Laser structuring of organic optoelectronic devices

The Organic Photovoltaics group of the Karlsruhe Institute of Technology (KIT) studies the fabrication, optimization and simulation of organic solar cells and semiconductor devices. We focus on the evaluation of new materials, deposition techniques and device fabrication, including all steps from single layer deposition and structuring to device characterization. The task of this work was to build large-scale organic light emitting diodes (OLEDs) for luminaires. This required an invisible series connection of OLEDs to reduce the device current and hence to mitigate ohmic losses. A femtosecond laser was used to selectively structure the layers.

The high resistance of the semi-transparent electrodes in OLEDs lead to severe ohmic losses. The ohmic losses lead to inhomogeneous light emission from the device. The problem can be solved by connecting smaller OLEDs in series. The smaller area of the devices limits the current, hence decreasing the total power losses on the device while maintaining the same luminance. To monolithically connect the device in series three patterning steps are performed, henceforth referred to as P1, P2 and P3 (Figure 1). P1 electrically separates the bottom electrode. P2 allows the connection of the top and bottom electrodes and P3 separates the top electrodes. The area between this P1-P3 is does not emit light and should be minimized. Laser ablation is a proven method to structure P1, P2 and P3 and decrease the inactive area.

KIT is one of the biggest research and education institutions worldwide and has the potential of reaching a top position in selected research areas on an international level. The objective is to turn KIT into an institution of top research, excellent scientific education, and a prominent location of academic life, life-long learning, comprehensive advanced training, unrestricted exchange of know-how, and sustainable innovation culture. The project was undertaken by Joshua Fragoso.

Karlsruher Institut für Technologie

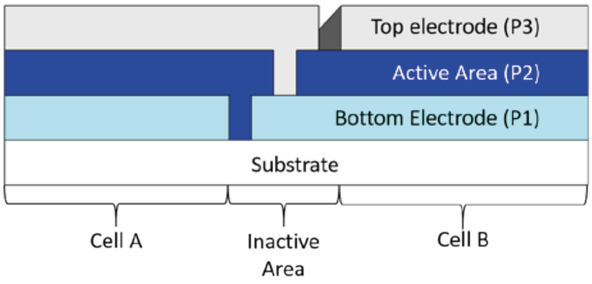

Figure [1]. *Subdivided devices using a monolithic connection. The three patterning steps P1, P2 and P3 are shown.*

Measurements

To structure P2 it pivotal to preserve the bottom electrode unscathed. In this case, P2 is composed of three different layers, SuperYellow/PEI/ZnO. The total thickness of all three layers is between 50-60 nm. Figure 2 shows the 3D contour of the laser-written line at λ=550 nm with F=210 mJ/cm^2 and 95% pulse overlap. The ablation depth goes beyond 60 nm, and part of the bottom electrode is removed (dark blue area).

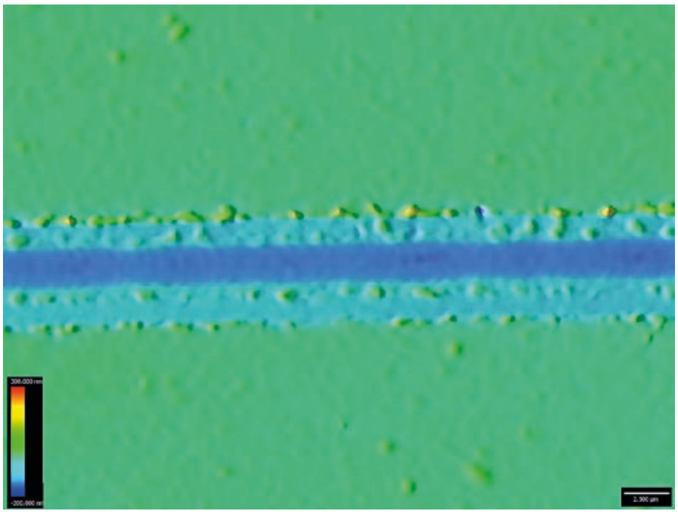

Figure [2]. *3D contour of a laser written-line at λ=550 nm, F=210 mJ/cm2 and 95 % pulse overlap.*

