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Nanotechnology for photovoltaic cells and energy efficiency

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Abstract. The intent of this paper is to connect science and technology in order to demonstrate how, in the field of on photovoltaic technologies, thin film solar cells have been the focus of many research facilities in recent years that are working to decrease manufacturing costs and increase cell efficiency. New research suggests that it might be possible to add a nanoscopic relief pattern to the surface of solar cells that makes them non-reflective significantly boosting efficiency and at the same time making them highly non-stick and self-cleaning. The paper presents the challenges and approaches to engineer the active layer of the cell, in order to obtain cells made up of components assembled with precision on the nanometer scale and with such properties as to increase the yield of conversion of solar radiation into electricity.

Introduction

Most of the research is nowadays concentrated on producing nanomaterials. Nanostructuring, which is the patterning of materials with nanoparticles, changes the surface texture and produces an absolutely different effect. Solar energy represents one of the most abundant and yet least harvested sources of renewable energy. In recent years, tremendous progress has been made in developing photovoltaics that can be potentially mass deployed. Of particular interest to cost-effective solar cells is to use novel device structures and materials processing for enabling acceptable efficiencies [1]. The use of nanostructures in photovoltaics offers the potential for high efficiency by either using new physical mechanisms or by allowing solar cells which have efficiencies closer to their theoretical maximum, for example by tailoring material properties. There are two obvious problems with photovoltaic cells, solar panels [2]. First, they are very shiny and so a lot of the incident sunlight is simply reflected back into the sky rather than being converted into electricity. Secondly, they get dirty with dust and debris caught on the wind and residues left behind by rain and birds. Therefore, the scope of the ongoing research to increase the efficiency of photovoltaic cells is addressed on two large faces, one intrinsic to the technology used and oriented to minimize the amount of light reflected by the solar panels and which is not converted into energy, the other more external to the technology adopted, bound to reduce the need for periodic cleaning of the panels (Fig. 1).

If not properly maintained on a regular basis, solar panel's efficiency can be reduced by 25/35 percent in a single month, with obvious economic consequences; In fact, the dirt does not allow all the sunlight from reaching the cells. Until now, the only way to tackle the problem was to wash the panels with a particular solution of water and biodegradable mild soap, including through automated cleaning systems, definitely recommended for large photovoltaic systems or on-roof mounted systems (Fig. 2). It is recent news that by the combination of research in the field of photovoltaics and nanotechnology - a union that has long proved successful in the implementation of solar ultra-light, very flexible and paintable - another way, more convenient and less dispersive seems to have finally come to curb the problem: self-cleaning solar panels.

Figure 1. View of photovoltaic panels

Figure 2. Researchers found that dirty solar panels only lose about 7.4 percent of their efficiency.

Methodology

The scientific Journal “International Journal of Nanomanufacturing”, recently published the results of a research conducted by a team of Chinese researchers, in collaboration with the Cardiff University. Zuobin Wang of Changchun University of Science and Technology (China), Jin Zhang of Xi’an Technological University (China) and colleagues at Cardiff University (UK), who are partners of the EU FP7 LaserNaMi project (*Laser Nanoscale Manufacturing*), have devised an approach to lithography, the process used to “print” microelectronic circuits, that allows them to add a pattern to the surface of a solar cell. The features of the pattern are so small that individual parts are shorter than the wavelength of light. This means that incident sunlight becomes trapped rather than reflected passing on more of its energy to electricity-generation process that takes place within the panel [3]. Therefore, what are the characteristics due to which these panels can be considered self-cleaning? First, the nanoparticles applied on the surface make it non-stick. In this way it is possible to prevent the sedimentation of all those impurities normally transported by atmospheric agents and birds.

The same particles also make it water-repellent, so that any liquid in contact with the surface such as water, humidity or other, can slip away quickly. Finally, these new photovoltaic surfaces are characterized by the microroughness. As a matter of fact, the panel is less reflective, the reflection of light is attenuated so that this can transit into the photosensitive layer in greater quantity. The panel gains in efficiency and produces the larger amount of energy at equal surface. The hydrophobic and non-stick nature of these panels has led the Chinese team to compare them to the lotus plant [4]. Dirt particles are picked up by water droplets due to a complex micro- and nanoscopic architecture on the surface, which minimizes the droplet's adhesion to said surface. In fact, the leaves of the lotus plant have a particular surface structure, which makes them extremely hydrophobic and makes them constantly clean: this is a property that nanotechnology is already a long time trying to reproduce for materials such as textiles and paints through the so-called “lotus effect” (Fig. 3). Aluminum surfaces were rendered highly super-hydrophobic by immersion in sodium hydroxide, in order to make them rough, and then were coated with 2 nanometers of perfluorononano [5]. The electron microscopy shows that the aluminium surface so treated resembles that of a lotus surface with a porous micro structure containing trapped air.

