Scattering and plasmonic phenomena of nanoparticle self-assembled arrays in the thin-film organic lighting devices and photovoltaics

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Introduction

Application of nanoparticle-based plasmonics

Coupling between excitons and plasmons

Finite-Difference Time-Domain (FDTD)

- FDTD directly solves Maxwell’s curl equations in the time domain.
- The most common method to solve these equations is based on Yee’s mesh and computes the E and H field components at points on a grid with grid points spaced Δx, Δy, and Δz apart.
- The E and H field components are interfaced in all three spatial dimensions.

References


Experiment

Results & Discussion

Precise control of plasmonic nanostructures

3D-FDTD simulation of intensity of OLED devices

OLED devices with Au nanostructure

Organic Photovoltaics with Au nanostructure

Precise control of plasmonic nanostructures

Block copolymer phase-separated patterns

Gold Pattern Dimension

Height (nm)

Dot 18 ~ 25

Line 10 ~ 15

Gold Nanostructures

Au pattern treatment with HAuCl₄ and etching.

3D-FDTD simulation of intensity of OLED devices

Simulation result shows notable improvement with the contents of plasmonic nanoparticles, about 27.8% in terms of intensity for dot patterns of Au nanoparticles.

OLED devices with Au nanostructure

Light emission efficiency (internal quantum yield) shows notable improvement with the contents of plasmonic nanoparticles, about 33.1% and 43.8% in terms of current efficiency for dot and line patterns of Au nanoparticles, respectively.

Organic Photovoltaics with Au nanostructure

Current density vs. bias voltage for OSC devices with ITO/Au nanostructures/PEDOT:PSS coating/P3HT:PCBM/LiF/Al for different morphologies of Au patterns


Conclusion

- We have successfully demonstrated the LSPR-enhanced OLEDs and OPVs by using a solvent annealing induced self-assembly process for BCPs: formation of patterns, such as simple Au dot and line patterns was controllable by the selection of the solvent at annealing process.
- The LSPR resulting from near-field enhancement can facilitate the radiative recombination of excitons, in favor of the decreasing the energy lost as non-radiative generation, and increasing the total number of excitons created in the emitting layer.
- Simulation result suggests that the SPP mode can be generated easily by direct energy transfer from electron-hole pairs without any special structures. Generated surface plasmon can be extracted from the interface as light and the emission efficiencies should be increased.
- The triggered LSPR resulted in a dramatic enhancement in the performance of the OPVs, showing a significant increase in the Jsc and the PCE by up to 126% of the reference value.