Thin-films in photovoltaic applications - trends, novelties and perspectives

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Photovoltaic materials using thin films are increasingly used on an industrial scale. This is partially due to their extremely high efficiency, but mainly, to the possibility of upscaling the production of thin films on an industrial scale. An additional advantage of this approach is the possibility of growing active layers on a wide variety of surfaces. Furthermore, increasing the efficiency of the cell using nanomaterials can take place through the use of low-dimensional structures, thanks to which additional energy levels are obtained, allowing the use of transitions at longer wavelengths from the spectrum of electromagnetic radiation.

The maximum coefficient of light energy conversion into electricity in semiconductor systems is determined by the so-called Shockley-Queisser limit, which is approximately 32% with an optimal bandwidth of 1.2-1.3 eV. However, this efficiency can be increased by using solutions based on semiconductor nanostructures. Such cells are called Third-Generation Photovoltaic Cells. One of the types of nanostructures that play an important role are the so-called quantum dots, *i.e.* small semiconductor grains with sizes in the order of nm. The advantage of such systems is due to the lack of translational symmetry, the limitation on quantum transitions resulting from the behavior of the wave vector (equality of the wave vector of the photon and the electron) is removed. Removal of this limitation leads to the fact that absorption can occur from deeply lying discrete levels to high-energy states. This allows the usable range of the light spectrum to be significantly increased. Another advantageous fact resulting from the location of an electron and a hole (exciton) in the area of a quantum dot is the slowing down of thermalization processes and increasing the effective number of generated carriers through transitions in which the exciton, relaxing to lower energy, generates another exciton (the phenomenon of multiple exciton generation).

For the production of photovoltaic systems using low-dimensional structures and thin layers, advanced material growth techniques are currently used, including ALD, MOCVD, and PVD, allowing for precise control of the parameters of the manufactured materials.