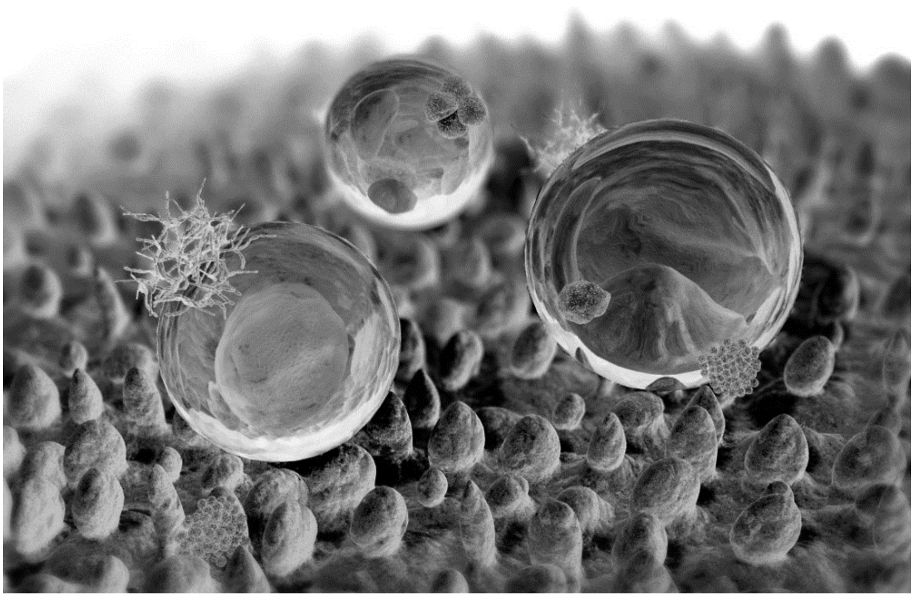

Figure 3. Computer graphic of a lotus leaf surface.

The team's work indicates that a patterned layer on top of the active part of the panel can avoid the energy losses due to reflection from the surface. It directly boosts absorption of sunlight in the visible spectrum and into the near-infrared part of the spectrum, all of which contributes to a boost to the overall electrical efficiency of the panel. The team suggests that printing the surface of the photovoltaic cell so that it is covered with nanoscopic cones would provide the optimal combination of making the panel non-reflective and hydrophobic and so self-cleaning. The solution proposed by the Anglo-Chinese team, through the print of these particular nanoparticles on the photovoltaic surface , seems to promise a good combination of factors that, solving the problem of cleaning, it gets as a "side effect", a higher efficiency of the panel itself and therefore, the production of a greater amount of energy.

Experimental and results

The Massachusetts Institute of Technology (MIT), after analyzing the polymer films [6] and the photovoltaic 3D, is now focusing on the research that will lead to significantly reduce both weight and structure of the solar cells in order to make the panels lighter and thinner. By developing solar cells thinner, the MIT researchers face more issues: for one thing, they make available for applications where weight is a factor, like in the transportation sector, such as aeronautics or space, or for use in remote areas of the developing world, where transport costs of these technologies are significant. Secondly modules lighter and thinner could also contribute to ease of installation and could cut down on project costs.

