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Temperature dependency of silver paste with regards to print quality and electrical performance of screen-printed solar cells

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Abstract

It is common knowledge that paste rheology is greatly influenced by temperature. In general, a higher temperature will lower the viscosity of Thick Film paste. Screen printing is the most common method of transferring silver Thick Film paste to a silicon wafer to create a Solar Cell. Presumably, Thick Film paste with varying rheology will have a varying print quality. However, there have been no studies to validate this theory or show to what degree this is or isn't true. Line quality plays a large factor in electrical performance of a Solar Cell. Uneven and/or broken finger lines will cause higher line resistance. Lines with too much slumping will cause optical losses and also cause a higher line resistance. These factors can be controlled by proper printing. It is important to understand the extent temperature has in effecting rheology, print quality and electrical performance. This paper will examine the effects temperature has on these parameters.

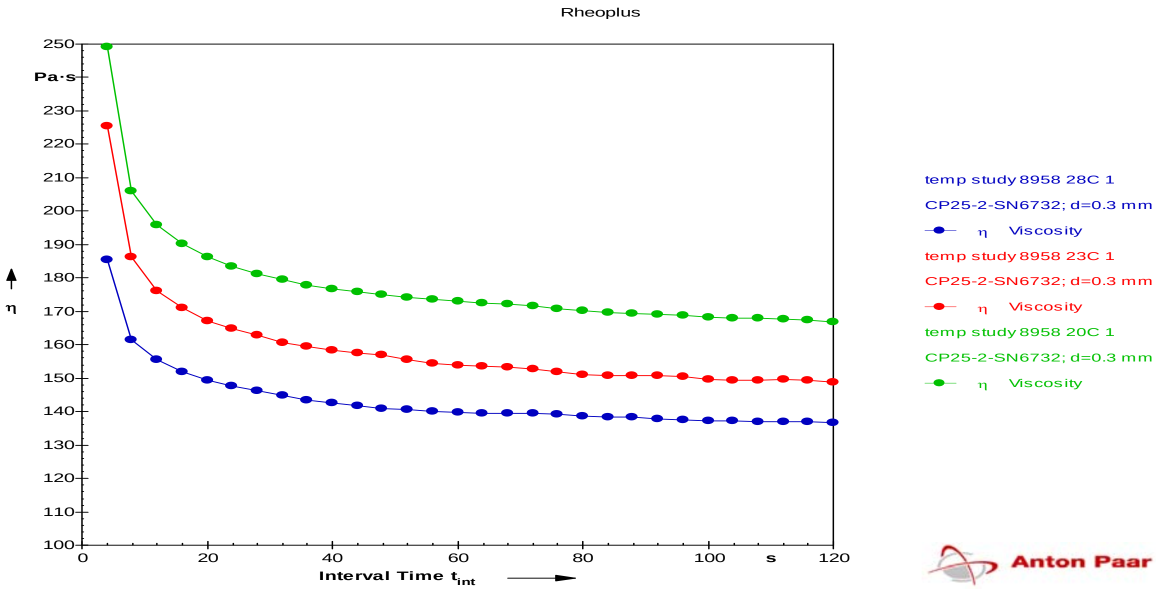
Printing parameters such as pressure, downstop, snap off, speed and squeegee hardness were controlled to eliminate variation from the printer. One screen was used and the wafers were all similar in minority carrier lifetime. One experimental paste was made and a rheology study was performed. Flowcurves on a cone and plate measuring system were generated at 20ºC, 25ºC and 30ºC with a constant speed. A temperature sweep was then performed plotting viscosity points between 15ºC and 35ºC. The paste was then split into three containers and stored at 20ºC, 25ºC and 30ºC. The printing screen and wafers were also stored at these temperatures to simulate a real room temperature shift. The screen printer was set up with the controlled parameters and each paste was printed on three wafers before temperature was able to fluctuate. Wafers were then measured for aspect ratio at wet, dried and fired stages. Aspect ratio data was recorded. Once fired, wafers are ready to be tested for electrical performance. The focus of the electrical performance will be on Line Resistance.

