

RGO-Cu₂S Films: A Better Counter Electrode for Quantum Dot Solar Cells

The high absorbance and tunable band gap of semiconductor quantum dots (QD) makes their application in quantum dot sensitized solar cells appealing. However, the efficiency of these cells has lagged behind their dye-sensitized counterparts. One contributing factor is the poor kinetics of electron transfer from the typical platinum counter electrode (CE) to the typical polysulfide electrolyte. This causes polarization of the CE, which limits solar performance. Previous work¹ showed that brass (Cu/Zn alloy) counter electrodes, which form Cu₂S when the surface is exposed to the electrolyte, increase the rate of electron transfer but quickly corrode due to the continued reaction of Cu and Zn with S²⁻. In the present work, reduced graphene oxide (RGO) was used as a binding material for Cu₂S to create a more stable Cu₂S counter electrode.

To create solutions that could be deposited onto an optically transparent electrode (OTE), copper (I) acetate (CuAc) and graphene oxide (GO) were suspended in ethanol, sonicated, centrifuged down to remove excess copper in solution and resuspended in ethanol. These solutions were spray coated onto OTEs and subsequently the GO was reduced electrochemically or via UV

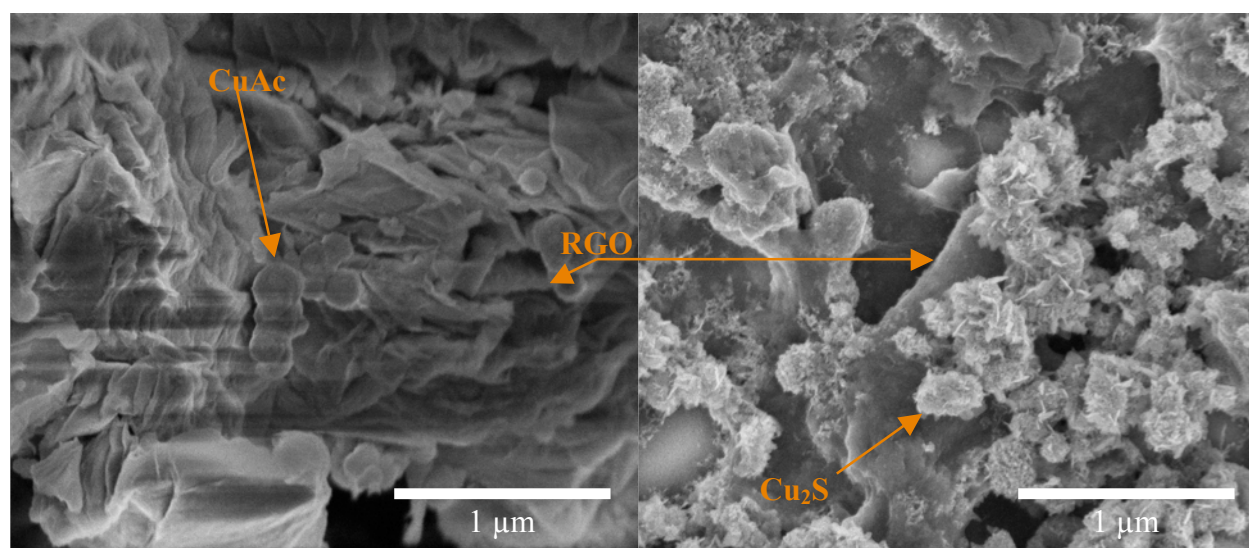


Figure 1. SEM images of electrode before (left) and after (right) immersion in polysulfide solution. EDS confirmed the presence of copper (both) and sulfur (right).

¹ Hodes, G. J. *Electrochem. Soc.* **1980**, *127*, 544.

light or heat. Immersing these electrodes in the polysulfide solution formed Cu_2S particles, as illustrated by the SEM images in **Fig. 1** below. The electrodes and the reduction step were also examined via Diffuse Reflectance and FTIR.

The ratio of copper (I) acetate to GO in the solutions was varied to determine which gave the best solar cell performance. Solutions were prepared at a constant concentration GO (12.5 mg/mL) with varying amounts of copper. With the same working electrode, the IV curves for the resulting counter electrodes were collected (**Fig. 2**). Solar cell performance increased for Cu:GO ratios up to 3:1 (mass Cu: mass GO). For higher ratios, performance leveled off or decreased. The reduction method and the number of spin coats were also varied. The reduction method had no effect on performance and the effect of the number of spin coats was also minimal. The Cu_2S -RGO CEs outperformed Pt significantly—in the best case, increasing efficiency to 1.1% from 0.7% with a Pt CE. The best Cu_2S -RGO CE performed better than old brass, but still did not match the performance of fresh brass. RGO- Cu_2S CEs were stable and showed no drop in performance after repeated use, but further work should be done to quantify their stability relative to brass. This summer, in addition to learning the concepts behind the operation of QD solar cells, I also learned

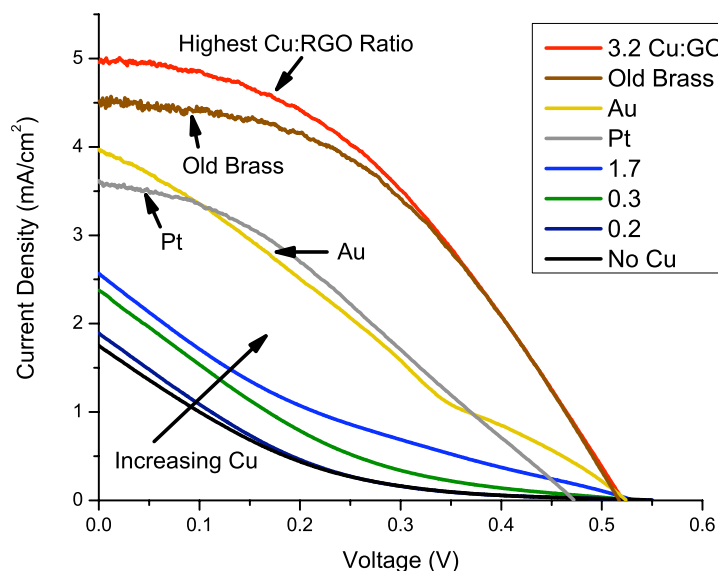


Figure 2. The IV curves for the examination of varying Cu:GO ratios.

the type of dedication and perseverance required to do substantial research. This semester I intend to attain better electrochemical data to quantify the kinetics of electron transfer at the counter electrode and the extent of polarization and write up the results of the combined research.