

Alivisatos and Grätzel Win The BBVA Foundation Frontiers of Knowledge Award for Clean Energy-related Nanomaterials



2021-03-01

The BBVA Foundation Frontiers of Knowledge Award in the Basic Sciences category has gone in this thirteenth edition to Paul Alivisatos (University of California, Berkeley, United States) and Michael Grätzel (Ecole Polytechnique Fédérale de Lausanne, Switzerland) for their fundamental contributions to the development of new nanomaterials already in use for the production of renewable energies and in latest-generation electronics.

“Grätzel’s groundbreaking work includes the invention of a dye-sensitized solar cell named after him,” reads the committee’s citation, while “Alivisatos has made pioneering contributions in using semiconductor nanocrystals for energy and display applications.” In the above video, committee chair Theodor Hänsch, Director of the Division of Laser Spectroscopy at the Max Planck Institute of Quantum Optics, reads out the award citation.

Scientists have long been fascinated by the way in which light interacts with matter, and the quest to control this interaction in fine detail is at the basis of some of today’s most powerful technologies. Alivisatos and Grätzel are leaders in controlling the play of light-matter through the use of nanomaterials that act upon the latter. The committee recognizes them as key figures in the fundamental science that led to “the development of nanostructured materials for energy-related applications.”

Grätzel – nominated by Jean S. Hesthaven, dean of the School of Basic Sciences at the Ecole Polytechnique Fédérale de Lausanne (EPFL) – was the first to combine molecular systems with nanoparticles to create a new kind of solar cell that mimics photosynthesis, bringing closer the goal of converting sunlight into a clean, efficient and cheap source of electricity on a major scale.

Alivisatos created nanocrystals of barely a thousand atoms, known as “quantum dots,” to emit light whose color can be minutely controlled. He has also used these nanocrystals to explore new renewable energy sources. At present, the most advanced application of his

work is a new generation of screens that incorporate quantum dots to achieve high color quality, already on the market as QLED televisions, standing for Quantum Dot LED. Professor Alivisatos was nominated by Jennifer Doudna, Director of the Innovative Genomics Institute at the University of California, Berkeley, winner of the Frontiers Award in Biomedicine in 2017 and Nobel Chemistry Laureate in 2020; Mike Witherell, Director of the Lawrence Berkeley National Laboratory; and Milan Mrksich, Vice President for Research at Northwestern University.

In a sense, Alivisatos remarked in a video conference after hearing of the award, “Michael has looked more at how to get electricity from the light coming into the system, whereas I’ve probably done a bit more work where energy is extracted in terms of light coming back out of the system, and then making something that people can use.”



[Michael Grätzel](#)

Emulating photosynthesis

Photosynthesis, whereby the leaves of plants convert sunlight into organic matter – essentially just a means of storing energy – is the natural process that gave Grätzel his inspiration.

Plants use chlorophyll and other pigments to absorb as much as they can of visible light; the chlorophyll molecule is so structured that it emits electrons when excited by the sun’s photons, triggering chemical reactions to build organic matter with water and carbon dioxide. Grätzel’s solar cells also use a pigment that takes the role of chlorophyll, harvesting the sun’s light and generating electrons which are then collected and transported by a semiconductor material such as titanium dioxide.

His masterstroke was to arrange the titanium dioxide in nanoparticles. Each titanium dioxide nanoparticle is coated in pigment, and the result is a liquid that holds the nanoparticles and serves to fabricate the solar cells.

“That was the first use of nanoparticles to build photovoltaic cells, something no one had thought of before,” said Grätzel in a video conference following news of the award. “The first time we tried it was so exciting, we were genuinely astonished because the response we got [of light conversion into energy] was thousands of times greater than we had expected.”

He and his team presented their new photovoltaic solar cell in a 1991 paper in Nature – “A low-cost, high-efficiency solar cell based on dye-sensitized colloidal TiO₂ films” – since cited tens of thousands of times. This was the world’s introduction to what would come to be the new DSSC or dye-sensitized solar cells, also known simply as Grätzel cells in honor of their inventor.

