# Direct Print Metal Nanoparticle Inks for Si Solar

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## Abstract

*Silicon solar technology continues to be the most widely used photovoltaic technology having benefited from many decades of research and refinement. However, more efficient photovoltaic technologies continue to gain market share due to increased solar efficiency and ever decreasing production costs. In order for silicon solar technology to remain competitive in the future the overall cost must be reduced. Cost reductions can be realized through reduced material usage and changes in silicon solar cell architectures. The development of novel methods for application of metallic grid lines serves as a pathway to address both issues. Applied Nanotech, Inc. has been researching materials for direct non-contact printing of metallic grid lines in silicon solar cells.*

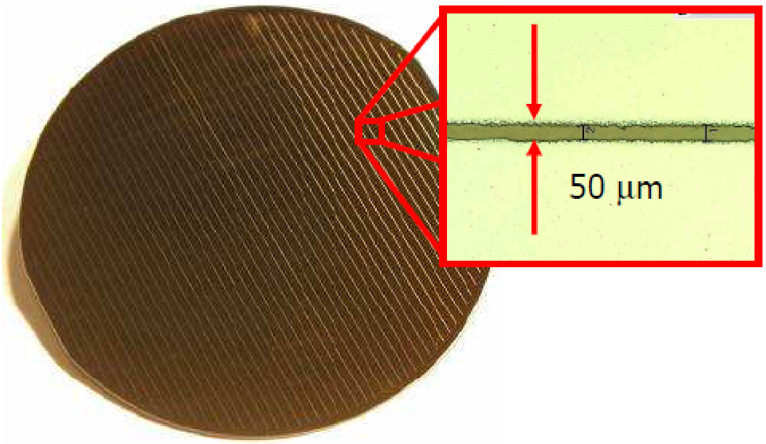
*Electrical contacts are a critical part of photovoltaic technology and represent a difficult area for silicon solar cell production. Next generation solar cells will rely on ultra-thin silicon wafers that present multiple challenges to high-rate manufacturing. The current method for the application of electrode lines is screen printing using metallic pastes of aluminum and silver. Most commonly aluminum is printed as a global contact on the backside of the wafer and silver is printed as a high resolution grid on the frontside of the wafer. While quick and efficient screen printing is not compatible with the sub-150 µm wafers that promise reduced materials cost and increased efficiency. For example, the force applied during the screen printing process can break the fragile, thin-silicon wafers. In addition, current paste formulations have high viscosity that limits the minimum thickness of the electrode. These "thick" electrodes have several problems. First, the coefficient of thermal expansion (CTE) of the aluminum is quite large and can cause the wafer to bow as the aluminum expands at an increased rate compared to the silicon. In extreme cases the wafer can break due to the limited amount of curvature that the silicon can withstand. In an effort to curtail this expansion glass frit is commonly added. While this does decrease the CTE it also greatly lowers the conductivity of the aluminum. This requires additional paste thickness to meet the current density requirements of the large area cells. On the front side, screen printing has limited resolution. This causes increased shadowing and limits the overall efficiency of the cell. The front gridline paste materials must also be capable of diffusion through the anti-reflective coatings (ARC) and passivation layers. The mechanism of "burn-through" is handled by addition of glass frit to the metallic paste and once again limits conductivity. Because of these issues solution based printable materials that can be processed in ambient conditions present an attractive alternative for future Si solar production.*

*ANI has developed several nanoparticle-based inks for Si solar applications. Such materials are much more cost effective, environmentally benign and materials efficient compared with existing manufacturing methods. The integration of non-contact print technologies with silicon solar manufacturing requires suitable materials and inks that can be easily printed and cured to form the conductive feed lines on the solar cell. These inks can be printed by a variety of non-contact print methods including; spray printing for large areas, Optomec's Aerosol Jet® technology for high resolution, and inkjet for fast through-put. Key parameters for ink performance include ease of printing, print quality, line width and resistivity in final cured form.*

