Electroluminescence in organic light emitting diodes

Experimental and conceptual exploitation of an innovative topic for education of chemistry in school

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Introduction

OLEDs (organic light emitting diodes) are innovative illuminants, which we increasingly face in products from everyday life, such as mobile phones or flat TV-screens. In the near future further applications like transparent and flexible displays [1] will be accessible with these organic structures. This lecture is a contribution to a didactical exploitation of this innovative topic.

Principle of electroluminescence

The light emission in the presented OLED is based on the formation of electron-hole-pairs within conjugated polymers with semiconducting properties. Therefore a suitable polymer like PPV (fig. 1) has to be placed between a transparent anode and a metallic cathode (fig. 2). By application of an electric voltage electrons (on the cathode side) and holes (on the anode side) are injected into the polymer layer. The charge carriers drift along the electric field towards each other and recombine via fluorescence (or thermal radiation). Electroluminescence leads to high efficient illuminants with low driving voltages.

Figure 1: Structure of poly(p-phenylenevinylene) (PPV)

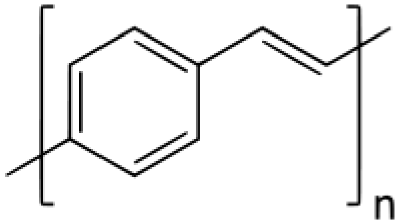
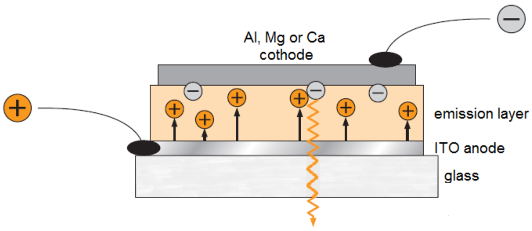


Figure 2: principle of electroluminescence



Experimental approach

The experimental part focuses on a self-made OLED based on low-cost materials and some special materials supported by our team. This OLED is a one-layer-system made of an ITO-glass, which has been coated with the emitter polymer Superyellow® (Merck) (fig. 3). A special lowcost spincoating machine was used for this. The cathode consists of Galinstan® (Geratherm) and was injected into the tape layer by a syringe. A strap of magnesium provides the connection to the cathode. The OLED reaches a light density of approx. 100 cd/m^2 at a voltage of 12 V (fig. 4). The emission maximum is at 560nm (green/yellow).

Figure 3: Schematic assembly of the self-made OLED and structure of the copolymer Superyellow (a PPV derivative)

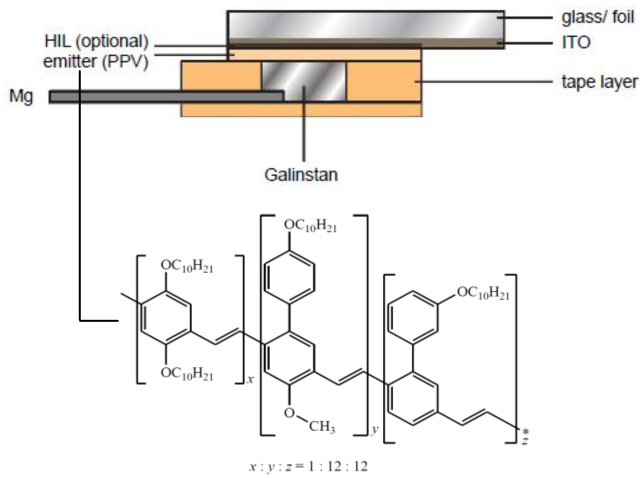
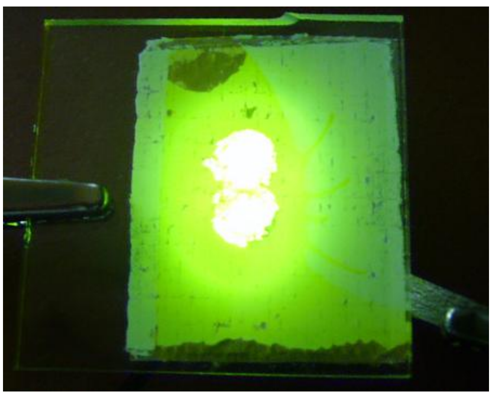
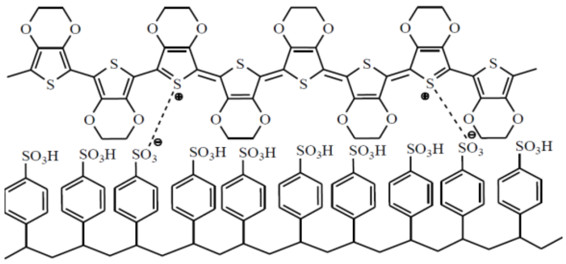