The MIT researchers explain that half the cost of today's current solar panels is found in support structures, installation, wiring and control systems, expenses that could be kept down through the use of lighter structures. The team found that an effective solar cell could be made from a stack of two one-molecule-thick materials: graphene, a one-atom-thick sheet of carbon atoms, and a chemical compound such molybdenum disulfide. By stacking two layers of what are called two-dimensional materials such as graphene and molybdenum disulfide, Jeffrey Grossman, an associate professor of Power Engineering at MIT, and his team have created a solar cell that is only 1 nanometer thick. It is predicted that two layers of graphene and molybdenum disulfide could create a solar cell with 1 to 2 percent efficiency in converting sunlight to electricity. While that is low compared to the 15 to 20 percent efficiency of standard silicon solar cells, it is achieved using material that is a thousand times thinner and lighter. Finally, the materials themselves are much less expensive than silicon and because the sheets are so thin, they require only minuscule amounts of the materials to further bring down overall costs. An additional advantage of these materials 2D is their long-term stability , even in open air; other solar-cell materials must be protected under heavy and expensive layers of glass. Grossman explained that these types of materials are essentially stable in air, under ultraviolet light, and in moisture. They are also extremely robust. The real crux of these projects, however, is that of the production on an industrial scale. At this time researchers are engaged in computer modeling of materials but the results will be on the side of production and marketing.

The research on graphene is only the tip of the iceberg in terms of utilizing 2-D materials for clean energy. In particular, a team of scientists at MIT has created a new polymer film capable to generate electricity by drawing on a ubiquitous source: water vapor (Fig. 4), a renewable and widely available. The new material changes its shape after absorbing tiny amounts of evaporated water, allowing it to repeatedly curl up and down. Harnessing this continuous motion could drive robotic limbs or generate enough electricity to power micro- and Nano electronic devices, such as environmental sensors. The innovative material is composed of two different polymers, arranged in interlocking: polypyrrole, hard but flexible, that provides structural support to the device, and the polyol-borate, a soft gel that swells when it absorbs water. The polymeric film functions as a sort of muscle: it is in fact able to change shape due to the absorption of small amounts of water vapor, curling repeatedly. Exploiting this continuous movement , it is possible to produce small amounts of electrical energy sufficient to power the battery of biomedical devices and other nanosensors used for the detections. The researchers are now working to improve the efficiency of the conversion of mechanical energy to electrical energy, which could allow smaller films to power larger devices. Scientists know that this new material has enormous potential and can be of great help to achieve greater efficiency in the process of conversion of mechanical energy into electrical energy.

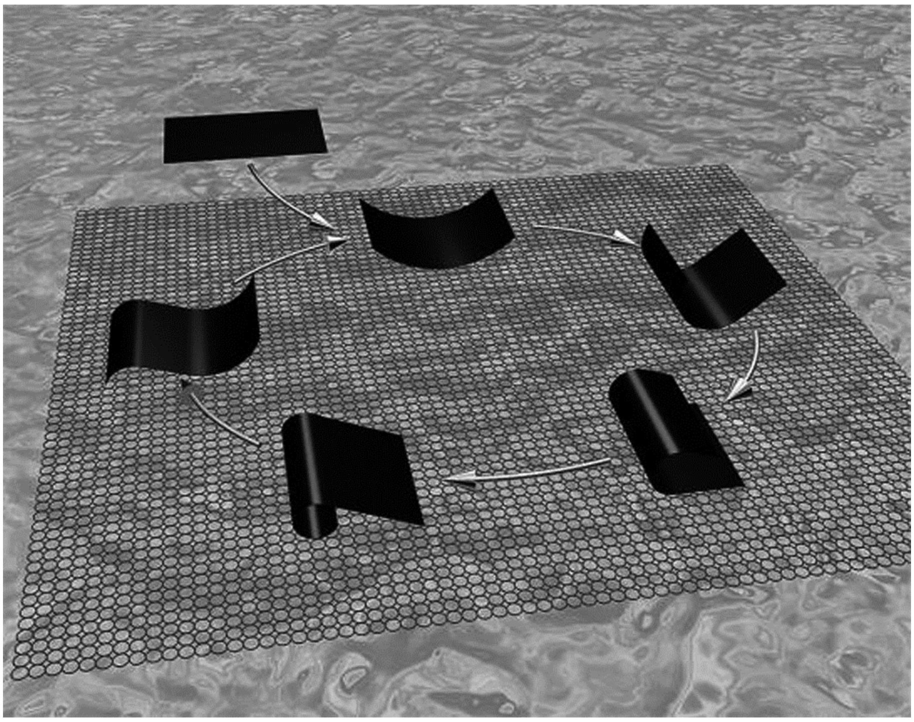

Figure 4. Actuator by water vapor.

