Enhancement of top emission for organic light-emitting diode via scattering surface plasmons by nano-aggregated outcoupling layer

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Abstract:
A stable self nano-aggregated bathocuproine (BCP) film was fabricated and introduced atop of a conventional organic light emitting diode (OLED) for enhancing top emission. It leads to a 2.7–2.1-fold enhancement on top emission at applied voltage from 4 to 9 V which is much larger than the 1.5–1.3-fold enhancement for a device overlaid with an amorphous BCP film. The more effective outcoupling of this method probably arises from surface plasmon (SP) modes being scattered by only the nanostructured surface, and thus without phase cancellation, at the BCP/air boundary. Moreover, this method nearly preserves the original electroluminescent spectra and has no damage on electrical properties.

1. Motivation
Nondestructive method to introduce nanostructures into OLEDs for SP enhanced emission

Organic layers

Previous work: holographic lithography[1], solvent assisted micromolding[2], nanoimprint lithography[3]
Possible problems: degradation of active organic materials bad effects on electrical properties

2. Approach
Formation of self nano-aggregated BCP film

2.1 Fabrication
Vacuum evaporation: BCP(80nm)/Ag(50nm)/quartz, BCP(80nm)/quartz
Preserve in vacuum at room temperature for 24 hours

2.2 Nanomorphology
AFM morphological images (3µm×3µm) (a) amorphous BCP/quartz; (b) nano-aggregated BCP/quartz; (c) Ag/quartz; (d) nano-aggregated BCP/Ag

A surface depth modulation of approximately 30–40 nm can efficiently scatter SPs as light [4].

2.3 Formation mechanism of nano-aggregated BCP film

Existence of excimers

Photoluminescence

Aromatic hydrocarbons subject to excimer formation.

Formation mechanism
Indicated by excimers existence, molecules diffuse and agglomerate to minimize the total surface energy.

3. Characterization
Investigation of the SP resonance wavelengths

Photoluminescence decay dynamics at 524nm

SP resonance over green emission

Contributed from reflection and interference

Reduced lifetime and enhanced photoluminescence indicate resonant coupling of spontaneous emission into SPs.

4. Application
SP enhanced top emission in OLEDs

SP modes scattered only by the single nanostructured surface thus without phase cancellation[5]

Reduced Ag cathode reflection

The outcoupling capability of the nano-aggregated BCP film is ~60% higher than that of the amorphous film.

5. Outlook
Formation of different self nano-aggregated BCP film through surface modification
SP enhanced blue and red emission in OLEDs
Application for enhanced full-color emission in flexible OLEDs

Reference