

# Examining Metal/SnS Contact Resistances for the Increase of SnS Solar Cell Efficiency

**Shay Goff Wallace**

**Materials Science and Engineering, University of Minnesota-Twin Cities**

*NNIN REU Site: Center for Nanoscale Systems, Harvard University, Cambridge, MA*

*NNIN REU Principal Investigator: Prof. Roy Gordon, Chemistry and Chemical Biology, Harvard University*

*NNIN REU Mentor: Leizhi Sun, Chemistry and Chemical Biology, Harvard University*

*Contact: walla403@umn.edu, gordon@chemistry.harvard.edu, leizhis@gmail.com*

## **Abstract:**

Many current solar cell technologies use toxic elements (such as cadmium) and rare elements (such as tellurium, indium, and gallium) in their construction. These components add expense and are major impediments to increased usage of solar cell technologies. As a result, research is being done into solar cells that use non-toxic and abundant elements such as tin (II) sulfide solar cells. The focus of this research was the investigation of the contact resistance of the metal back contact of a tin sulphide (SnS) solar cell. SnS solar cells have a record efficiency of only 2.04. This efficiency needs to be increased for these cells to be commercially viable.

## **Background:**

Tin (II) sulfide solar cells utilize SnS deposited onto a metal back contact via atomic layer deposition (ALD). The production and structure of these cells is described by Sinsermuksakul et al. [1]. A crucial part of a solar cell is the metal back contact (molybdenum in the case of Sinsermuksakul [1]). This contact between SnS and the metal contributes a resistance to the electrical circuit known as the contact resistance. This contact resistance affects the efficiency and by selecting a contact with a low contact resistance, the overall efficiency of the cell should be increased.

The method used to examine the contact resistance of the metal/SnS contact is known as the transmission line method (TLM). Specifically, the method used was the transmission line method with circular patterns, similar to the method described by Deepak [2]. This method involves measuring the resistance of metal patterns on a substrate and using the physical geometry of the patterns to determine both the contact resistance of the metal and the sheet resistance of the substrate.

This research involved examining patterns of different metals to determine their contact resistances with SnS. The metals examined were aluminum, gold, copper, indium, molybdenum, nickel, and titanium.

## **Experimental Procedure:**

First, samples of SnS were formed by depositing SnS onto thermal oxide on silicon via atomic layer deposition (ALD). All of the samples were as deposited by the ALD reactor and some were then annealed in H<sub>2</sub>S. The samples next had the circular metal patterns deposited onto them. The metal patterns were created by using photolithography to create a pattern of exposed substrate and then depositing 300 nm of the metal onto the sample with electron beam evaporation. After this process, the remaining mask pattern was removed, leaving just the circular metal patterns on the surface.

After the metal patterns were created on the SnS substrates, the resistance of each pattern was determined via I-V probe testing. This testing revealed that copper, indium, and aluminum created non-Ohmic contacts and thus did not need to be investigated further as they would not lead to an increase in efficiency. However, nickel (Ni), titanium (Ti), molybdenum (Mo), and gold (Au) did form Ohmic contacts. A plot showing the current-voltage characteristic of nickel on annealed SnS is shown in Figure 1. Each line is a different pattern size. For each metal, the resistance of each pattern size was plotted against a parameter based on the geometry of the pattern. An example of this relationship for Ni on annealed SnS is shown in Figure 2. The equation of the line of best fit of these points allows values for the contact resistance and sheet resistance to be obtained. The slope is the sheet resistance and the intercept is a factor based on both the sheet resistance and contact resistance. The results of the calculations of both sheet and contact resistance for all Ohmic metals are shown in Table 1.

## **Results and Conclusions:**

As can be seen in Table 1, gold has the lowest contact resistance. However, the cost of gold means that it could be uneconomical to use it in a solar cell that is meant to be cheaper than current technologies. Even though the identity of the substrate (either annealed or as-deposited SnS) is in question for the gold contacts, it is clear that it has the lowest contact resistance by

far. The next best choice for back contact is the currently used material, molybdenum. This means that molybdenum is still the best choice for back contact in a SnS solar cell.

As can also be seen, there was great variation in the measurements of sheet resistance for each of the samples. This was likely due to difficulties in the delicate processes involved in both fabrication and characterization. The sheet resistance values should be more consistent as the SnS films were all deposited in the same run and should thus have very similar hole concentrations and resistivities. This consistency in sheet resistance was shown in previous work by this research group. Additionally, the sample of Ni deposited onto as-deposited SnS has a rather high contact resistance in comparison to other values. This could also be due to problems in fabrication and characterization.

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### References:

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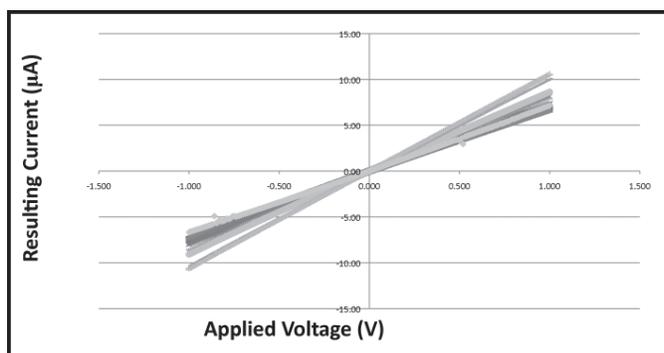


Figure 1: Current vs. voltage measurements for nickel patterns of various sizes on annealed nickel.

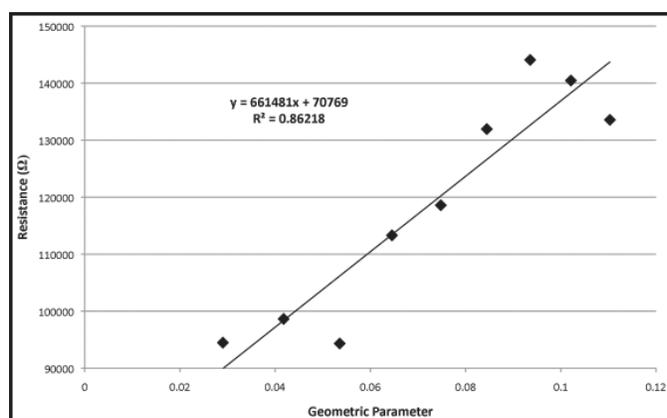


Figure 2: Resistance values of various pattern sizes vs. a geometric parameter of the pattern size. The slope of the line of best fit is the sheet resistance and the intercept is a result of the sheet resistance and the contact resistance.

	Sheet Resistance (kΩ/sq)	Error in Sheet Resistance (kΩ)	Contact Resistance (Ω-cm <sup>2</sup> )	Error in Contact Resistance (Ω-cm <sup>2</sup> )
Annealed Nickel	661.5	100	1.868	0.496
As-Deposited Nickel	1861.3	907.4	35.588	20.092
Annealed Titanium	1424.7	94	0.662	0.154
As-Deposited Titanium	4461.3	275.2	0.343	0.194
Annealed Molybdenum	1473.5	109.6	0.163	0.085
As-Deposited Molybdenum	7232.8	123.3	0.187	0.046
As-Deposited* Gold	1858.9	70.5	0.000749	0.003582
*Gold could be on annealed SnS				

Table 1: Sheet resistance and contact resistance values for various metal patterns deposited onto both annealed and as-deposited SnS.