# Physicists take inspiration from spilled milk

August 12 2011, By Jordan Reese

Ivan Biaggio, professor of physics, and Ph.D. candidate Pavel Irkhin have developed an imaging technique that could help overcome a bottleneck impeding the efficient conversion of solar energy.

(PhysOrg.com) -- Two Lehigh physicists have developed an imaging technique that makes it possible to directly observe light-emitting excitons as they diffuse in a new material that is being explored for its extraordinary electronic properties. Called rubrene, it is one of a new generation of single-crystal organic semiconductors.

Excitons, which are created by light, play a central role in the harvesting of solar energy using plastic solar cells. The achievement by Ivan Biaggio, professor of physics, and Pavel Irkhin, a Ph.D. candidate, represents the first time that an advanced imaging technique has been used to witness the long-range diffusion of energy-carrying excitons in an organic crystal.

One way to understand the mechanics of excitons, says Biaggio, is to pour a cup of milk on the floor. The milk spreads out in all directions from the point of impact. How far it goes depends on the type of surface on which it lands. Now imagine that the milk has been replaced with particle-like bundles of energy and the floor with an ordered arrangement of organic molecules.

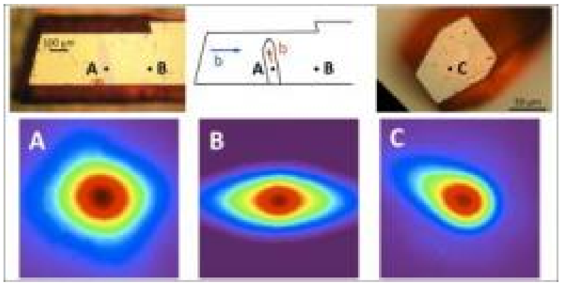
Biaggio's group used a focused laser beam to create the particles – the excitons – in a crystal made of organic molecules. They tracked the movements of the excitons over distances smaller than the size of a human hair by directly taking pictures of the light that they emit. Unlike the spilled milk, the excitons spread only in a direction corresponding to a particular arrangement of molecules.

## Hope for overcoming a solar bottleneck

An understanding of exciton diffusion is critical for plastic solar cell technology, in which the absorption of light creates excitons instead of directly inducing a current, as it does in the most commonly used silicon systems.

After they are created in plastic solar cells, excitons diffuse toward specially designed interfaces where they drive electrons into an external circuit, creating the flow of electrons we know as electric current. This diffusion process is one of the technical challenges limiting the efficiency of plastic solar cells.

"This is the first time that excitons have been directly viewed in a molecular material at room temperature," said Biaggio. "We believe the technique we have demonstrated will be exploited by other researchers to develop a better understanding of exciton diffusion and the bottleneck it forms in plastic solar cells."




Top: Crystal facets and locations with exciton diffusion experimentation. A: Micrometer thin crystal on bc facet, with different orientation. PL pattern shows exciton diffusion effect in the thin crystal and below. B: Clean bc facet. C: Crystal facet where b axis is not parallel to the surface, producing asymmetric PL pattern. Credit: Ivan Biaggio, Lehigh University

When will we have cheap and efficient plastic solar cells? It is the goal of researchers around the world to improve exciton diffusion lengths until they become as large as the light absorption—that's the point when sunlight is most efficiently collected and converted into energy.

An article by Irkhin and Biaggio, titled "Direct Imaging of Anisotropic Exciton Diffusion and Triplet Diffusion Length in Rubrene Single Crystals," was published July 1 by the journal *Physical Review Letters*.

The work was supported by a Faculty Innovation Grant from Lehigh, which provides resources to develop novel ideas and demonstrate new approaches to important research questions.

Thanks to the direct imaging of the diffusing excitons, Irkhin and Biaggio were able to obtain precise measurement of their diffusion length. This length was found to be very large in a particular direction, reaching a value several hundreds of times larger than in the plastic solar cells that are presently used. This is the first time that excitons have been directly viewed in a molecular material at room temperature, and it is believed that the widespread adoption of the technique developed by Irkhin and Biaggio will lead to significant progress in the field.

"It is important that physicists explore the most fundamental phenomena underlying the mechanisms that enable solar energy harvesting with cheap organic materials," said Biaggio. "Organics have lots of unexplored potential and the very efficient exciton diffusion that we have observed in rubrene may build the basis for new ideas and technologies towards the development of ever more efficient and plastic solar cells."

Provided by Lehigh University