Molecular Solar Cells

Investigators
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Abstract

We have made progress in establishing a new deposition method for a wide range of organic and inorganic materials including materials that don't sublime and dissolve only in minute concentrations. This unique ability is expected to lead to more efficient thin-film organic solar cells devices with a broader spectral coverage going into the near IR. We have also demonstrated the ability to use the proposed electron spin resonance technique to image electron spin phantoms on the nanometer scale. This technique will provide the first direct look into the operation of organic solar cells.

Introduction

This project focuses on increasing the efficiency of solar cells based on stable organic pigments. These are materials that have been developed for applications in plastic coloration and paints. They are therefore likely to satisfy the requirements for a solar cell material, i.e. they are low-cost, non-toxic, abundant and stable. The major challenge that needs to be addressed is their low efficiency. In this project, we aim at increasing the efficiency of pigment-based solar cells by optimizing the nanoscale ordering of the molecular materials, by varying the energy levels of the molecules, and by exploring new materials that cannot be deposited using conventional methods. We will also do the first measurements of the fundamental lifetime of pigment based solar cells in UHV conditions.

Background

The highest efficiencies reported in the field of organic solar cells are now in the 5-7% range. These numbers will keep climbing and we hope to have substantial contributions in driving these efficiencies to higher numbers using new thin-film deposition methods and access to a wider range of materials. Our main goal, however, is to provide a technology that has a potential commercial impact by focusing on materials that are stable. Moreover, our work focuses on understanding the fundamental operation of these devices. This understanding is currently missing and it is clear that improvements in our understanding will lead to improved device designs.

Results

In the first few months of this project, we have made progress in establishing the tools required for the project. In particular, we have made substantial progress in establishing a unique deposition method (aerosol deposition), that puts our lab in a unique position to make devices out of a very wide range of materials that so far could not be explored. We have also made progress in demonstrating a nanoscale electron spin resonance imaging method to look at the operation of organic solar cells.

Establishment and Optimization of Deposition Tools

We proposed to develop a number of novel deposition methods such as aerosol deposition (AD) and supercritical deposition (SD) in addition to existing methods such as organic vapor phase deposition (OVPD). The OVPD system is under construction with partial funding from this award and will be finished mid-summer. We are in an exploration phase to acquire or build a SD tool.

The AD method was refined to a point where it is now useful for the fabrication of solar cells. Briefly, the system consists of an ultrasound nebulizer that generates 2μm droplets of a solution or suspension. These droplets are charged using corona discharge, leading to Coulomb explosion of the droplets into much finer droplets. This results in fast solvent evaporation and it ensures that the resulting organic nanocrystals are small enough to form smooth, device quality films. Electrostatic fields are used to drive the particles to the substrate. A schematic of the method is shown in Fig. 1.

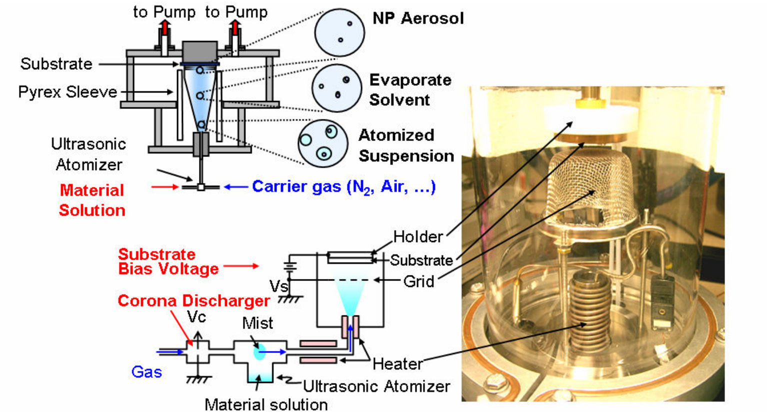

Figure 1: Schematic diagram and photograph of the optimized aerosol deposition tool that was recently developed in our lab.

The refined AD tool allows us to deposit high-quality films of virtually any material. An example of the effect of the corona discharge to refine droplet size is shown in Fig. 2. Without corona discharge, the 2μm droplets generated by the nebulizer result in large aggregates of nanoparticles after the solvent evaporates, resulting in poor quality films. When corona discharge is used to refine the droplets, individual nanoparticles can be deposited.

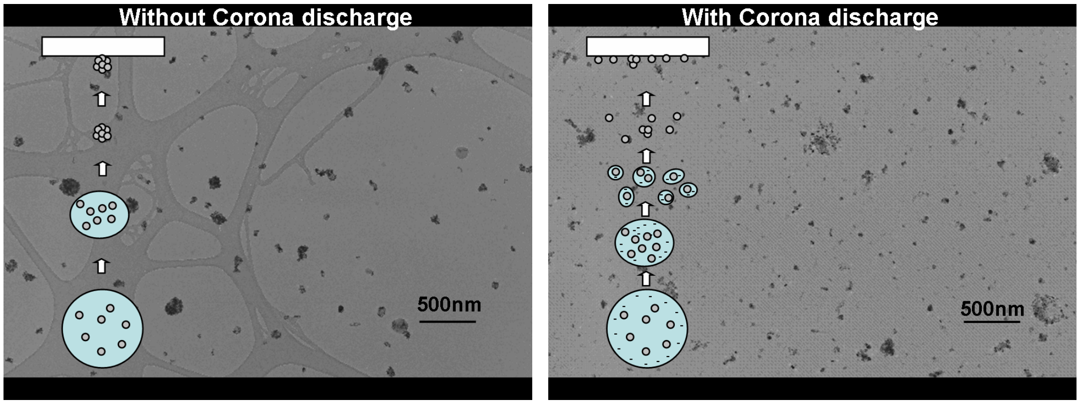

Figure 2: Effect of using corona discharge to refine droplet size on the resulting film quality.