Recently, another example had highlighted the potential of structures defined as “solar 3D”: A company that had borrowed the name from the innovative technology, the Solar3D proposed that [7]. A tree consisting of photovoltaic cells was made and an increase in efficiency compared to a linear structure was observed. MIT has implemented the study primitive and has produced two types of structures that can exploit the energy contained in sunlight with different implications: a cube-shaped with a groove and another one similar to an accordion. While the former seems more complicated to reproduce in industrial terms, the second would be a rapid development at affordable prices. These new solutions would be particularly suitable for those areas subject to frequent phenomena of widespread cloudiness or positioned at higher latitudes. In the near future we may then attend an integration in the same walls of buildings or the construction of real energy towers in parks or motorways.

Conclusions

Photovoltaic cells does not create any pollution when creating electricity but it is not economical enough to replace standard electricity. Since large amounts of cells are required to produce large amounts of electricity, they are not ready for producing electricity on a large scale. There are more available areas where these cells can be put, and the efficiency is increasing while the costs keep going down. As the research and development of green renewable energy continue, advisors who manage investments are recommending people to invest in it (Fig. 5). For years, solar companies have been on the hunt for more efficient solar cells that can produce more energy than conventional panels are generating. Solar3D Inc. has paved the way by developing a breakthrough in 3rd dimensional solar cell technology, which will improve the conversion of direct sunlight into electricity. The company has completed a thorough simulation analysis, which compared conventional solar cells and its breakthrough technology.

The work is oriented to create another one truly new generation of cells. Through a layered design in 3D it should be possible to increase the energy efficiency levels far unthinkable for this type of technology. Technically, the objectives achieved would be the following: a reduction of the phenomenon of reflection of photons - which obviously greatly lowers the energy capacity of a plant - thanks to a particular design of the cell which would make it able to retain them, regardless of the inclination solar. It would be just the 3D structure to allow this “magic”: an innovative system for the conversion of light into electricity highly efficient [8]. The work is still in the planning stage and would Solar3D developing only the first prototypes. Interestingly, then, as the main material which is working on both the silicone: cheap and easy availability. The result sees this initiative producing 200 percent more power output than solar cells currently in the market.

It is too early to say whether this prototype will really be the new frontier of photovoltaics. However, projects such as Solar3D mark the path of technological progress, outlining what are the priorities and expectations: a new generation of solar panels and with economic efficiency increasing.

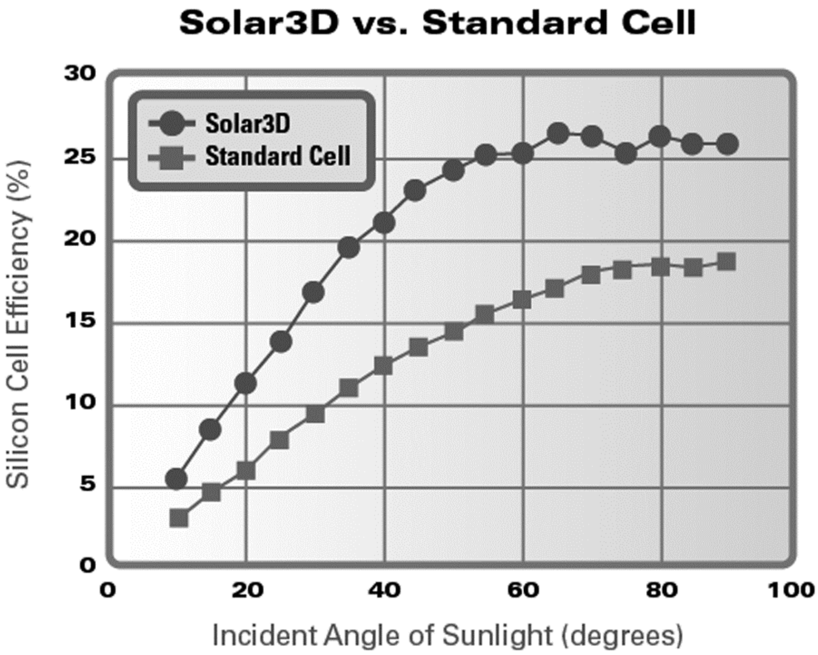

Figure 5. Efficiency of solar 3D.

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