Figure 4: Electroluminescence of the self-made OLED at 12V



A flexible version of the OLED has been achieved with a conducting PET-foil [1]. Due to the higher electrical resistance the Flexi-OLED additionally needs a hole injection layer (HIL). This layer consists of PEDOT:PSS (fig. 5) and is applied between the ITO and the emission layer by spincoating from an aqueous 2-propanol solution. The HIL increases the conductivity of the PET-foil, but primary leads to a simplified hole injection by bridging the energy gap between the HOMO of the emitter polymer and the conduction band of the ITO. This way a flexible version of the self-made OLED can be achieved, which at 12 V shows an electroluminescence comparable to its rigid pendant (fig. 6).

Figure 5: Structure of the 'hole-injector' Poly-(3,4-ethylenedioxythiophene)poly(styrolsulfonate) (PEDOT:PSS)



Poly-(3,4-ethylendioxythiophen) poly(styrolsulfonate) (PEDOT:PSS)

Figure 6: Electroluminescence of the Flexi-OLED at 12 V

Multimedial exploitation

To understand how organic polymers can be activated for electroluminescence, one has to consider the elementary processes in the OLED. The interactive Flash-animation [3] (fig. 7) vividly illustrates these processes on an appropriate level corresponding to core concepts of general chemistry. Besides charge carrier injection, charge carrier transport and recombination, also the hopping mechanism of charge carriers between molecules is demonstrated in short movies. The user is able to gather detailed information and further animations on each elementary process and the components of the OLED via buttons (e.g. in fig. 8).

Figure 7: Flash-animation on the elementary processes in an OLED

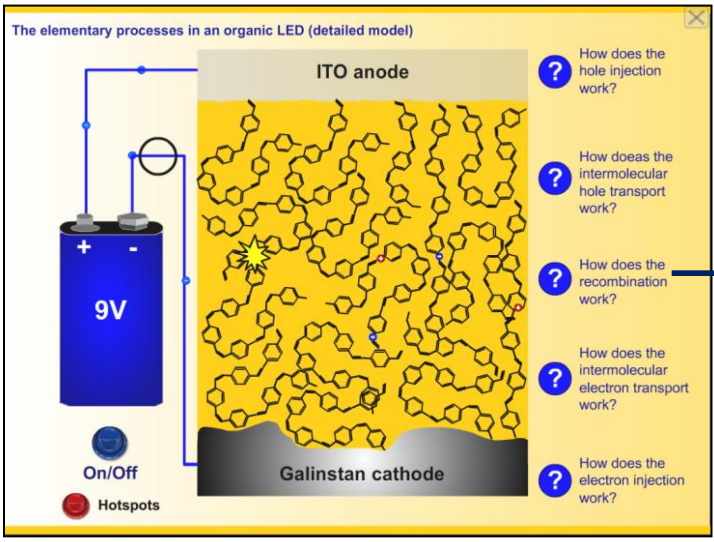
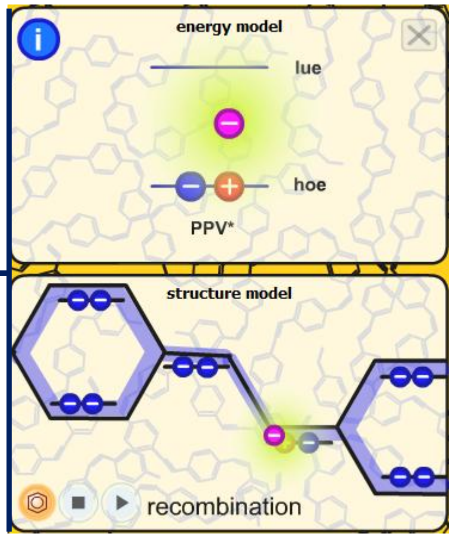


Figure 8: Visualization of the electron-hole recombination in the Flash-animation



[1] *A. Banerji, M.W. Tausch*, Funktionelle Farbstoffe. PdN-ChiS, 59 (8), 6 (2010)
[2] *A. Banerji, M.W. Tausch*, Elektrolumineszenz in organischen Leuchtdioden. PdN-ChiS, 59 (4), 42 (2010)
[3] http://www.chemiedidaktik.uni-wuppertal.de/material/interactive/index.htm > Elementarprozesse in der OLED