Low Cost Metallization Inks for Photovoltaics

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Abstract

Commercial Si wafer solar cells employ screen printed Ag grids as the front contact and Al layers as the back contact. The drive to decrease cost is pushing manufacturers to seek both lower cost materials and methods. One obvious material change is to replace Ag with lower cost metals such as Ni and Cu. Shifting to thinner Si wafers is another reasonable cost saving measure, but it will also necessitate replacing contact methods like screen printing. Inkjet and aerosol jet printing are excellent non-contact choices. These tools have been incorporated into NREL's Atmospheric Processing Platform, along with complementary rapid thermal processing capabilities. We have used these tools to deposit Ni/Cu bilayer grids as the front contacts and Al layers as the back contacts on 21 cm² Si solar cells. To our knowledge, this is the first time all non-contact printed metal contacts on Si solar cells have been demonstrated. These studies also show the potential of non-contact printed Al, Ni, and Cu inks to contribute to the fabrication of low-cost photovoltaic devices.

Introduction

A typical commercial Si wafer-based solar cell employs an Ag grid as the front contact and an Al layer as the back contact, both of which are currently produced by screen printing metal pastes onto the wafer.[1] Decreasing cost is still important, however, and one obvious method to meet this objective is to replace Ag with a lower cost metal such as Cu. Cu diffuses very readily into Si, so a Ni layer will be necessary to act as a diffusion barrier between Cu and the underlying Si wafer. Such Ni/Cu bilayer grids must be deposited very quickly with good resolution in order to be useful in a production line. Shifting to thinner Si wafers is another reasonable cost saving measure, which will also require some substantial changes to a manufacturing line. Contact methods like screen printing will cause unacceptably high breakage rates if they are used with these thinner wafers. As a result, alternative high speed and non-contact metallization methods are needed, and inkjet and aerosol jet printing are excellent choices. We have used these techniques to deposit Ni/Cu bilayer grids as the front contacts and Al layers as the back contacts on Si solar cells. To our knowledge, this is the first time all non-contact printed metal contacts on Si solar cells have been demonstrated.

Materials and Methods

The inkjet and aerosol jet printers used in this work are part of the Atmospheric Processing Platform (APP) at NREL.[2] This versatile tool provides an inert environment where the printers and the complementary rapid thermal processing tool are housed.

Two different types of inks have been used in this study. One category of ink is built around particles of Al, Ni, or Cu. These particle-based inks can be prepared at high solid loadings of 60 weight % metal, which enables rapid deposition of features over a wide range of thicknesses as shown in Figure 1.

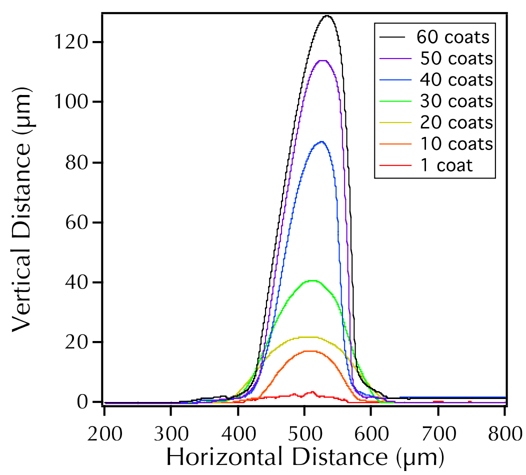

***Figure 1**. Cross-sectional profiles of printed Al lines*

The other type of ink contains Ni and Cu complexes that decompose to the metals when they are heated appropriately. Such metalorganic decomposition (MOD) inks typically contain lower concentrations of metal, which makes them useful for depositing very thin and uniform coatings. After printing and sintering conditions were established, 18 cm² solar cells were prepared by printing Al features and Ni/Cu grids on standard n/p doped Si wafers.

Printed MOD Inks

The inert environment of the APP was an important component of producing high quality Ni and Cu features from the MOD inks, because these metals are readily oxidized at elevated temperatures in air. Control of the substrate temperature (180-250°C) and ink deposition rate produced high-resolution lines (~50 µm) with tunable thickness. Both the Ni[3] and Cu lines had near-bulk conductivities after being printed in this modest temperature range. Ni lines like that shown in Figure 2 were deposited on bare Si and sintered to produce contact resistivities of 30 mΩ-cm².

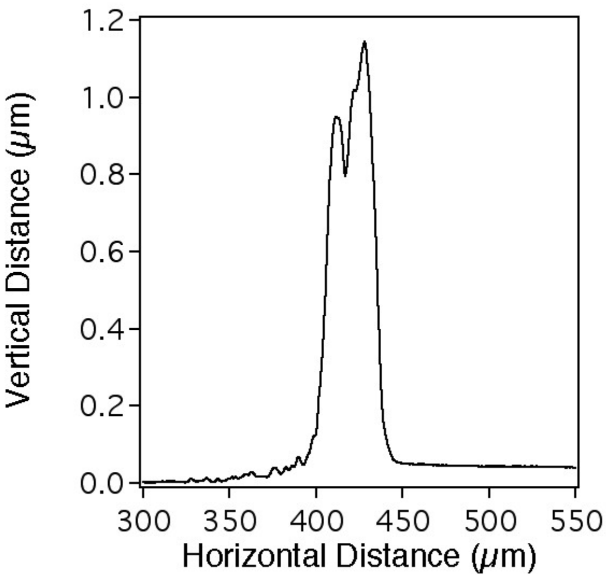

***Figure 2**. Cross-sectional profiles of printed Al lines*

Printed Particle Inks

The metal particle inks were printed at much lower temperatures of 25 - 50 °C, so the APP's inert atmosphere didn't become important until the sintering was carried out. The metal lines printed from the particle inks approached bulk values after appropriate sintering, and they were also approximately 100 µm wide at all thicknesses. The Al lines can be fired over a wide temperature range of 550 – 900 °C to produce contact resistivities to Si as low as 20 mΩ-cm^2. The Ni lines achieved contact resistivities to Si as low as 10 mΩ-cm^2.

Conclusion

We have established good contact between printed Al or Ni features and Si wafers, which are important steps toward the ultimate goal of all non-contact metallized Si wafer solar cells. Cells with non-contact printed Al as the back contact and Ni/Cu bilayers as the top contact have also been prepared. The inert environment of the APP was key to completing these studies that demonstrate the potential of non-contact printed Al, Ni, and Cu inks to contribute to the fabrication of low-cost photovoltaic devices.

References

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Author Biography

Heather A.S. Platt trained as a synthetic inorganic chemist with Douglas A. Keszler at Oregon State University. During this time, she synthesized and characterized little known iron and copper chalcogenides, ultimately identifying several as promising solar absorbers. After completing her PhD, Heather joined the Atmospheric Processing Team at NREL. Her current research interests include using high-speed methods and earth-abundant materials to produce low cost solar cells. She is also a member of the Materials Research Society.