UNIWERSYTET WARSZAWSKI

WYDZIAŁ FIZYKI

# *Procesy fizyczne warunkujące trwałość i sprawność energetyczną polimerowych ogniw słonecznych*

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# Abstract

This PhD thesis presents research on the physical processes occurring in polymer solar cells, aimed at improving the stability and efficiency of photovoltaic cells. Polymer solar cells belong to the third generation of photovoltaic cells. Despite their advantages, such as ease of manufacturing and low production costs, polymer solar cells still require important improvements. First of all, polymer cells have lower efficiency than silicon cells. Additionally, some of the materials used in them have high degradation rate. These two problems, their causes and ways of counteracting them are the main topics discussed in this PhD thesis.

Great emphasis was placed on light absorption, which is the first stage of converting light energy into electricity. Materials with different absorption bands were used. A large part of the work was devoted to the study of ternary active layer PBDB-T-2F:BTP-4Cl-12:$PC_{70}BM$ containing two types of acceptors (a fullerene derivative and a non-fullerene acceptor), which significantly increases the generated photocurrent. The semiconductor materials were selected so that their absorption range optimally covered the solar spectral range. The total content of both acceptors in the tested ternary active layer was optimized. During the work, cell efficiency of up to 9.2% was achieved.

The efficiency of the cell depends on the charge separation yield, which is influenced by arrangement of quantum levels of the materials forming the junction. Searching for optimal parameters, a number of new $C_{60}$ and $C_{70}$ fullerene derivatives were tested. The best results were achieved for indene fullerene derivatives, and the highest efficiency for the hexyl group ($C_{70}$-IPH). Higher voltages were observed resulting from the higher LUMO level in $C_{70}$-IPH. The stability of samples with indene fullerene derivatives was identical to that obtained for the commercially available PCBM derivative.

Most of the research was conducted on cells in a standard configuration, but also cells in an inverted configuration were investigated. Such cells have theoretically higher stability and can be used in tandem cells. A number of ETL hole-blocking layers were tested: ZnO in various varieties and $TiO_x$.

Moreover, for the active layers PTB7-Th:$PC_{70}BM$ and PBDB-T-2F:BTP-4Cl-12, the annealing temperature was optimized, which has a huge impact on both the efficiency (order of phase separation) and the stability of the cells. For PTB7-Th:$PC_{70}BM$ samples stability was significantly improved by increasing the T50 degradation time from approximately one year for the unheated sample to 9-22 years for the heated samples.