Key words: Solar Cell, aspect ratio, line resistance

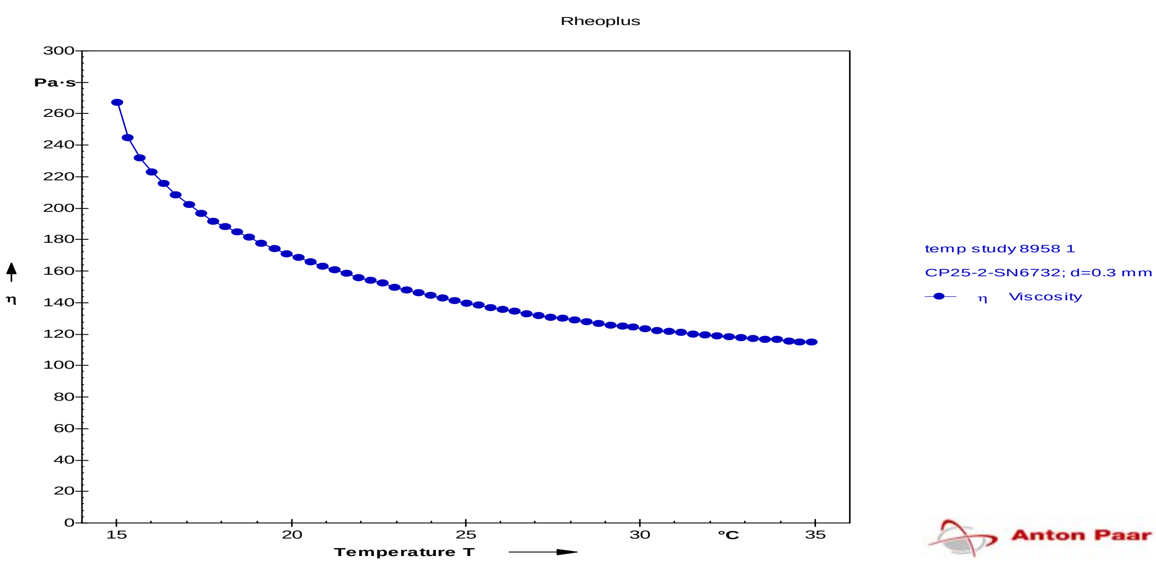
Explanatory Pages

1. Rheology study

Two rheology tests were performed. The first is a test at 3 different temperatures; 20ºC, 25ºC and 30ºC with a constant rate to illustrate the rheology differences at these different temperatures. As you can see the higher the temperature the lower the viscosity.



The second test was a temperature sweep to demonstrate rheology changes as the temperature ramps from 15ºC to 35ºC. As you can see, a 20º Celsius range will cause a shift in viscosity from about 270 Pa s to 130 Pa s at 1 reciprocal second.



2. Screen parameters

To control variation, one screen was used to print all three pastes with different temperatures. Different screen parameters will have a different effect on print quality however, for the purpose of this study the screen parameters are controlled to ensure the only variation we see is from the paste temperature.

Emulsion	Wire	Mesh	Weave	Line Opening
0.8 mil	0.9 mil	325	22.5º	95 µm

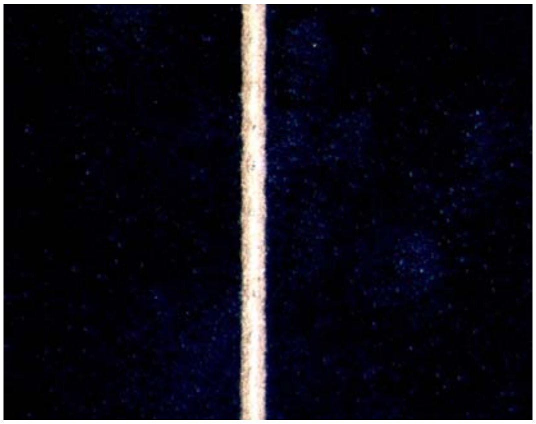
3. Print parameters

To further control variation the printing parameters were held constant. Different paste chemistry's may have different printing parameters. Since this is the same paste at different temperatures, the parameters are held constant so any variation can be traced back to the temperature variation.

