SEQUENTIAL MULTILAYER COATING PROCESS FOR FLEXIBLE ELECTRONICS.
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Abstract:
Worldwide billions of dollars are invested every year in research and development equipment, as well as in production facilities, in the field flexible electronics (Figure 1). These flexible electronic devices usually consist of a stack of thin functional layers, which are preferably applied from solution. Recent publications show an increasing interest in high speed coating technologies like slot die - and slide coating, because these technologies are designed to apply layers from solution to substrates in roll to roll processes. Therefore they seem highly suitable and especially slide coating would be ideal to apply simultaneously multi layers. However, it is very complicated to create stable coating conditions due to physical differences between the functional materials and solvents of the layers. An alternative approach to this problem is, to have sequential coating of the layers by means of slot die coating and drying of the layers. A novel process concept was developed to enable sequential processing in an extremely clean environment. The latter is necessary to prevent contamination of the vulnerable layers by small airborne particles, which have a strong negative effect on the overall yield.

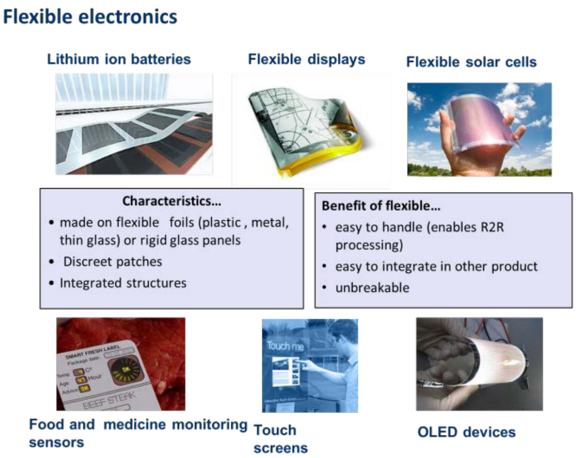

Figure 1. Examples of flexible electronic devices.

Introduction.
Sequential processing in one process pass is common in industry, mostly in order to reduce the production costs. This however becomes rather complicated when the process yield is dominated by particle and chemical contamination, for example by means of touching of the functional side of the web to process parts like nips or idler rollers.
In the case of photovoltaic and organic light emitting diodes the thickness of the functional layers is usually in the range of 20 to 200nm. Particles larger than this, may cause serious defects and have a negative influence on the lifetime and yield of the product. This is one of the main reasons to develop a process which enables multiple processing without contact between the topside of the web and process parts.

Process design.
The process concept which was developed, consist of two slot die coating stations in order to enable subsequent coatings. The schematic drawing of Figure **2** shows the process floorplan and illustrates the separation of the process parts between cleanroom and none cleanroom area. The winder, rewinder and coating stations are located in the cleanroom and the dryers outside of the cleanroom. The advance of this separation is,

that the footprint of the cleanroom is small in comparison to the total process area and therefore it is relative easy to control the environment and cleanliness level.

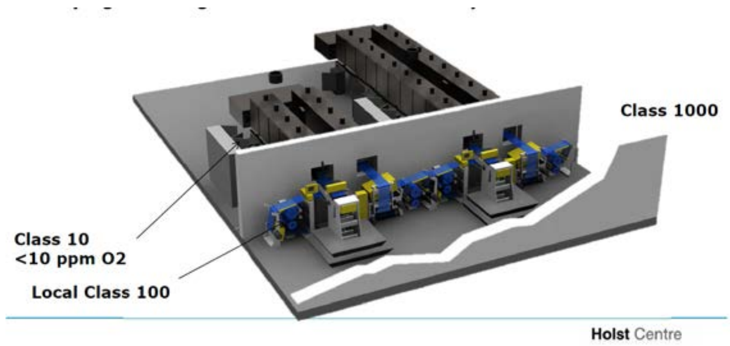

Figure 2. Schematic drawing of two subsequent coating stations in one process.

