# Birefringent organic layers in top- and bottom emitting OLEDs

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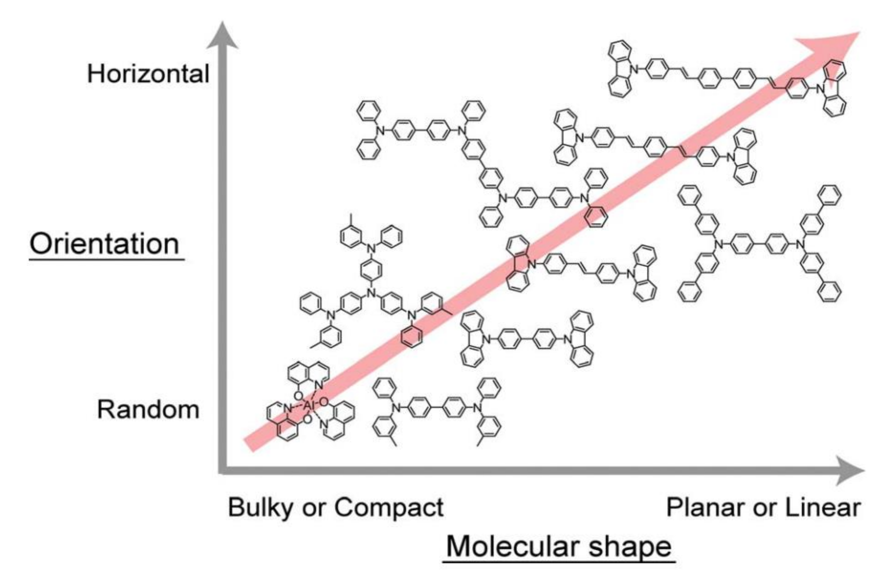
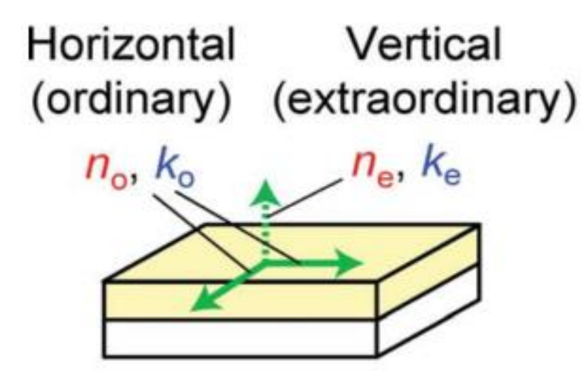
The emission characteristics of organic light emitting diodes are dictated by the electronic and optical properties of the layers that make up the device. Great efforts have been made to optimise, amongst others, the outcoupling efficiency of these devices. Tuning the thickness of each of the layers can, with precise knowledge of the complex refractive index, greatly increase the optical outcoupling efficiency and allow for sensitive tuning of other emission characteristics. Birefringence in organic layers has been observed and can be very strong (|Δn|> 0.2)[1]. When this birefringence is taken into account in optical simulations[2] it can be used to increase outcoupling efficiency[3] and tune the angle dependant emission. We present guidelines and the potential benefit of birefringent organic layers in both top- and bottom emitting OLEDs.

## Anisotropic Organic Layers

Organic molecules with a planar or linear shape tend to form layers with anisotropic refractive indices.

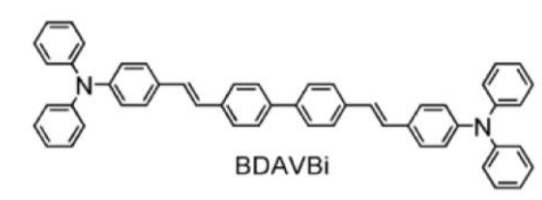
The anisotropy can be positive or negative, depending on the temperature of the substrate during deposition.



