Organic light emitting diodes using graphene electrodes

Jens Meyer[1], Piran R. Kidambi[2], Christ Weijtens[1], Alba Centeno[3], Amaia Zurutuza[3], John Robertson[2] and Stephan Hofmann[2]

[1]Philips Research, Weisshausstrasse 2, 52066 Aachen, Germany
[2]Department of Engineering, University of Cambridge, 9 JJ Thomson Avenue, Cambridge CB3 0FA, UK
[3]Graphenea S.A., Tolosa Hiribidea 76, E-20018 Donostia, San Sebastian, Spain

Contact: jens.meyer@philips.com

Abstract

Electrode materials combining high electrical conductivity and optical transparency are crucial components for organic light emitting diodes (OLED). Graphene is thereby a highly promising alternative to commonly used Indium tin oxide (ITO), in particular considering that unlike ITO graphene is flexible and, when grown via Chemical Vapor Deposition (CVD), not constraint by limited natural resources. Critical challenges for graphene based OLEDs not only relate to the further improvement of large-area, controlled graphene CVD [1,2], but also to its integration, in particular to achieve efficient charge injection and graphene doping. Several dopants have recently been introduced, but most are chemically not stable or not applicable for organic electronic devices.

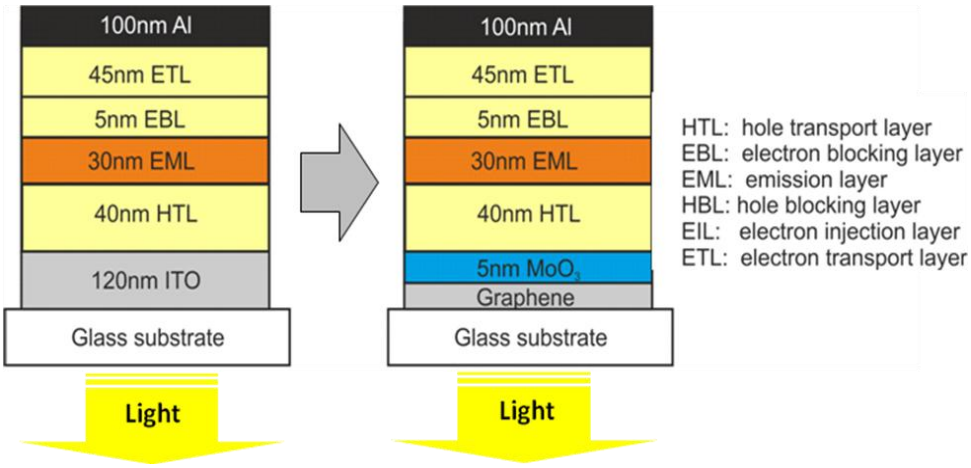

Figure 1: Scheme of OLEDs with ITO electrode and graphene electrode.

Here we show that transition metal oxides, such as MoO_3, are very efficient and stable p-type dopants for graphene which can be easily integrated in the OLED fabrication process. Our process is based on scalable graphene CVD [1,2] and the doping is carried out via thermal evaporation analogous to all following OLED layers.
With in-situ 4-point probe measurements we find that only a few nanometers of MoO_3 are sufficient for efficient doping leading to a more than three-fold improved sheet resistance.
In addition, ultra-violet and x-ray photoemission spectroscopy (UPS, XPS) studies of the doping process reveal a large interface dipole of 2.2 eV and band bending caused by an electron transfer from graphene to MoO_3. The strong p-doping of graphene is enforced by the deep lying electronic states of MoO_3 which exhibits a work function of >6.5 eV.[3] The energy level alignment at the graphene/MoO_3/organic interfaces as measured with UPS shows only very small energy barriers for hole-injection.

Thus, MoO_3 allows not only an efficient p-doping of graphene, but also provides a suitable matching for efficient hole-injection from graphene into the OLED layers. Based on this process, we demonstrate CVD graphene based OLEDs that show electro-optical performances similar to conventional ITO based devices, as shown in Figure 2.

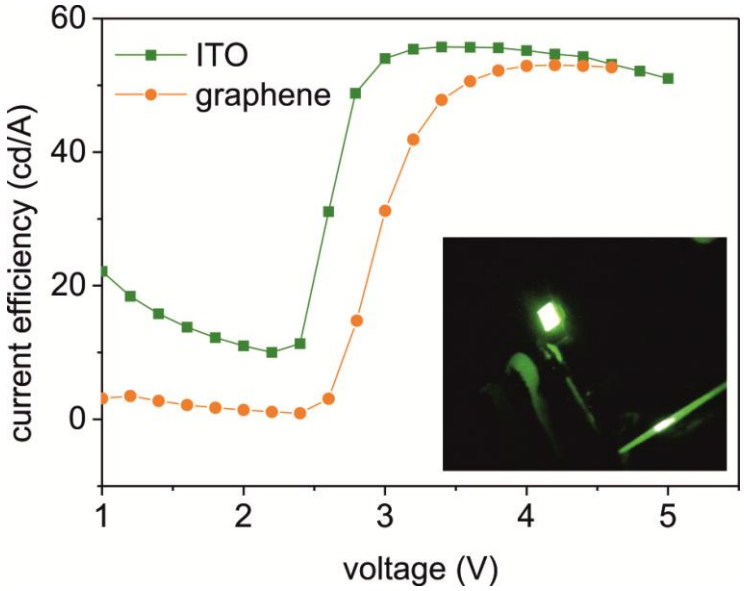

Figure 2: Current efficiency vs. voltage characteristics of OLEDs with ITO and graphene electrode, respectively.

Acknowledgment

The authors acknowledge funding from the EC project Grafol

References

[1] Kidambi et al., J. Phys. Chem. C (2012) DOI 10.1021/jp303597m.
[2] Weatherup et al., ACS Nano (2012) DOI 10.1021/nn303674g.
[3] Meyer et al., Adv. Mater. (2012), 24, 5408.