The discovery would lead to “thousands of patents,” he himself remarks, and open up “a whole new field of research.” For the Grätzel cells offer multiple advantages: abundant raw materials, a cheap manufacturing process, transparency – meaning they can be mounted on windows, flexibility and the capacity to obtain electricity from even ambient light of the kind you find in any room. In 2013, they were used to create a colorful glass façade for the convention center on the EPFL campus.

The cells’ efficiency is approximately 15%, less than that of conventional silicon cells. But this drawback could soon be overcome with another type of cell following on from Grätzel’s, known as perovskite cells. This material, which also starts from a liquid so is suitable for flexible surfaces, entered use in 2009 and in less than a decade had achieved efficiencies of 25%. Grätzel, who has also been a pivotal player in perovskite cell research, remarks that “the speed of perovskite cell efficiency gains is on a scale not seen in any other material.” Indeed the figures coming in are already comparable to those of silicon.

Whatever degree of reach Grätzel’s cells eventually achieve, the committee highlights the power of his work to launch new lines of research on use of nanomaterials in the renewable energies domain.



[Paul Alivisatos](#)

Nanocrystals for high-resolution screens

Alivisatos' nanocrystals, also known as quantum dots, are likewise at the core of multiple applications, from the search for new clean energy sources to consumer electronics by way of biomedical imaging techniques. The U.S. scientist is himself a leader in the development of nanocrystals, a new kind of macromolecule that can be studied, controlled and widely used – in a liquid medium, like Grätzel's nanoparticles.

Ultraprecise control of nanocrystal size brings with it control over the color of light it emits, as the new laureate explains: “An electron in a nanocrystal can emit light and the color of that light will depend on the nanocrystal's size. If it is a little bit smaller the energy of the light will be higher, so it will be bluer light. And in this way you can use nanocrystals to make materials that emit the full rainbow of colors; such a large rainbow that you can reconstruct with it every color you can see in nature.”

Among its most successful applications are the displays developed in the mid-1990s that are now a part of QLED television sets. Alivisatos showed that it was possible to manufacture them in a way that combined high resolution with energy saving efficiency.

“In a color display,” he elaborates, “there is always a red, a blue and a green color that can be excited. And those colors interact inside your eye – mixtures of them – to reproduce all the colors that we can see around us. When we put quantum dots into a television to produce the reds, greens and blues, the size of the particle can be used to precisely tune the color to match the best spot in energy, which matches the receptors in your eye. So that's an example which enables, for example, artists and photographers to achieve better color reproduction, but it also results in very, very high efficiency for those displays, which means that they consume less energy and they can be used in a variety of new applications.”

In the biomedicine field, Alivisatos and his group have developed nanocrystals for the staining of biological samples – by adjusting the size of the nanocrystal, the liquid will tag one or other cell type. In fact, hundreds of quantum dot-based products are now commercially available for bioimaging purposes.

The environmental dividend of nanomaterials

The two laureates are convinced that, given the serious threat of climate change and the need to ramp up production of renewable energies, the new lines of research enabled by their work in nanomaterials could provide forefront solutions from the realm of science and technology.

“Climate change,” says Grätzel, “is certainly a major challenge. We need to curtail our use of fossil fuels, while scaling up photovoltaic energy supply by a factor of 200 in the next few decades. That means new technologies, and, in this respect, the dye-sensitized cell has led onto the new perovskite cell, whose efficiency in pilot tests is already outperforming that of conventional silicon cells.”

Alivisatos, meantime, is convinced that nanomaterials have yet to reveal their full potential, and that they have a part to play in tackling the key environmental issue of our time: “Climate change is one of the greatest challenges facing humanity, and part of that challenge is to learn how to make new materials that can harvest the energy of the sun and put it to beneficial use with as few losses as possible. But also, to do it on a vast scale. It turns out that nanomaterials can be made in extremely high quality but at relatively low cost. And they can be used to absorb light from the sun, and absorb it without losing it to thermal energy or heat, which allows more efficient conversion to electricity. Michael Grätzel has already shown some uses of nanomaterials in solar energy but there will be many more over the years to come.”

Read the [original article](#) on BBVA Foundation Frontiers of Knowledge Awards.