Microcavity OLED Example Using UniMCO...

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Introduction...

OLED displays are an emerging flat-panel technology based on layers of organic materials forming a p-n junction that emits light when injected holes and electrons recombine. The organic materials are commonly either small molecules or conjugated polymers. The thickness of the organic layers is comparable with the wavelength. Therefore, a modification of the emission characteristics is possible by using a microcavity structure which alters the optical mode density within the microcavity. Microcavity OLED can greatly enhance light output efficiency, tune or purify colors, and increase device lifetime.

Set up analysis parameters...

Here we will design a microcavity OLED device, whose central resonant peak is located at 550 nm. The system consists of a Metal (Al)-DBR microcavity structure on a glass substrate.

Now start UniMCO program by clicking the “unimco3” icon. Click the button to bring up the “Analysis Parameters” control, and set the parameters as shown in the figure on the right.
Create microcavity structure...

Click the “Done” button in the “Analysis Parameters” control, as shown in last section. Next, create the microcavity structure in the "Layout Window", as shown in Fig.1.

Right click the substrate and select “Set Substrate Parameters”. Set the substrate parameters according to the window as shown in Fig.2. Click the “Done” button in the “Substrate” window.

Right click “DBR1: Group1” and select “DBR1 Parameters”. Set DBR1 parameters according to Fig.3. Click the “Done” button. It can be seen that the DBR is made of TiO2 and SiO2.
Right click “Spacer1: Group1” and select “Spacer1 parameters”. Set Spacer1’s parameters as shown in Fig.4. Click the "Done" button.

Right click “Emitter” and select “Set Emitter Parameters”, which brings up a parameter setup window for the emitter, as shown in Fig.5. Please note that the emitter layer has a thickness of 70 nm and the material Alq is specified. Click the “Done” button.

Right click "Metal" and select “Set Metal Parameters”. Select "Al" as the metal type as shown in Fig.6. Click the "Done" button.

This finishes the parameter setup process for the microcavity structure of a microcavity OLED device.

**Calculate optical field distribution...**

Click the button on the main window to bring up the “Calculate Optical Field” control, as shown in Fig.1. Click the “Start Simulation” button to calculate optical field distribution. After the simulation is finished, click the "Plot Results" button. The optical field is displayed as in Fig.2.

This result shows that there is a strong interaction between confined photons and excitons in the microcavity. It also shows that the microcavity structure is not optimized yet, because the maximum optical field is still located outside the cavity.

Click the "Close" button to close the control.
The figure on the right is the "Calculate Reflectivity" control window. Click the "Start Simulation" button. UniMCO starts calculating the reflectivity, transmission, absorption, phase shift, and penetration depth.

It can be seen that the resonance peak of the microcavity reflectivity (at 550 nm at zero view angle) shifts toward a shorter wavelength gradually with the increase of the view angles (Fig.2-4), which is called blue shift, while the reflectivity of the bottom mirror (DBR mirror + glass substrate) is dependent strongly on both wavelength and view angle (Fig.5-7). The reflectivity of the metal mirror is not very dependent on both wavelength and view angle (Fig.8-10). We can also obtain the penetration depth from this.
reflectivity calculation.

2D results can be extracted from this 3D calculation: we can plot the reflectivity as a function of wavelength at given view angles (Fig.11), or as a function of view angle at given wavelengths (Fig.12, and the polar plot Fig.13).

It can also note that the UniMCO 3.0 allows the user to display the results in various plot formats, such as 3D surface, checkerboard, contour, etc. with different color map options.

Fig.2 Reflectivity of the microcavity (surface plot)

Fig.3 Reflectivity of the microcavity (contour plot)

Fig.4 Reflectivity of the microcavity (checkerboard plot)

Fig.5 Reflectivity of the DBR (surface plot)

Fig.6 Reflectivity of the DBR (filled contour plot)

Fig.7 Reflectivity of the DBR (contour plot with labels)
Fig. 8  Reflectivity of the metal mirror
(surface plot)

Fig. 9  Reflectivity of the metal mirror
(filled contour with labels)

Fig. 10  Reflectivity of the metal mirror
(checkerboard plot)

Fig. 11  Reflectivity of the microcavity as
a function of wavelength

Fig. 12 Reflectivity of the microcavity as a
function of view angle

Fig. 13  Reflectivity of the microcavity
as a function of view angle (polar)
Calculate light output...

Fig. 1 shows the "Calculate Light Output" control. Click the "Start Simulation" button. After the simulation is finished, click the "Plot Results" button. The "Plot 3D Light Output" control appears (Fig. 2). In this control window, we can plot 3D light spectrum, integrated light spectrum (including EL efficiency), and color coordinates if the light output is visible spectrum. Click the Light Spectrum button to bring up the "3D light Spectrum Plot" control window (Fig. 3), from which we can plot various EL results.

Fig. 4 and 5 show the light spectrum toward the microcavity OLED front (i.e., the guided mode plus extracted mode). The light spectrum to the microcavity OLED back (the leaky mode) is displayed in Fig. 6 and 7. It can be seen that the light in the leaky mode is greatly reduced by the microcavity comparing the light in the extracted and guided modes (to the device front).

Fig. 8 and 9 plot the extracted EL spectrum, which is the "useful" light from the microcavity OLED.

The integrated EL spectrum (integrated over all view angles) as a function of wavelength is shown in Fig. 10, and the
integrated EL (integrated over all wavelengths) as a function of view angle is displayed in Fig. 11 and 12. We can see that the EL from the microcavity OLED is greatly enhanced.

UniMCO 3.0 allows the user to display many more results, such as the EL efficiency, the EL as a function of wavelength at a given wavelength, the EL as a function of view angle at a given view angle, the EL contributed from the S-wave, P-wave, and vertical wave polarization components, etc.

Here, we only show the total light output for the "In-Plane" dipole case. For most thin active (or emitting) layer devices, the in-plane dipole model should work well, while for thick active layer devices and small molecular OLED, the isotropic dipole model works better. The user can also plot the other spectra, such as S-wave, P-wave, and vertical component, and to see how each component contributes to the total light output. The user can also examine the input light distribution (EL0) and compare it with the EL (the light spectrum with cavity).
Fig. 10  Integrated light (extracted) as a function of wavelength

Fig. 11  Integrated light (extracted) as a function of view angle

Fig. 12  Polar plot of the Integrated light (extracted) as a function of view angle