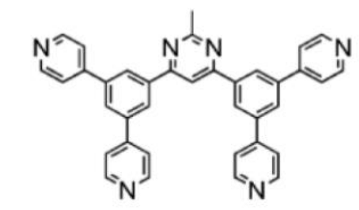

$$\Delta n = n_e - n_o$$

EML
Δn=-0,25



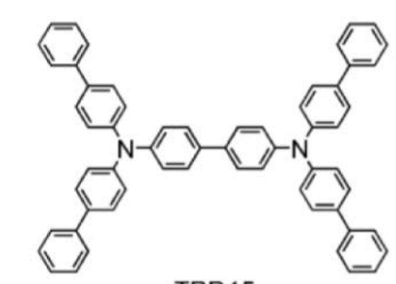
BDAVBi

ETL
Δ n=-0,27



B4PyMPM

HTL
Δ n=-0,17



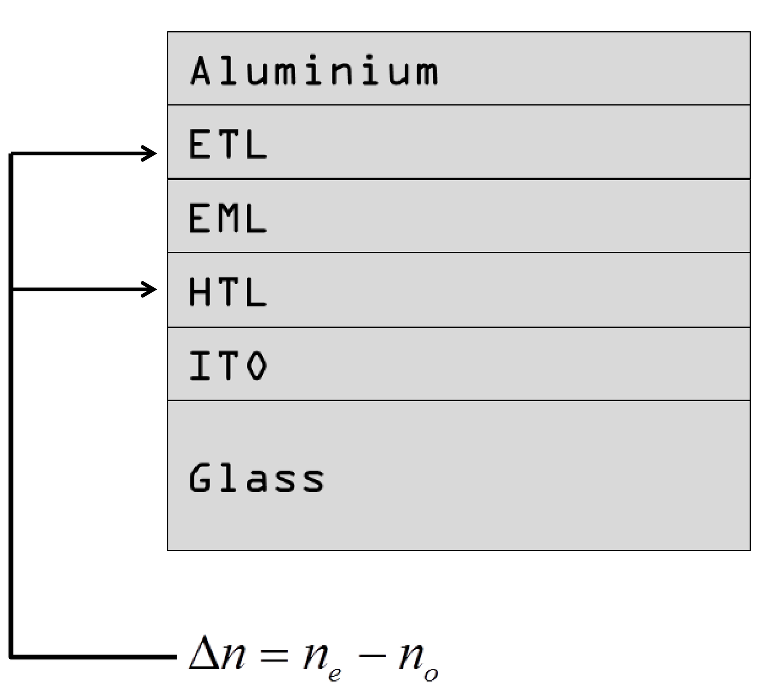
TPD15

## Bottom emitting OLED

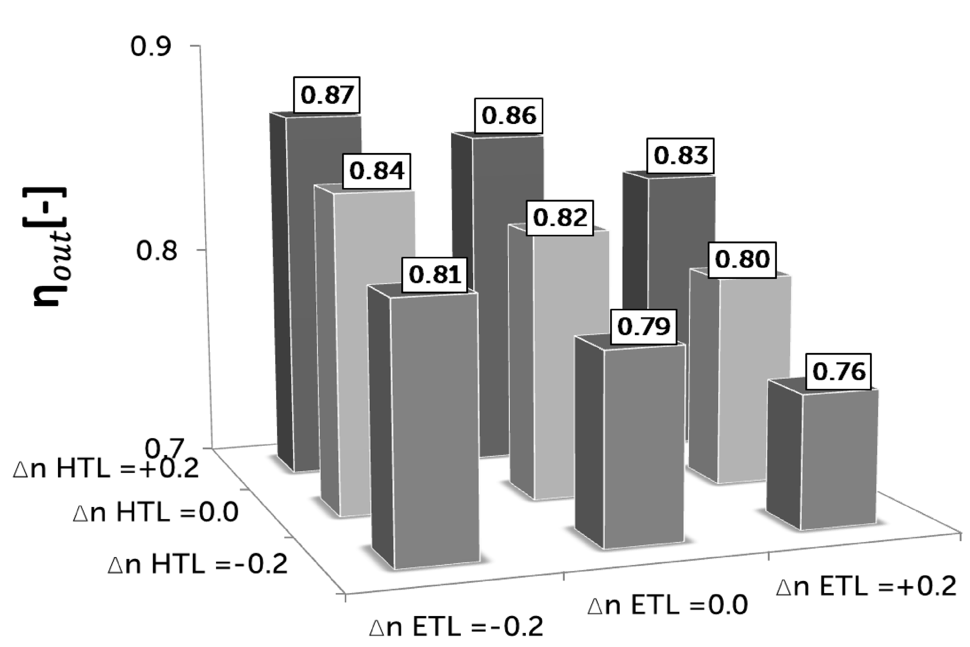
The potential of anisotropic organic layers is assessed by calculating the maximum outcoupling efficiency to the substrate.