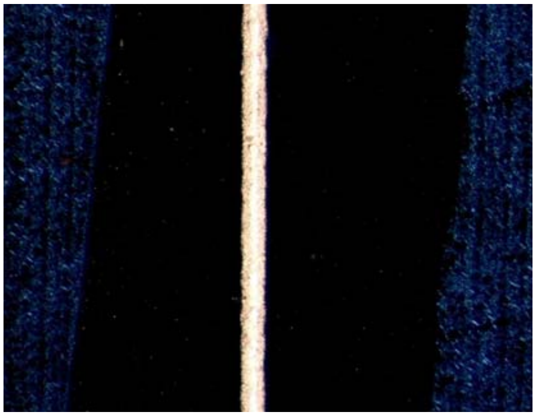
Pressure	Downstop	Speed	Snapoff	Squeegee Hardness	Squeegee Angle
20 lb	10 mil	8 in/sec	50 mil	70	50º

4. Optical photos

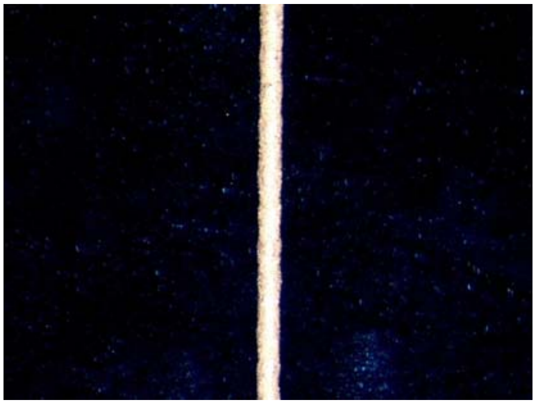
The experimental Solar Cell paste was printed on multicrystalline, non textured 6"X6" wafers. Photos were taken of each wafer and each temperature in the wet, dry and fired stage. Below are photos of a wafer at each temperature after they have been fired.



