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XPS and ToF-SIMS sputter depth profiling of OLEDs using Ar-cluster ion sources

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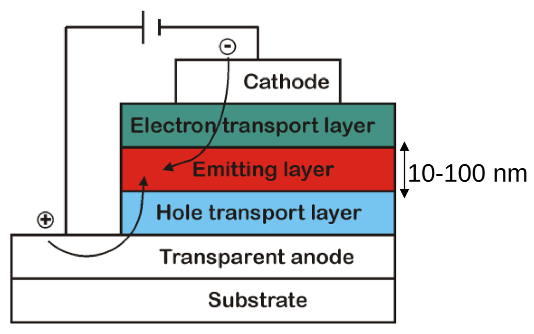
Introduction

Research on organic light-emitting diodes (OLEDs) has gained much attention due to the potential for cheap and ultrathin illumination sources with high color range. In multilayer OLEDs the carrier injection efficiency from the electrodes into the light emitting layer is improved by layers for hole or electron transport and blocking. Vacuum evaporation is the standard method to produce precisely defined interfaces, but it is an expensive process with high material usage. Alternatively, the wet chemical processing has advantages in production cost, deposition rate and area.

But the solution process shows problems with the intermixing of the subsequently coated functional layers. The specific nature of small molecules used for OLEDs with their high mobility for diffusion in combination with low dry film thicknesses of only a few nanometers is challenging.


Source: Holst Center


Source: TFT,KIT



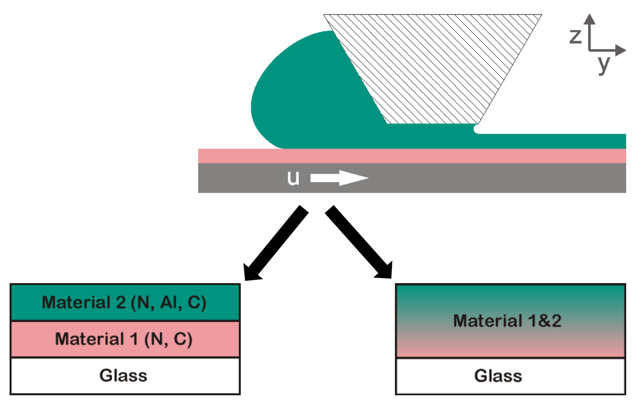
Multi Layer Deposition

For a better understanding of the physical limitations of liquid-phase processed multilayer OLED structures, the possibility to characterise the material mixing between layers during coating and drying, and the comparison to evaporated layers is crucial.

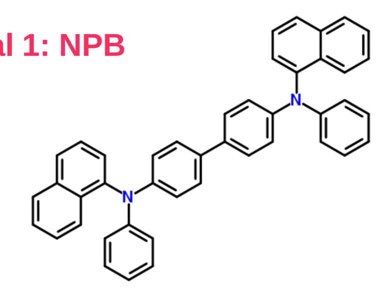
Coating solution of Material 2 onto dry layer of Material 1 on glass:

Self-metered coating method
Knife coating

Pre-metered coating method
Slot coating (TSE/TFT)

