Fabrication and Characterizations of Plasmonic Nanostructures for Organic Photovoltaics

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Abstract:
Metallic gratings with a periodicity in the subwavelength regime have been shown to produce a variety of effects. When combined with photovoltaics, these nanogrids can lead to an increase in absorption at wavelengths that are dependent upon the periodicity of the grating. Gold gratings of periodicity 500 nm and 350 nm were fabricated using electron beam lithography. Fabrication techniques for the nanogrids and the application of the photoactive layer are presented, as well as transmission and absorbance spectrums for organic photovoltaics with and without plasmonic enhancement.

Introduction:
Photovoltaics are semi-conducting materials that absorb photons to create electron hole pairs that are then collected as current. It is a clean power supply that, for all practical purposes, will never run out and there is more than enough of it to meet all of our energy needs. Despite this, photovoltaics make up a very small percent of our energy supply due to prohibitively high cost of production. Organic photovoltaics currently have low absorption efficiencies, low carrier diffusion lengths, degrade over time, and are expensive to fabricate [1]. However, many researchers believe that they have the potential to make photovoltaics cost effective for large scale power production in the near future. To compensate for the low carrier diffusion length, thin films are used. However, thin films demonstrate poor absorption.

To address this problem, we propose the use of metallic nanogrids in the subwavelength regime to enhance the absorption of thin film organic photovoltaics. These gratings interact plasmonically with incident light and couple it at the interface of the nanogrid and the photovoltaic interface, increasing the optical pathlength of the light while maintaining a thin film of the photovoltaic material [2,3].

Methods:
The substrates used were 25 mm × 25 mm microscope slides. These slides were first cleaned using a 12 minute dip in piranha at 90°C. Electron beam lithography was then carried out using a JEOL 5710 SEM, a beam blanker, and the nano pattern generation software at the Colorado Nanofabrication Lab. The patterns were written into a polymer bilayer of 50 nm copolymer that was spun-on,

Figure 1: SEM image of the 500 nm periodicity grid.

Figure 2: AFM of the 500 nm periodicity grid.
from a solution concentration of 4.5%, at 4000 RPM for 30 seconds, and 50 nm PMMA that was spun-on, from a solution concentration of 2%, for 4000 RPM for 30 seconds. After each deposition, the sample was baked at 170°C for 15 minutes. A beam current of 10 pA, an acceleration of 30 kV and an area dose of 75 µC/cm² was used.

The patterns were then developed using a 1:3 MIBK:IPA solution for one minute, followed by a five second spray rinse in IPA, and were then blown dry. A metallic trilayer of 5 nm aluminum, 5 nm chromium, and 30 nm of gold was then deposited using a three boat thermal evaporator. Lift-off was then performed with PG remover at 60°C with ultrasonic vibration in five minute intervals until the pattern was observed to be clean.

Figure 1 shows a scanning electron microscope (SEM) image and Figure 2 shows an atomic force microscope (AFM) image of the 500 nm periodicity grid. The CuLCPC₁₂ was suspended in a solution of toluene at a concentration of 10 ± 1 mg/ml and spun on to the 350 nm grating at 2500 RPM with five seconds of acceleration and 30 seconds spin time. The PCDTBT was suspended in dichlorobenzene at a concentration of 7.0 ± 0.2 mg/ml and spun on to the 500 nm grating at 3000 RPM with five seconds of acceleration and 30 seconds spin time.

**Results and Conclusions:**

The optical transmission of the nanogrids was measured using an optical spectrometer. As can be seen in Figures 3 and 4, the spectra with and without the grids for each respective photovoltaic have approximately the same shape with a shift up to a point. The shift is due to the inherent absorption of gold on the glass. However, when the spectra start to diverge, plasmonic effects are being seen.

As can be seen in Figure 3, an increase of ~ 0.12 OD was observed for PCDTBT at an optical wavelength of 860 nm and of 0.033 OD for CuLCPC₁₂ at an optical wavelength of 610 nm. These numbers take into account the absorption of the gold by subtracting the average distance between the curves in plasmonically inactive regions from the maximum difference between the curves in the active region.

Similarly, in Figure 4, a decrease of 21% transmission was observed for PCDTBT and 77% transmission for CuLCPC₁₂. These increases in the absorbance characteristics of these organic photovoltaics show great promise as a way to increase organic photovoltaic efficiency.

**Future Work:**

The next stage in this research is to fabricate a working photovoltaic chip with nanogrid enhancement and one without, and to perform comparative electrical measurements on the two samples. This would provide definitive evidence as to the exact effectiveness of the nanogrid enhancement for photovoltaic efficiency.

**Acknowledgements:**

I would like to thank the National Science Foundation and the National Nanotechnology Infrastructure Network Research Experience for Undergraduates (NNIN REU) Program for their funding and support this summer, the Colorado Nanofabrication Laboratory and staff for their crucial assistance in lab use, Saumil Joshi for mentoring me, and my P.I., Dr. Won Park, for his assistance and guidance this summer.

**References:**

