, and glass used in calculation are $-42.0708+11.9472i$, $-10.5459+0.8385i$, $-6.29+2.04216i$, and 3.06, 2.25).[4] Figure 1 shows the calculated power dissipation spectrum[5,6] for a dipole source embedded in the structure of OLEDs described in the authors' letter. When $k_\parallel/k_0$ is in the range $0 \le k_\parallel/k0 \le 1$ and $1 \le k_\parallel/k0 \le n$ are the outcoupling modes and the waveguided modes, respectively. Where n is the refractive index of the emissive material ($n_{\rm Alq3} = 1.75$ at 550 nm light wavelength), $k_0 = \omega/c$ is the free space wavevector, and $k_\parallel$ is in-plane wavevector. The peaks in the spectrum represent coupling of the source to SP1, SP2, SP3, and SP4 modes.

The authors mistook that the SP2 and SP3 modes at the interfaces of Alq_3/Al and TPD/Au are the same value. In addition, the SP modes at the interface of the air/Al and the interface of BK7 glass/Ag were not taken into account by the authors.

Due to $k_{\rm SP2} > k_1$ and $k_{\rm SP3} > k_1$, the light given off by the emitter cannot directly couple to the SP2 and SP3 modes at the interfaces of Alq_3/Al and TPD/Au. The coupling to the two SP modes can occur by near field emitting of organic molecular. The light given off by emitter can directly couple to SP1 mode at the interface of air/Al ($k_{\rm SP1} = 1.012k_0$), which lead to minimum light reflectance with angle of 35.35°, but the coupling is quite weak, and will hardly be observed in experiment. The light given off by emitter can also directly couple to SP4 mode at the interfaces of BK7 glass/Ag ($k_{\rm SP4} = 1.687k_0$), which lead to minimum light reflectance with angle of 74.62°, which are not consistent with the authors' value.

In summary, we presented the SP modes existing in an OLED described in the authors' letter, and analyzed the coupling of these SP modes with the emitters embedded in the OLED. In our opinion, the minimum of reflectance in Fig. 2 of the authors' letter is hardly attributed to the coupling of SP modes and emitters in the OLED.

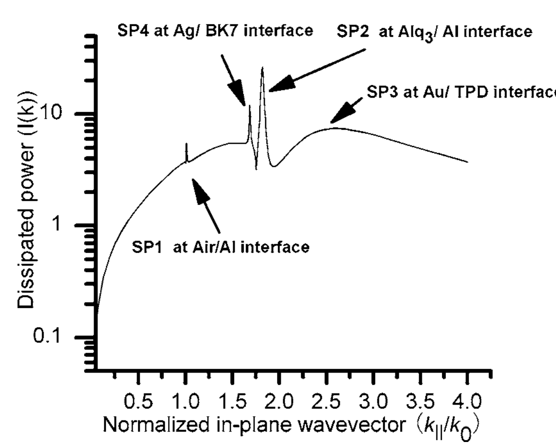

FIG. 1. Calculated power dissipation spectrum for an emitter located in the device. The large peaks at a normalized in-plane wavevector of 1.012, 1.818, 2.201, and 1.687 indicate power being lost to the SP modes at air/Al, Alq_3/Al, TPD/Au, and BK7/Ag interface, respectively.

[a]Author to whom correspondence should be addressed. Electronic mail: zhaoxinwu@mail.xjtu.edu.cn. Tel.: +86-29-82664867. FAX: +86-29-82664867.

The authors are grateful to the Ministry of Science and Technology of China (973 Program No. 2006CB921602) for support.

[1]D. M. Koller, A. Hohenau, H. Galler, F. R. Aussenegg, A. Leitner, J. R. Krenn, S. Eder, S. Sax, and E. J. W. List, Appl. Phys. Lett. **92**, 103304 (2008).
[2]P. A. Hobson, J. A. E. Wasey, I. Sage, and W. L. Barnes, IEEE J. Sel. Top. Quantum Electron. **8**, 378 (2002).
[3]H. Raether, *Surface Plasmon* (Springer, Berlin, 1988).
[4]E. D. Palik, *Handbook of Optical Constant of Solids* (Academic, London, 1985), p. 350.
[5]W. L. Barnes, J. Lightwave Technol. **17**, 2170 (1999).
[6]R. R. Chance, A. Prock, and R. Silbey, Adv. Chem. Phys. **37**, 1 (1978).