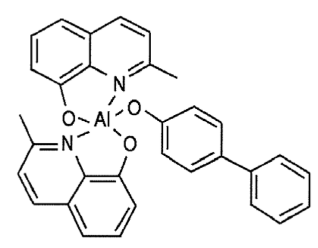


Material 1: NPB



N,N´-Di(naphth-1-yl)-N,N´diphenyl-benzidine

Material 2: BAlq

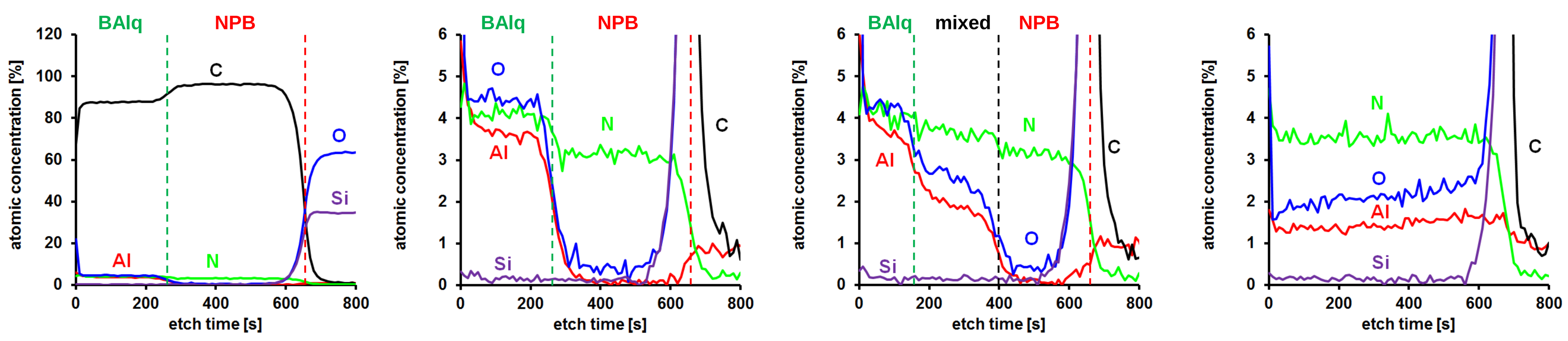


Bis(2-methyl-8-quinolinolate)-4-(phenylphenolato)aluminium

XPS: Mono Ar+ Ion Beam

Evaporation: (multi) layer systems on glass slides

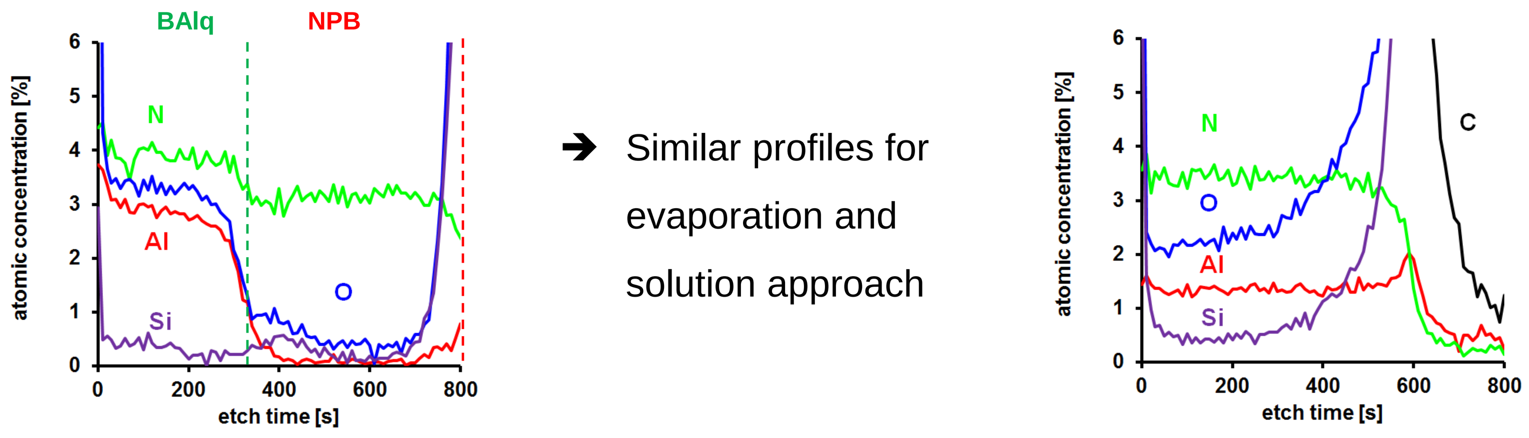
Defined double layer — Mixed interlayer — Mixed layer



Solution: (multi) layer systems on glass slides

Defined double layer — Mixed layer

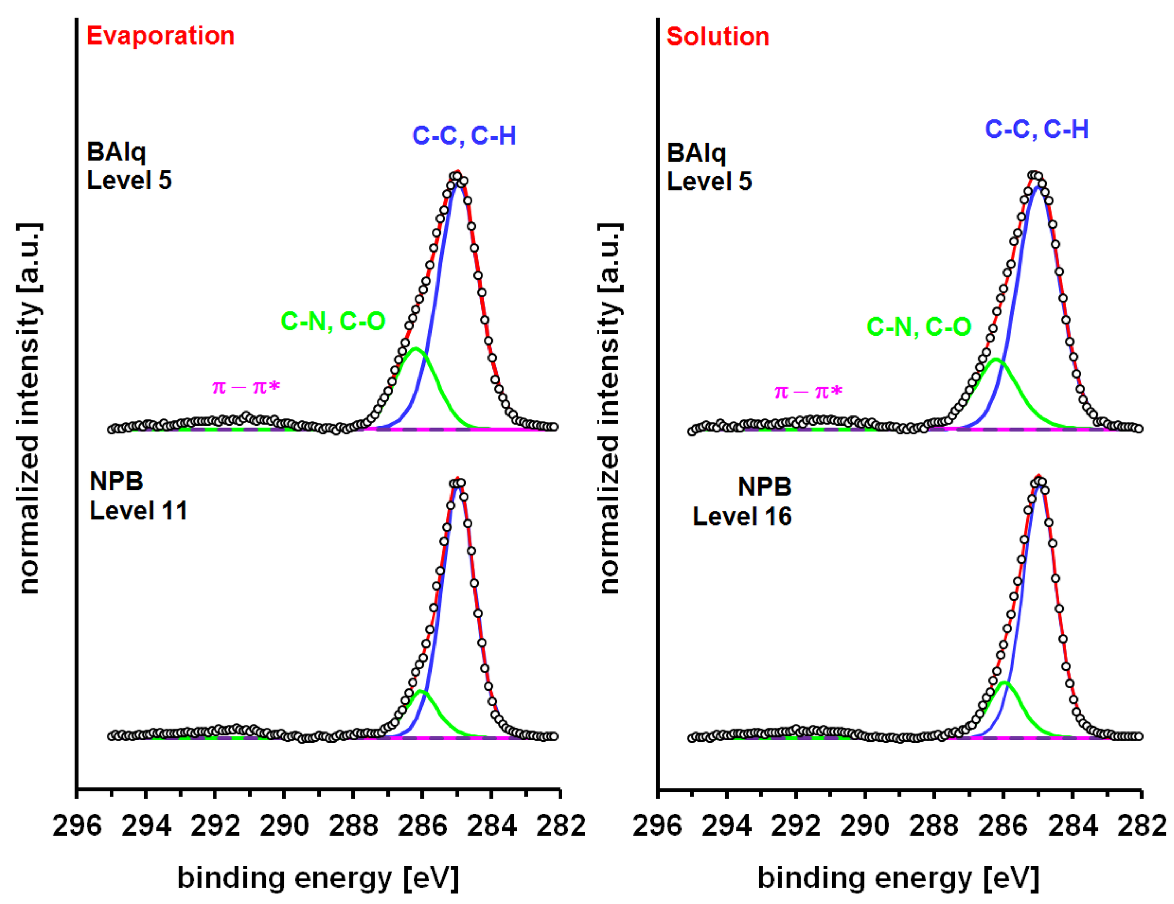
- Orthogonal solvent
- Solvent with high solubility