Fired cell printed at 20C



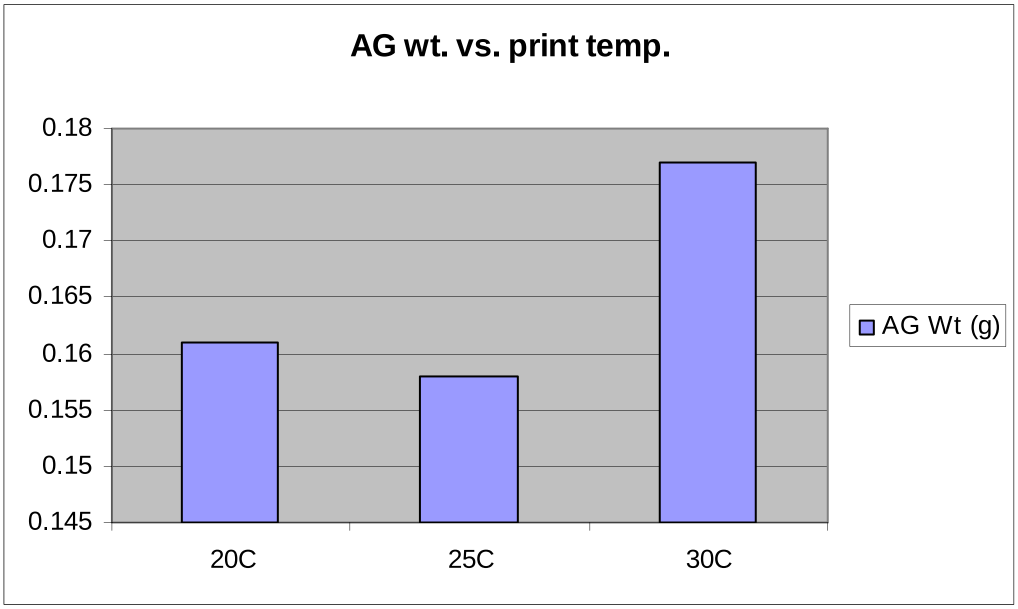
Fired cell printed at 25C



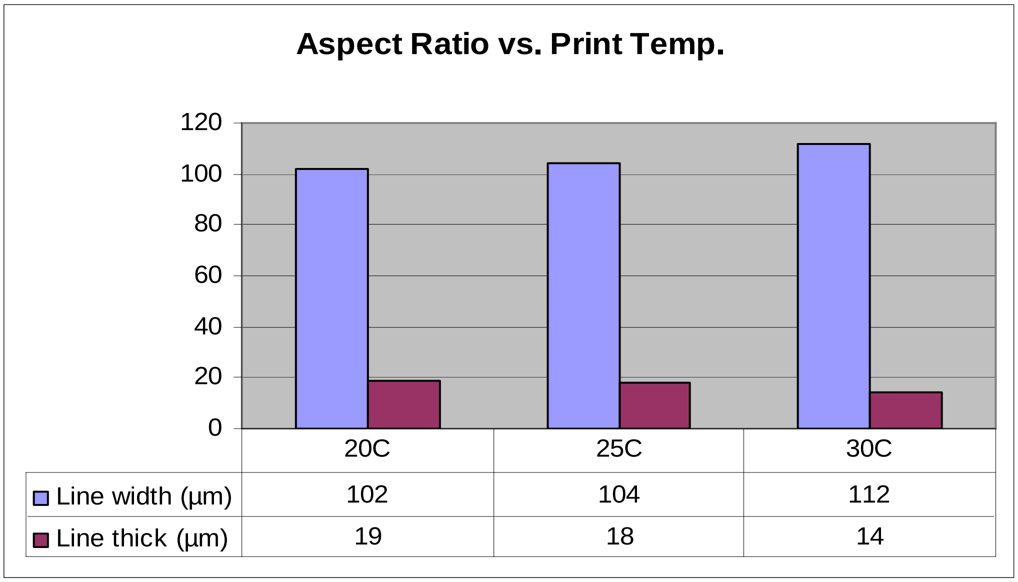
Fired cell printed at 30C

5. Results

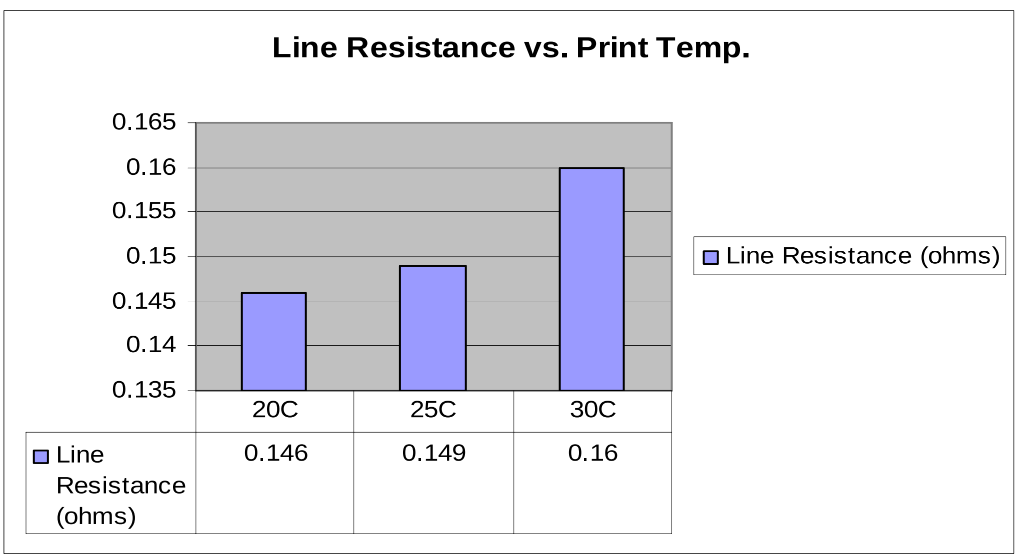
Theoretically, the lower the viscosity, the higher the paste transfer. To test this, after each wafer was printed at the different temperatures, the AG paste weight was recorded. The chart below shows that at a higher temperature, paste transfer is higher. It is also notable that at 20C and 25C there is virtually no difference in AG paste weight.



Another theory is the lower the viscosity of AG paste, the greater the slumping of finger lines. A slumping finger line will cause a poor aspect ratio. A poor aspect ratio can hinder electrical performance. The following chart illustrates the difference in finger line width and thickness. As you can see, for the lines with paste printed at 30C, the line width is greater and line thickness is smaller indicating slumping.



A poor aspect ratio should have a direct impact on line resistance. A thin and wide finger line will have a higher line resistance than a narrow and tall finger line. Assuming there are no line breaks, judging by the aspect ratio data there should be virtually no difference in line resistance of AG paste printed at 20C and 25C but we should see a higher line resistance with paste printed at 30C. The following chart proves this.



6. Conclusions

There is little difference in print quality and line resistance with paste printed at 20C and 25C. However, there is a significant change in paste transfer, aspect ratio and line resistance with paste printed at 30C. At 30C paste showed more slumping and an increase in line resistance. This study showed it is very important to have temperature controlled printing rooms when manufacturing Solar Cells.