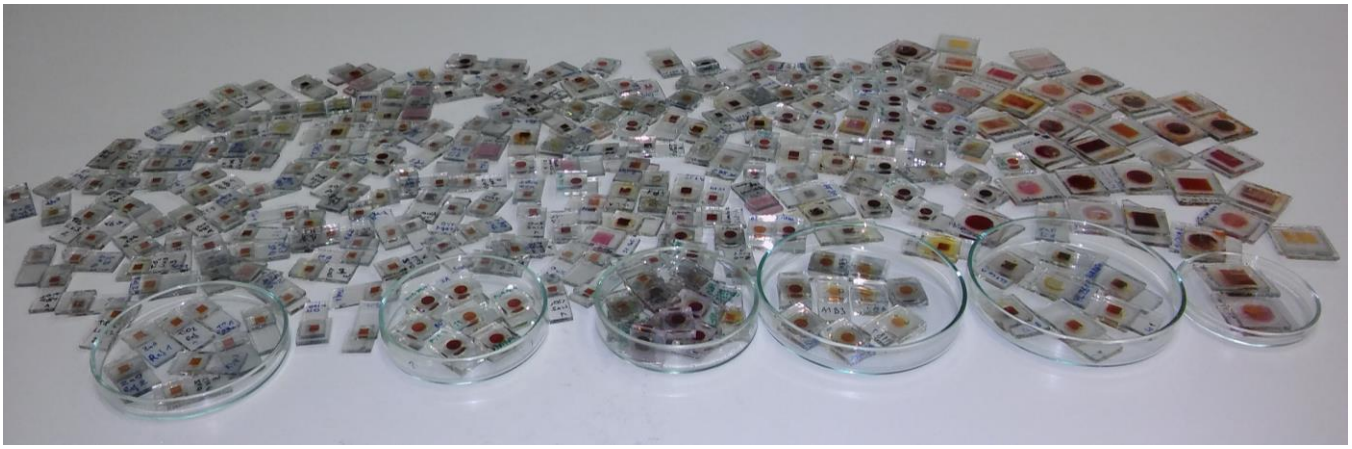
Description of project results: NCN no 2012/05/B/ST3/03284.
"Elementary charge-separation processes in dye-sensitized solar cells studied by time-resolved optical spectroscopy"

The project studied processes of charge separation in dye-sensitized solar cells (DSSC) occurring at different scales times: electron injection from the excited dye to the nanostructures of metal oxide (times from tens femtoseconds to single nanoseconds), dye regeneration (single microseconds) and charge transport in nanostructures (times from milliseconds to seconds). More than 300 prototype photovoltaic cells (figure) we were prepared and measured for the project realization. As the sensitizers, several efficient organic dyes (D149, D358, MK2, HY103, MK245) and ruthenium dye (N719) were employed. The investigated metal oxides were TiO_2 and ZnO, and the cells were filled with liquid electrolytes based on iodide or cobalt, both with various acidic and basic additives. Time resolved laser spectroscopy, impedance spectroscopy and basic tools to characterize the performance of photovoltaic devices were used in the studies. The project resulted in 11 scientific publications in journals whose total impact factor is over 60.



The project helped to explain the factors that limit the performance DSSC. It was found that for the majority of molecules tested (except for ruthenium dye) the performance is limited by the efficiency of charge separation in the shortest time range (from tens of femtoseconds to single nanoseconds) connected with the direct interaction between dyes and metal oxide nanoparticles (electron injection and fast recombination). These results challenge the prevailing widespread view that in the optimized DSSC the fastest stage charge separation occurs always with a quantum yield close to 100%. Besides, the project has contributed to a better understanding of photophysical processes taking place for organic molecules interacting with inorganic nanostructures. As it turned out, in this case one can observe many phenomena that do not occur during typical measurements of molecules in solution (self-quenching, energy transfer between monomers and aggregates). Another effect of the project is a detailed comparison of the charge separation using two different semiconductor materials: titanium oxide and zinc oxide. The project should help in the design of new solutions for more efficient DSSC and in the development of other sectors of photovoltaics using nanotechnology.