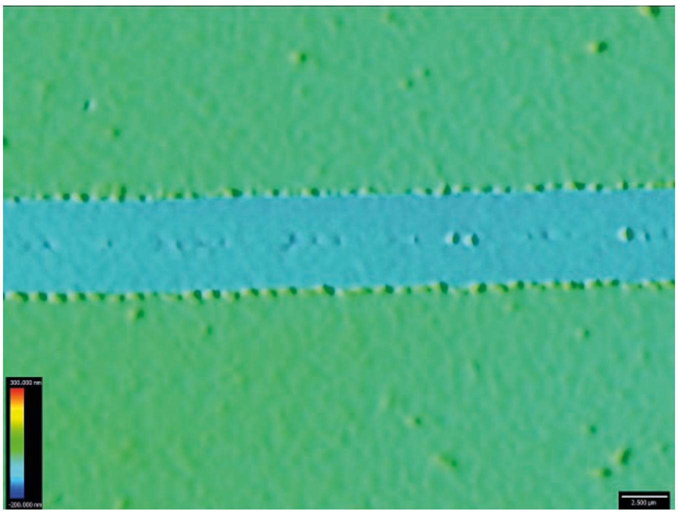

Figure [3] *3D contour of a laser written-line at λ=550 nm, F=110 mJ/cm^2 and 85 % pulse overlap.*

Figure 3 shows the 3D contour of the laser-written line at λ=550 nm with F=110 mJ/cm2 and 85% pulse overlap.

The ablation depth is optimized at 60 nm. The ITO shows negligible damage that does not hamper the performance of the device. Figure 4 shows the profile line of an optimized laser-written line. The profile shows an ablation depth of about 50 nm with a small line width below 5 µm.

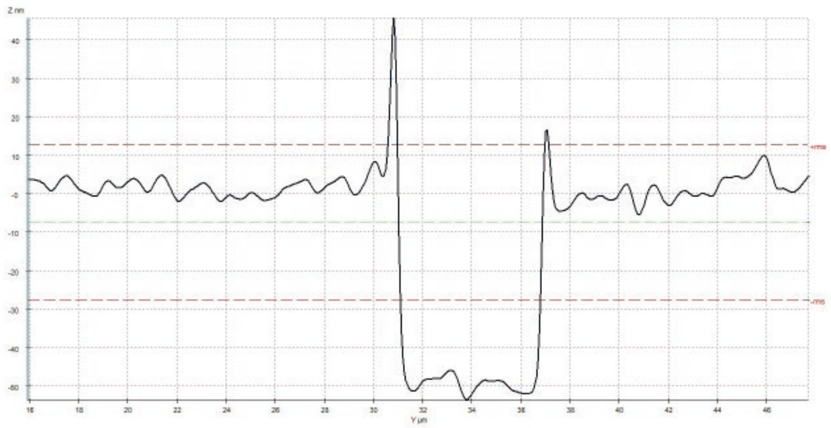

Figure [4] *Profile of a laser written-line at λ=550 nm, F=110 mJ/cm² and 85 % pulse overlap.*

The connection of OLEDs using a laser enables the reduction of the inactive area to below 40 µm in width, therefore concealing it to the naked eye. The use of the confocal microscopes enables us to quickly characterize the ablation.

Conclusions

Using the S neox confocal capabilities and the 150× objective, laser-written lines with a width of some micrometers and a depth of about 100 nm were monitored. The instrument allows to detect when the ablation is not selective by measuring the thin film layers.

Bibliography

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[2] J. Fragoso Garcia, S. Höfle, M. Zhang, J. Dlugosch, T. Friedrich, S. Wagner y A. Coslmann, «OLED Luminaires: Device Arrays with 99.6% Geometric Fill Factor Structured by Femtosecond Laser Ablation,» ACS Applied Materials & Interfaces, vol. 9, nº 43, p. 37898–37904, 2017.

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