$n_{iso}$ is a weighted average of the ordinary and extra-ordinary refractive indices. It is kept constant which allows for a fair comparison between isotropic and anisotropic layers

$$n_{iso} = \left[\frac{2n_o^2 + n_e^2}{3}\right]^{1/2} = 1.7$$



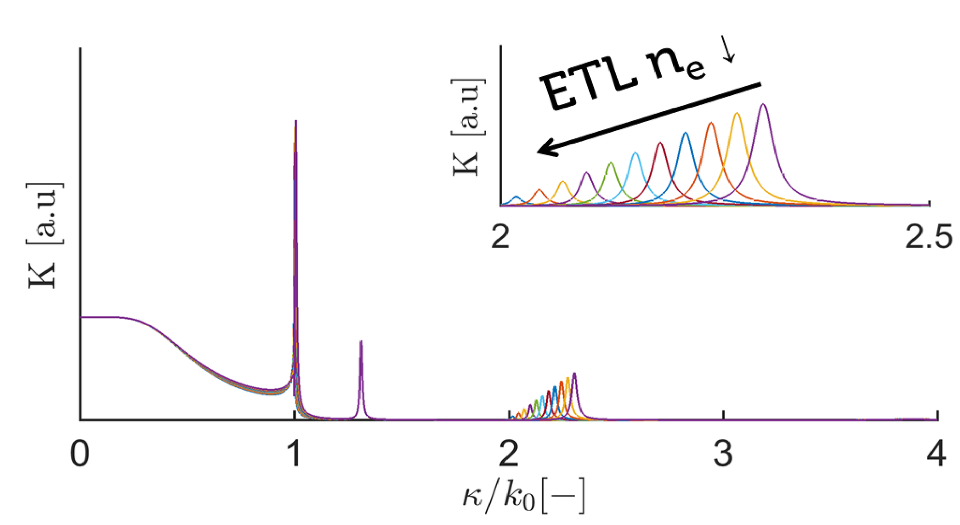

### Maximum outcoupling efficiency to substrate

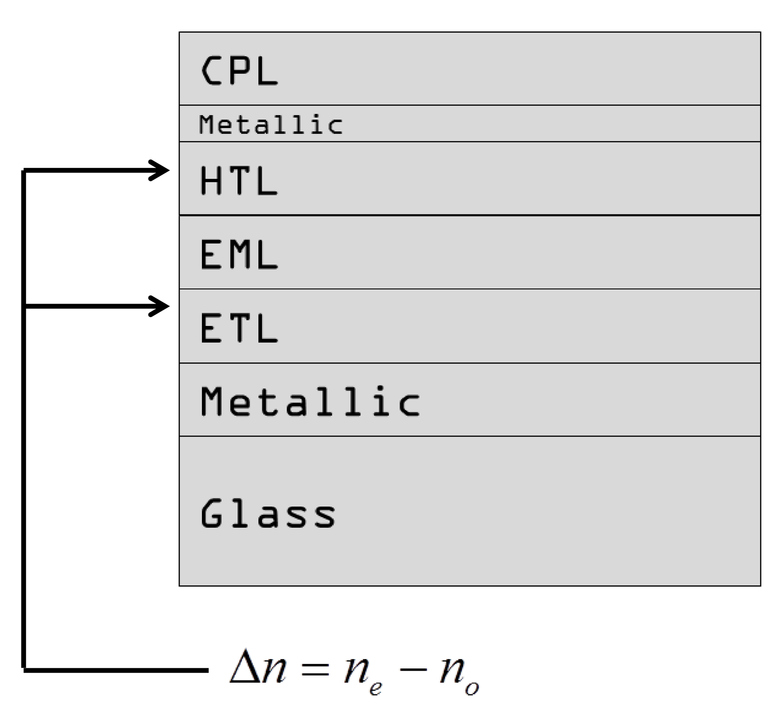



Proper use: +6%

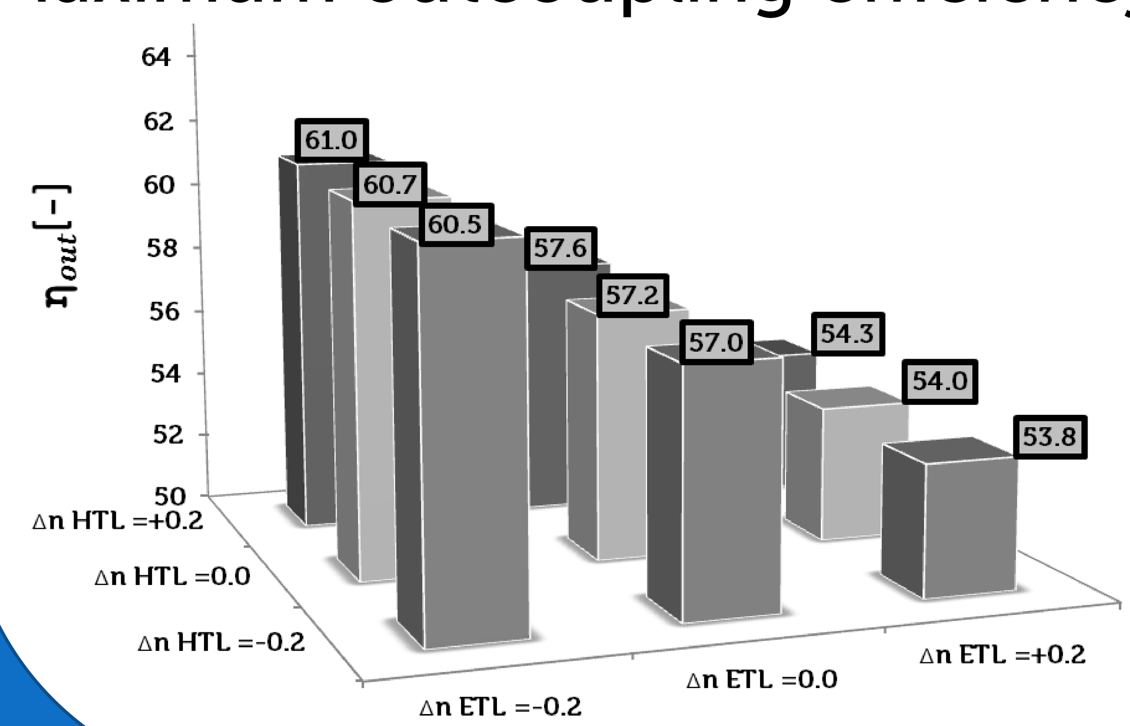
Improper use: -7%

## Top emitting OLED




### Maximum outcoupling efficiency to air




Proper use: +7%

Improper use: -6%

## Conclusion

Control over the optical anisotropy of organic layers is possible

**Golden rule:**
**ETL must be negatively anisotropic**

Good optical design [2] & [3]

Increased outcoupling efficiency

References:
[1] D. Yokoyama, "Molecular orientation in small-molecule organic light-emitting diodes," J. Mater. Chem., vol. 21, no. 48, p. 19187, 2011.
[2] L. Penninck, P. De Visschere, J. Beeckman, and K. Neyts, "Dipole radiation within one-dimensional anisotropic microcavities: a simulation method.," Opt. Express, vol. 19, no. 19, pp. 18558–76, Sep. 2011.
[3] M. K. Callens, D. Yokoyama, and K. Neyts, "Anisotropic materials in OLEDs for high outcoupling efficiency," Opt. Express, vol. 23, no. 16, p. 21128, 2015.