➔ Similar profiles for evaporation and solution approach

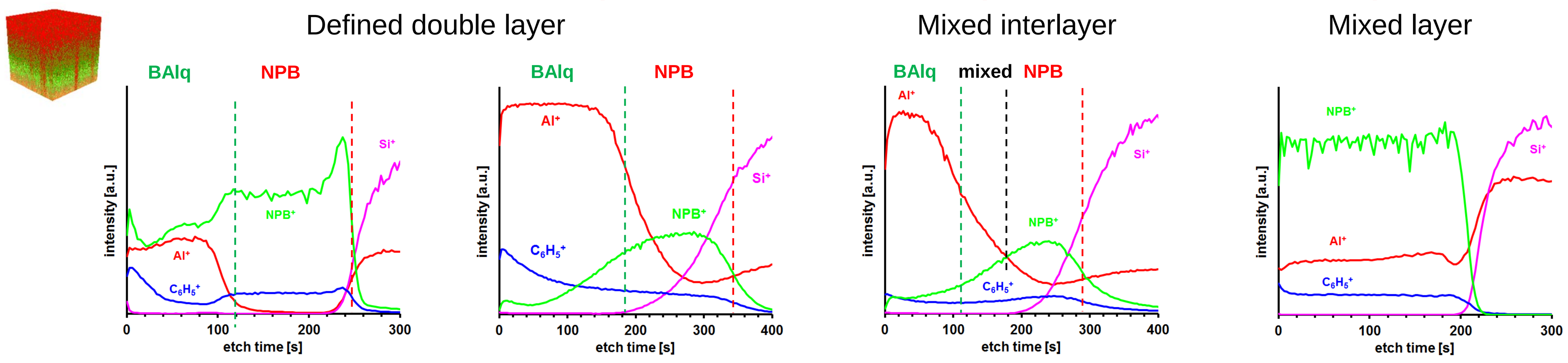
XPS: Ar-Cluster Ion Beam

Defined double layer



ToF-SIMS: Ar-Cluster Ion Beam

Solution — Defined double layer; *Evaporation*; *Evaporation* — Mixed interlayer; *Evaporation* — Mixed layer



- ❖ Mono Ar^+ and Ar-cluster ion beam sputter depth profiling reveal comparable elemental in-depth distribution
- ❖ Preserved chemical depth information only with Ar-cluster ion beam:
  - ⇔ XPS sputter depth profile:
    C-C/C-N,O ratios agree with theoretical values for NPB and BAlq
    $\pi-\pi^*$ peak indicates non-decomposed aromatics
  - ⇔ ToF-SIMS sputter depth profile:
    stable detection of the molecular NPB^+ ion $C_{44}H_{32}N_2^+$

Experimental

Thermo Fisher Scientific K-Alpha XPS-Instrument

- Micro-focussed monochromatic AlKα X-ray source
- Monatomic and gas cluster ion source (MAGCIS), 6 keV, cluster size: 2000 atoms
- Ar^+-ion source, 2 keV

ION-TOF GmbH ToF.SIMS[5] Spectrometer

- 25 keV Bi_3^+ primary ions; positive polarity
- Gas cluster ion source (GCIS), 5 keV, cluster size: 1000 atoms

Conclusions

- ❖ High mass Ar cluster ion sources for both XPS and ToF-SIMS enabling sputter depth profiling of organic materials while preserving the chemical/molecular information
- ❖ Layer deposition via solution process provides defined multi layer systems

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