Rapid Processing of Semiconductors for Photovoltaics Using Intense Pulsed Light

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<u>Extended Abstract</u> (six page maximum):

Thin film solar cells typically require post-growth heat treatment to improve the materials properties. In order to manufacture market competitive solar cells, material processing methods with low capital and running costs are required. One method for achieving this goal would be to use atmospheric processing techniques with a high throughput. Here we report the use of Intense Pulse Light (IPL) to process cadmium sulfide (CdS) and cadmium telluride (CdTe) thin films. IPL is an ultra-fast technique for the heat treatment of materials. Pulses of light from the UV to IR wavelengths are absorbed by the material, leading to localized heating and sintering. IPL has been used to successfully make Cu electrical contacts for use in electronic circuits[1], however little work exists on the use of IPL in the processing of semiconductor materials. The effect of energy input and the energy density (ED) of the pulse on the films optical, compositional and morphological properties of the films were investigated using UV-Vis spectroscopy, X-ray diffraction, photoluminescence and scanning electron microscopy. These analytical results are supported by computational analysis of the thermal response within the films. IPL sintering resulted in significant improvement to the crystallinity with processing times of less than 2 minutes.

The optical properties of IPL treated CdS was investigated by observing the change in color of the films and measuring the optical transmission of the films in order to determine the materials' bandgap. As the number of pulses was increased, it is clear that the film is undergoing a transition (Figure 1a). The results also show that the bandgap is reduced after only 26 pulses and remains constant after this point (Figure 1b). In this study, an ED of 8.6 Jcm^{-2} was insufficient to produce the temperature rise required to sinter the films even after 100 pulses was applied. This suggests that the absorbed energy was transported too fast away from the film to create the desired temperature rise. A finite element model was used to understand the significance of the substrate in the IPL sintering process. The lower ED pulses only increased the temperature of the film to approximately 200^{o}C, whereas pulses with higher ED's produced a temperature rise of approximately 800^{o}C for a brief period of time (Figure 1c).

Figure 2 shows the SEM topographical images of as-deposited and IPL treated CdTe using 100 pulses with an ED of 17.3 Jcm^{-2}. As expected, the low temperature nature of the electrochemical deposition results in nanoparticles, growing up from the substrate. Upon IPL treatment, the particle growth and melting was observed (Figure 2b). Thus, we have shown that the IPL method can be used to affect morphological changes to both CdS and CdTe nanoparticle films.

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[1] Dharmadasa, R, Jha, M., Amos, D. and Druffel, T, *Room Temperature Synthesis of a Copper Ink for the Intense Pulsed Light Sintering of Conductive Copper Films*, ACS Applied Materials and Interfaces, 2013. In Proof.

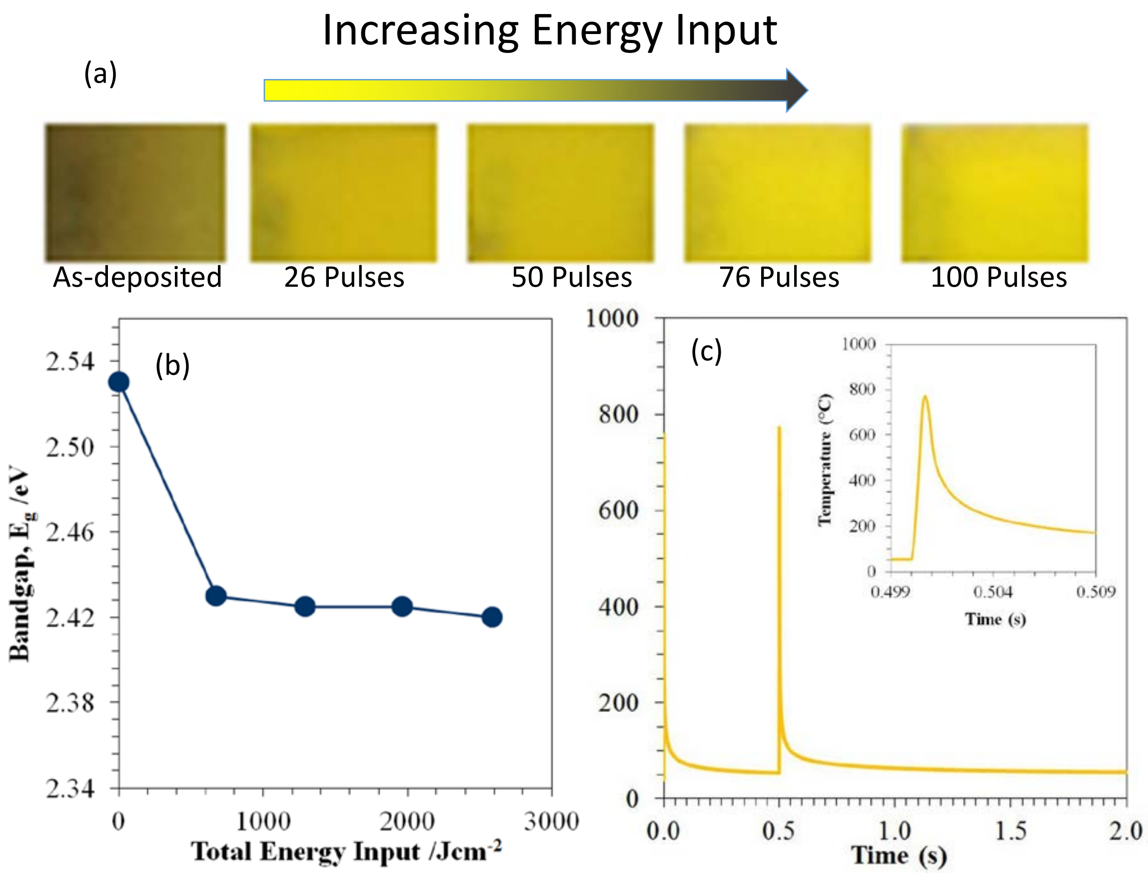

Figure 1. Changes to the optical properties of CdS IPL treated films observed by (a) color changes and (b) bandgap decrease. (c) Temperature rise in the IPL treated film as modeled using finite element analysis.

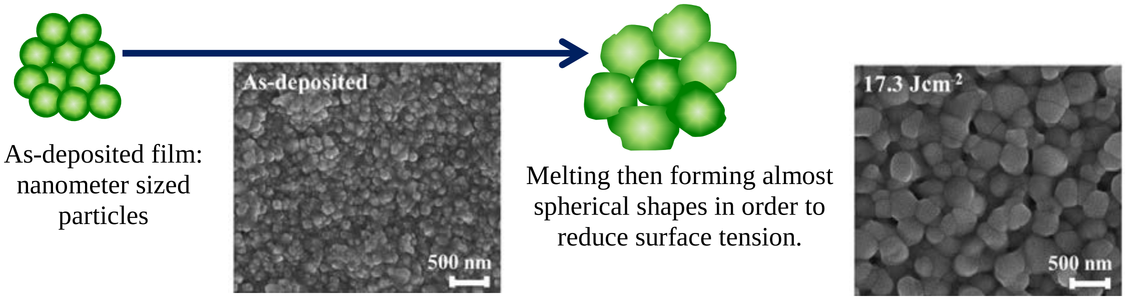

Figure 2. Response of an IPL treated CdTe nanoparticle film showing a clear increase in grain size using pulses of light with an energy density of 17.3 Jcm^{-2}.