OmniSim TECH NOTE

Modelling of Nanopatterning in LED's

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December 2005

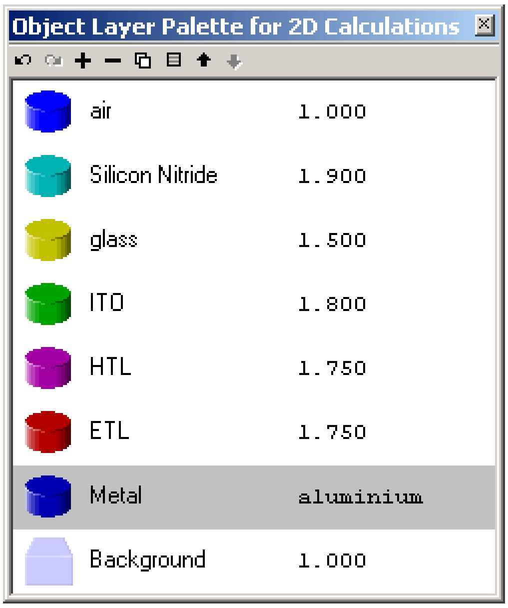
Abstract: OmniSim is used to improve the efficiency of light extraction from organic LED's by using nanopatterning. The problem is described in detail in reference 1

Introduction

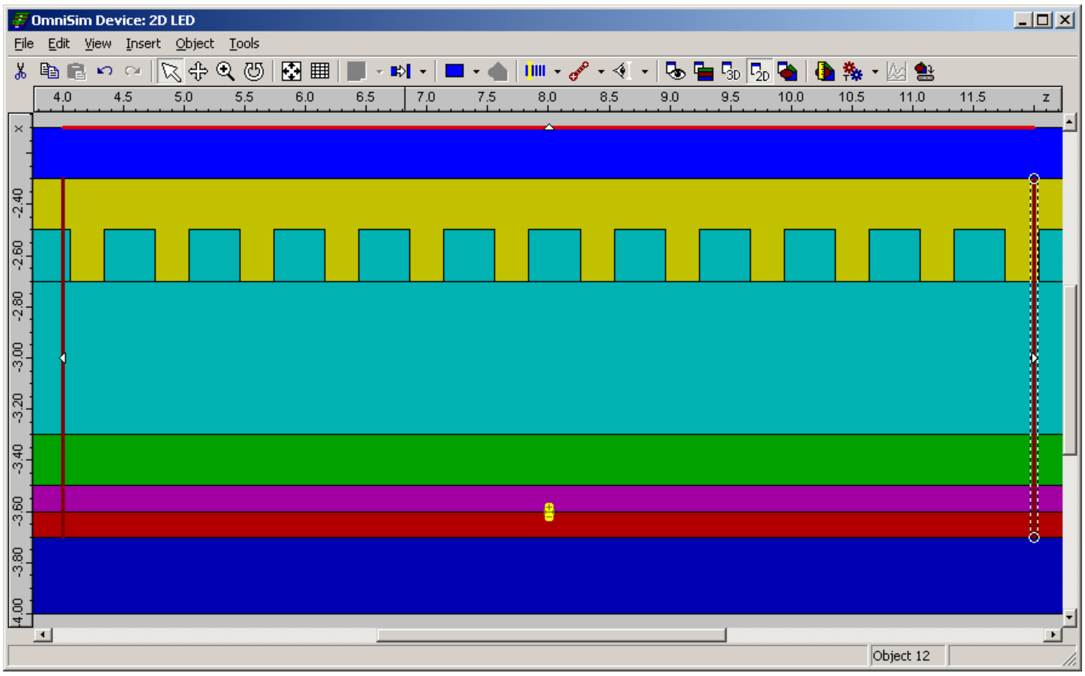
Nanopatterning of LED's is an attractive technique for improving the light extraction efficiency of such devices. This technical note shows how OmniSim can be used to define and simulate such devices. Both 2D and 3D simualtions are covered.

1.1 2D Simulations

First of all the problem was set up in 2D, as FDTD calculations are much quicker in 2D and can help to give good insights of the required designs. The 2D approximation will not be absolutely accurate, but it does help to identify trends. The different refractive indices were defined as below in the 2D object layer palette



The metal cathode was defined using the material database that is available with the latest version of OmniSim and all the other layers were defined as refractive indices. The object layers were then used to define the structure shown in figure 2. Each region was defined as a rectangle and the silicon nitride nanopattern was defined by using a sub-component of size 0.7 um by 0.4 um containing a 0.42 um rectangle of silicon nitride. An array of the subcomponents was then created to generate the nanopatterning. A dipole was placed at the top of the ETL layer, two sensors were placed at the left and right of the device and a third sensor was placed at the top of the device in the air region



The device was simulated using 2D FDTD with a step size of 0.02 um and using 4096 time steps. The simulation took about 1 minute and required about 30 Mbytes of RAM.

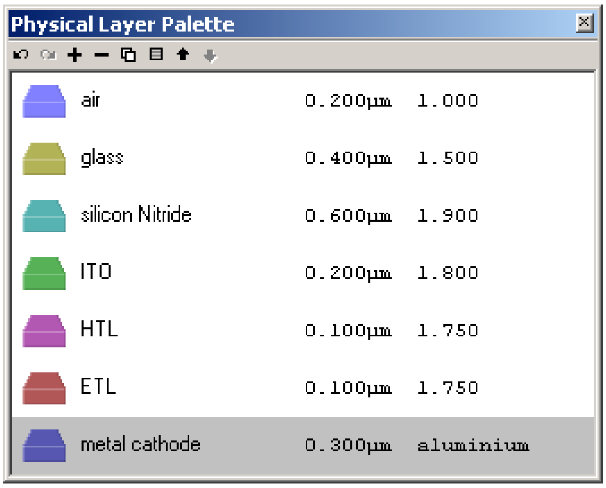
The following results were obtained, for different height of silicon nanopatterning.

