Polymer tandem solar cells
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Summary

The global demand for energy is expanding continually. Therefore, realization of green power sources are needed since combustion of fossil fuels will have serious consequences for the climate on the Earth. With a photovoltaic device, the solar light can be converted into electricity which is the most useful forms of energy. For this reason, solar cells have attracted much attention in the last decades as most clean, sustainable and renewable energy sources. In order to produce low-cost and large-area solar cells, organic materials provides many possibilities. Especially semiconducting polymers combine the favorable opto-electronic properties, such a high absorption coefficients, of organic materials with the excellent processing and mechanical properties of plastic materials. This implies that an organic solar cell can be processed from solution at room temperature onto (flexible) substrate using simple and, therefore, much cheaper methods such as spin (or blade) coating and inkjet printing. However, the formation of a bound-electron-hole pair that needs to be separated, the low mobility of charge carriers (or the mobility difference between holes and electrons) together with relatively narrow absorption spectra of the organic materials lead to relatively low performance (typically amounts to 4-6%). To improve the absorption of the solar radiation by organic solar cells, materials with a broad absorption band have to be designed or different narrow band absorbers have to be stacked in multiple junctions. When two (or more) donor materials with non-overlapping absorption spectra are used in a tandem (or multi-junction) solar cell, a very broad range (from visible to infrared) of the solar radiation can be absorbed by such a device. In addition to converting a larger part of the spectrum, tandem solar cells distinct advantage that photon energy is used more efficiently because the voltage at which chargers are collected in each sub cell is closer to the energy of the photons absorbed in that cell. There are several approaches organic tandem (multiple) cells reported in the last years, depending
on materials used for the active layer and the proper separating layer(s). The multiple organic solar cells can be summarized in three classes;

A) Tandem (multi-junction) solar cells in which low molecular weight organic molecules are used for all sub cells.

B) Hybrid tandem organic solar cells in which the bottom cell is processed from polymers by solution-processing while the top cell is made of vacuum-deposited low molecular weight organic molecules.

C) Fully solution-processed tandem or multi-junction solar cells in which all sub cells are processed from polymers.

The main subject of this thesis is solution-processed tandem solar cells that consists of two bulk heterojunction sub cells with complementary absorption spectra. A composite middle electrode separated the two sub cells. This middle contact serves two different purposes; as a charge recombination center, and as a protecting layer for the first cell during spin coating of the second cell. Since the bottom and the top cell are electrically stacked in series in this tandem cell, the open-circuit voltage of the tandem cell equals the sum of the open-circuit voltages of both sub cells. An open-circuit voltage of 1.4 V is achieved. The short-circuit current of this tandem cell is limited by the lowest value which is the current of the top cell. In this cell, the layer thickness of the bottom cell has to be optimized in such a way that the optical output is adapted to the absorption of the top cell.

A disadvantage of this approach is that the optimum thickness of the bottom cell, required to match the optical output, is not necessarily equal to the thickness where the bottom cell reaches its optimum performance. In order to improve the above-mentioned structure, a additional solution-processable, transparent and insulating layer can be used as separating layer. This layer serves as an optical spacer and leads to the fabrication of a 4-electrode tandem cell. In this way, the thickness of the bottom cell is optimized for its electrical performance and the optical output is tuned by varying the thickness of the optical spacer. The two sub cells can be coupled electrically in parallel or series since this optical spacer is
an insulator. The parallel configuration leads to a higher performance because the extracted current from the tandem device is not limited by the low current of the top cell any more.

The solar cells are not cheap enough yet for large-area applications. One of the ways to reduce the payback period (economic return-on-investment) is integrating the solar cells into a building. This means that the solar panel itself serves as the building materials as well as the source of electricity generation. A solar cell can be integrated into a building in different applications such as roofing structures and window materials. It is clear that semitransparent solar cells can not only be used in the tandem structures but also as windows on buildings. However, the semitransparent solar cells have lower efficiencies since less light can be reflected inside the device by the semitransparent cathode. The performance of semitransparent BHJ solar cells can be improved due to the addition of a prototype semitransparent cathode with photoluminescent properties. This luminescent cathode can be used in general for solution-processed organic semitransparent solar cells used for PV-windows applications.