In this concept, single or stacked dried functional layers are never in the contact with process parts. Because of this very important feature, damages like scratches and particle contamination can be prevented and this is one of the most crucial advantages of this process. Contamination of airborne particles of sizes larger than 0,3 µm are potential defects and they have a hudge impact on the product yield. This is also the reason that the vulnarable layers and printed structures should be applied in one process pass before winding on a roll. In practice this could mean that for the manufactturing of organic light emitting diodes or solar cells, five to seven printing and/or coating stations have to be integrated.

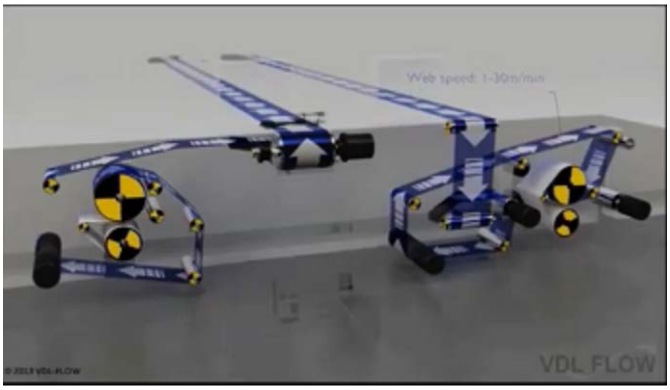

Figure 3. Artist impression of the webpass in the process. The topside of the foil does not physically touch any process part.

The dryers are constructed in such a way that motion - and web touching parts(on the rear side of the web) are limited. This is an advantage with respect to particle generation. For some applications it is necessary to run the process under nitrogen, therefore this option is available too.

Results and Conclusions.
Web transport was the first item which was tested in the process since this is a newly developed concept. The web behaviour of polymer foils in the range of 50 to 150µm and metal foils in the range of 18 to 30µm was evaluated and no problems were observed.

Initial particle counts in dryer part of the process without transportation of the web, showed values which correspond to a cleanliness level between 1 and 10 (Figure 4) according to the cleanroomstandard US FED STD 209E.

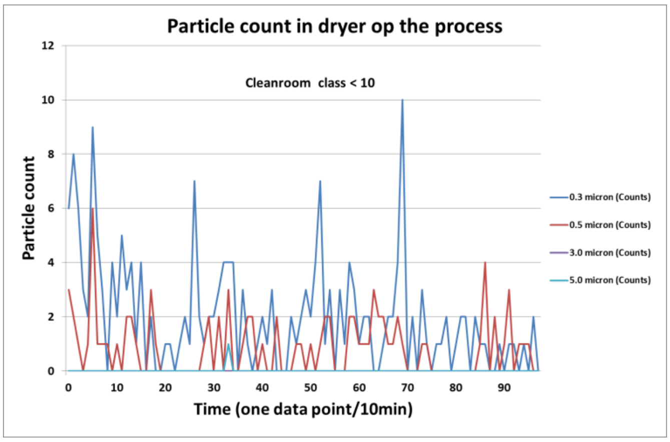

Figure 4. Particle count in the dryer section of the process.

The first coating tests have been performed and defect free uniform OLED devices could be produced, as illustrated in Figure 5. Although the number of performed coating tests is still limited, it is clear that the specifications of the process concept have been met and the manufacturing of flexible electronics from solution, like for example OLED's, is one step closer to realization.

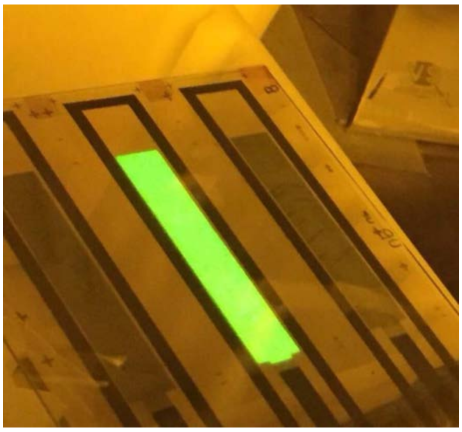
Figure 5. Bottom-emissive OLED on plastic barrier foil

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