Sensor	Nanopattern height=0	Nanopattern height=0.2	Nanopattern height=0.4
Air	0.78 W/um	.9 W/um	0.77 W/um
Left	1.04 W/um	.87 W/um	0.77 W/um
Right	1.01 W/um	.85 W/um	1.32 W/um
LED efficiency	27%	34%	46%

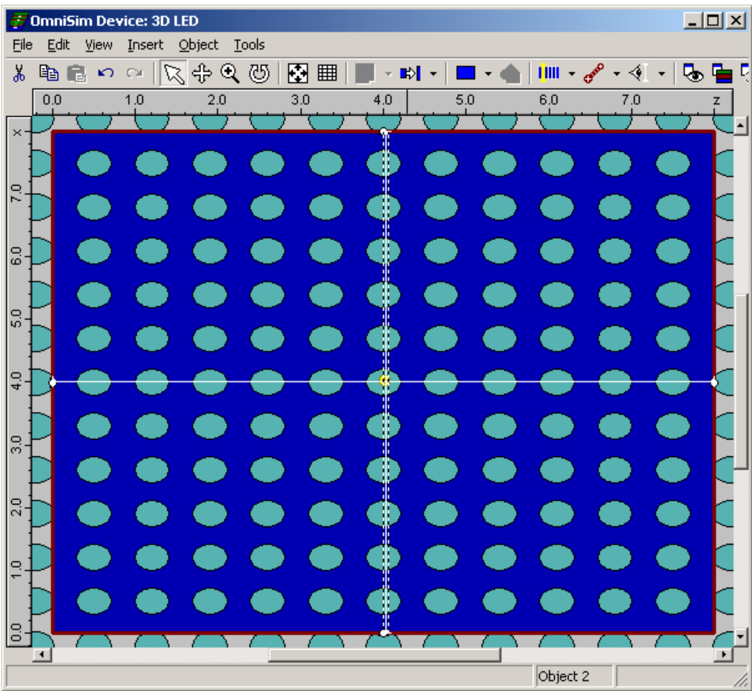
The results demonstrate quite clearly the expected improvement in LED efficiency due to nanopatterning. Simulations in 2D also showed that the device needed to be at least 8 um wide to include the multiple reflections.

1.2 3D simulations

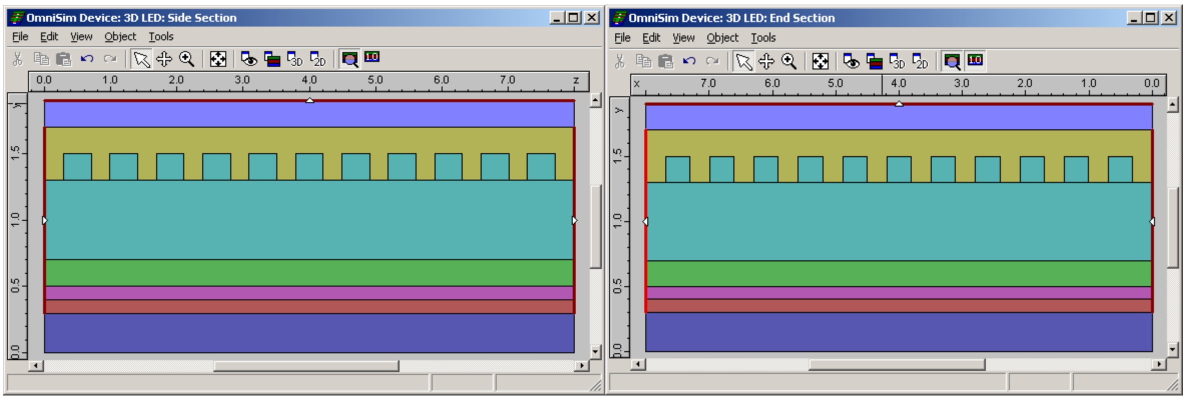
The device was next simulated in 3D, firstly the physical layers were defined as shown below.



Two masks were defined, the first mask was used to create a rectangle 8 um x 8 um, in which all the physical layers exist. The second mask used the etch and fill process to create the silicon nitride rods in the glass. The top view of the device is shown below.



By using side section and end section views, it is possible to check that the device is set up as required, as shown below.



To simulate this device would require over 10 Gbyte of RAM which is currently not possible due to the windows operating system. However we can make use of mirror planes and reduce the device to a 4 um by 4 um box with magnetic walls along the left and lower sides. The sensors can be reduced in size and also only two sensors are required along the sides. When these changes are made, the memory requirements drop to 900 Mbytes, which is much more reasonable and the simulation takes around 15 minutes.

The following results were obtained in 3D.

Sensor	Nanopattern height=0	Nanopattern height=0.4
Air	.44 W/um	.63 W/um
upper	.72 W/um	.60 W/um
Right	.72 W/um	.60 W/um
LED efficiency	23 %	34 %

In 3D the software has shown an improvement in LED efficiency although not as much as in 2D. The two sets of results demonstrate the value of using 2D to quickly identify trends but then to use 3D to fully characterise the results.

1.3 Conclusions

OmniSim has been shown to be of value in simulating nanopatterning in LED devices. Simulations can be performed in both 2D or 3D and sensors used to determine how much light enters the air ie the extraction efficiency.

OmniSim can use mirror planes to reduce the size of a problem in 3D to a more manageable problem and further improvements should be possible.

1.4 References

1) A high extraction-efficiency nanopatterned organic light emitting diode; Yong- Jae Lee et al; Applied physics letters; v82 n21; 26 May 2003; p 3779-3781