*We present high quality metal nanoparticle ink materials for direct print manufacturing of next generation silicon solar cells. The inks have low resistivity and are compatible with existing thermal processing steps. We present aluminum ink free of glass-frit that can be applied as patterned and global back contacts. After thermal processing the contact is low resistance, Ohmic and exhibits excellent back-surface field (BSF) formation. Printed inks from nanoparticle based aluminum provide a cured resistivity 2.3 times that of bulk aluminum. Our Silver Ink can be inkjet printed with increased resolution compared to screen printing. This ink formulation will be used to reduce wafer shadowing. We have also developed a nanoparticle nickel ink to be used as a barrier and/or seed layer in traditional top-contact cell structures.*

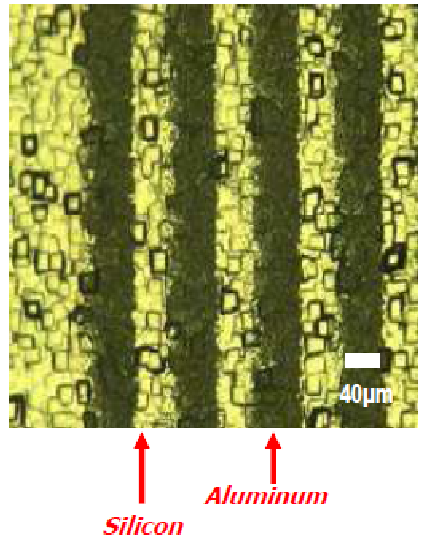
*The combination of our non-contact printable inks enables advanced silicon solar cell architectures such as backside, interdigitated contacts. These shadow-free frontside designs represent the ultimate in high-efficiency cell design. In addition to ink materials, a discussion of cell assembly and performance will be discussed.*

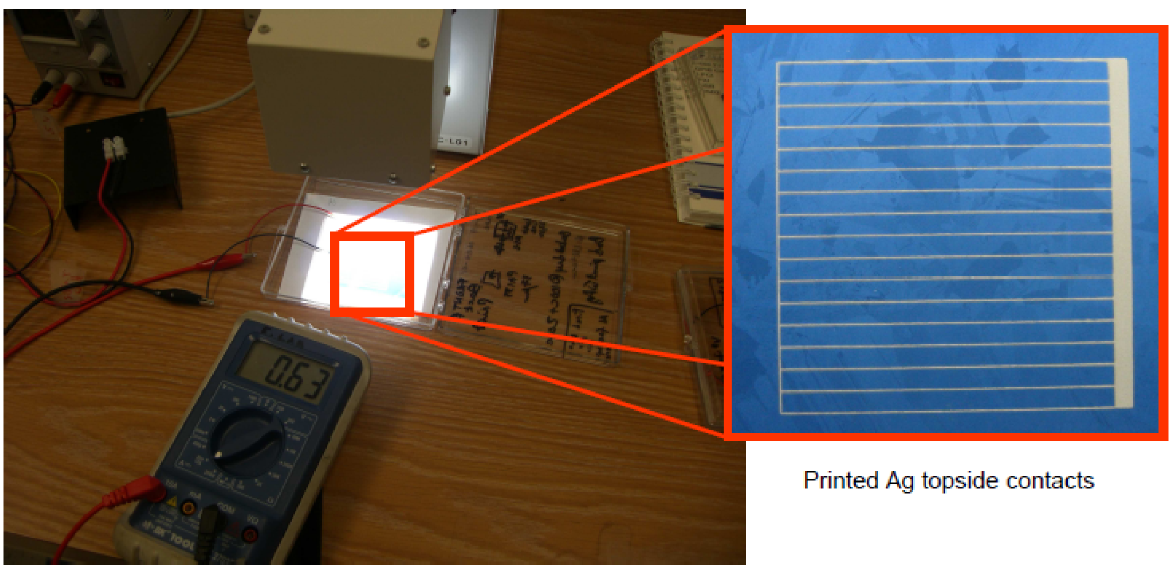
*This ink technology provides an accurate, robust, reliable and cost-effective method for increasing electrical energy efficiency in silicon solar cell production and usage. The switch to ink based materials for next generation PV devices represents a critical step that could dramatically change the cost-paradigm for solar technology, enabling the formation of critical, low-resistance contacts using methods previously unavailable to the photovoltaic industry.*




Printed 50 µm wide nickel grid electrodes on crystalline silicon was demonstrated by Aerosol Jet® printing.

50 µm aluminum lines printed on crystalline silicon



Printed Ag topside contacts

Working Solar Cell using ANI printed ink materials