Polymer solar cells thermal annealing of active layers – impact of annealing temperature on efficiency and ageing rate

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Polymer solar cells are a third-generation photovoltaic cells that attract a great research interest in the last years. Their most important part is an active layer responsible for solar light absorption and exciton separation. The active layer is a nanoscale blend of organic semiconductors: donor and acceptor materials forming of bulk heterojunction. Typically, it is polymer (e.g. PTB7-Th) and fullerene derivative (e.g. $PC_{70}BM$). Polymer solar cells have some advantages comparing to silicon solar cells: low cost and ecological production, low weight, flexibility, possible semi-transparency and ease of production of multi-junction cells.

There are also some important disadvantages: lower efficiency and weaker air stability. One of these cons, lower efficiency, has been improved by application of a non-fullerene acceptor materials in form of low band-gap organic molecules e.g. BTP-4Cl-12 [1]. Such new acceptors have higher absorption near maximum of solar light spectrum than regular organic acceptor e.g. $PC_{70}BM$ with maintaining the same or better electron mobility. For the new acceptor with lower band-gap there were developed new donor materials like PBDB-T-2F with matching band-gap and energy levels what increased efficiency to over 17% in 2019 [1].

We present our results of research on two active layers of polymer solar cells: well known PTB7-Th:PC70BM and state-of-art PBDB-T-2F:BTP-4Cl-12. We tested annealing temperature impact on crucial parameters of the cells and on their long time stability. Thermal annealing not only removes solvents residues but also improves carrier mobility. The effects of annealing on the cell efficiency were showed in Fig.1. We obtained maximum cells efficiency 5.1% for PTB7-Th:$PC_{70}BM$ annealed at 50°C and 8.1% for PBDB-T-2F:BTP-4Cl-12 annealed at 130°C. Optical absorbance spectroscopy was carried out to check influence of thermal annealing on excitonic transitions. We observed clear BTP-4Cl-12 absorbance peak redshift after annealing (Fig. 2). The photocurrent spectra confirmed efficient current generation in both donor and acceptor materials. To investigate long-time stability of the cells a 4 months ageing measurements were performed. We have found out that optimal thermal annealing significantly improved cell stability.

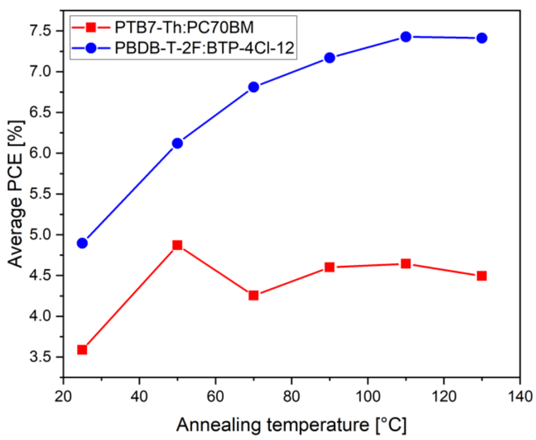

Fig. 1. Average power conversion efficiency (PCE) vs. annealing temperature.

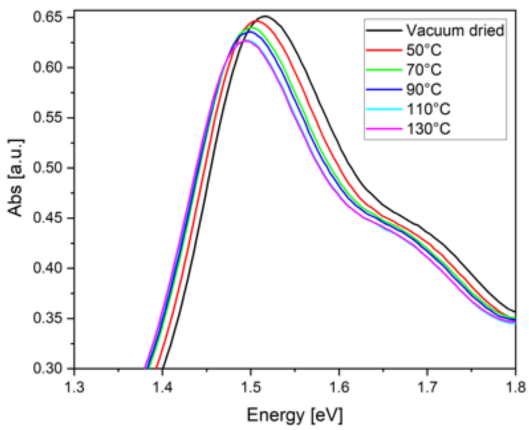

Fig. 2. Absorbance spectra of BTP-4Cl-12 annealed at different temperatures

[1] Y. Cui, *et al., National Science Review* **7**, 1239 (2020)