The improved film quality will allow us to investigate a wide range of NIR absorbers for their potential in organic solar cells. This aspect is ongoing.

Electron Spin Resonance Imaging of Operating Devices

The basic idea of electron spin resonance (ESR) imaging is shown in Fig. 3. The high magnetic field gradients found above arrays of nanomagnets are used to "slice" a layer into nm-thick regions that can be individually analyzed. The spin density (electrons or holes) in each slice can then be measured such that a 1D profile can be measured and compared to theory.

We analyzed the ability of arrays of both in-plane and out-of-plane nanomagnet arrays to be used for electron spin resonance (ESR) imaging purposes. The original studies were done for magnets polarized perpendicular to the substrate. Our new substrates are in-plane magnets with a different field distribution. We performed micromagnetic simulations of the magnets and calculated the geometry of the slices, as shown in Fig. 4. This information allows us to construct the deconvolution filters needed to go from an ESR spectrum to a 1D spin density profile.

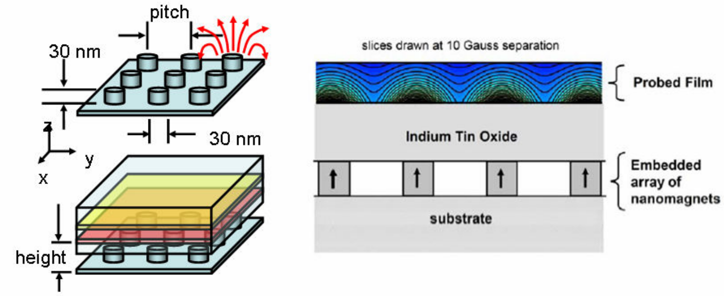

Figure 3: Concept of electron spin resonance imaging using arrays of nanomagnets to create very steep gradients in magnetic field that can be used to "slice" a layer under investigation into nm-thick regions.

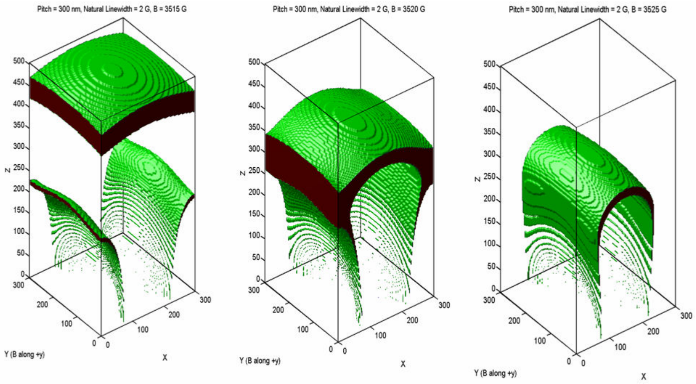

Figure 4: "Slices" for in-plane nanomagnets.

Preliminary data showing that spin density can indeed be measured on the nm scale using this method is shown in Fig. 5. The spin density phantoms were constructed by depositing thin layers of LiPc on a elastomer substrate that was then brought in contact with the nanomagnet arrays. For a single layer of LiPc, we see the expected broadening and shift towards lower external fields. For a triple layer of LiPc, we see three peaks that are associated with the presence of the magnets. Image reconstruction is underway.

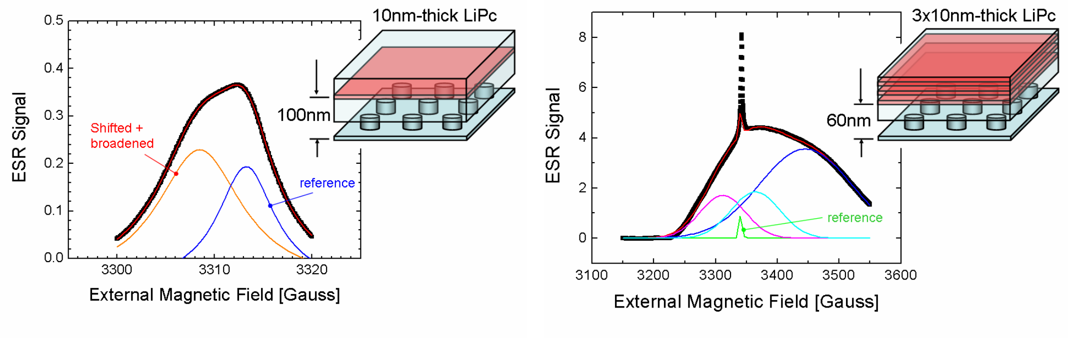

Figure 5: ESR spectra on LiPc phantoms near arrays of nanomagnets. Aside from reference peak (unaffected phantom not overlapping with nanomagnets), shifted and broadened peaks are observed.

Progress

The development of the aerosol deposition method with the resulting high film qualities is an important step toward the use of a wide range of materials with absorption in the NIR. This will allow us to test devices (single and multijunction) with a much higher efficiency potential in the coming year. Likewise, the ESR imaging method is a breakthrough technology that will allow unprecedented insight into the operation of organic solar cells.

Future Plans

Our immediate goal is to demonstrate devices extending to new spectral regions using the new deposition methods that we developed. New methods (organic vapor phase deposition and supercritical deposition) will be brought online in the coming year such that device architectures can be explored for improved device efficiencies. The ESR imaging method will be further developed (the main challenge is image reconstruction at this point) as a general technique to image spins on the nanoscale.

Publications

No publications so far.

Contacts

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