Drying Characteristics of Screen Printed Aluminum Paste on Silicon Solar Cells

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Introduction

This work focuses on the drying characteristics of two different aluminum pastes. Aluminum paste was investigated as it is the most challenging to dry. In the first part the thermal behavior of two pastes is analyzed and in the second part drying in an industrial inline belt dryer is evaluated while the influence of residence time, means of heating and exhaust management on solvent removal is determined.

Experimental Setup

All experiments were performed on an advanced, in-line belt dryer from Despatch Industries (DriTech SL) as well as on a traditional dryer.

The solvent removal percent was calculated by the following formula:

$$\frac{\text{(Weight before dryer)} - \text{(Weight after dryer)}}{\text{(Weight before dryer)} - \text{(Weight after final dryer)}}$$

Final dry: 20 min in a lab oven at 230°C. It was determined that this step removes all residual solvent that was not removed in the dryer, but affects the high-temperature binders minimally.

The two aluminum pastes used for this test are both widely used in c-Si mass production.

Paste Analysis

In order to gain an insight into the thermal behavior of different aluminum pastes a thermal gravimetrical analysis (TGA) was performed. In this analysis a paste sample is heated with a constant ramp of 10 K/min while the weight is continuously recorded. It was found:

- Large disparities exist between different aluminum pastes
- Paste A: Difficult to dry aluminum paste with minimum solvent removal temperature of 210°C
- Paste B: Easy to dry aluminum paste with minimum solvent removal temperature of 140°C

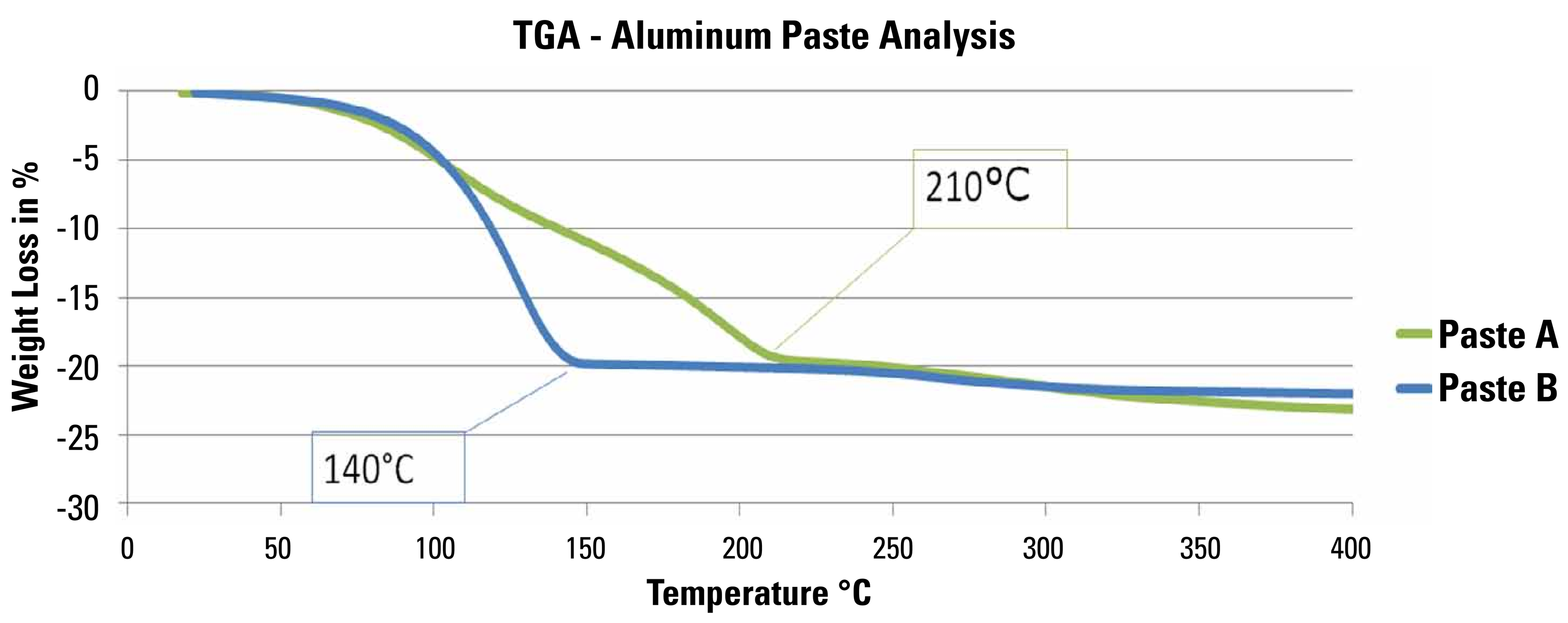

Figure 1: Thermal Gravimetrical Analysis of a difficult to dry Al paste (Paste A) and an easy to dry Al paste (Paste B)

Influence of Dryer Temperature

Temperature inside the drying chamber is historically the most important parameter for drying. All temperatures shown in this work refer to the peak temperature of the thermal profile. Thermal profile was measured on a bare silicon wafer.

Differences between pastes found during TGA translate into paste dependent peak temperature requirements

- Paste A: minimum temperature of 270°C - difficult to dry (figure 2)
- Paste B: minimum temperature of 190°C - easy to dry (figure 3)
- Temperature increase above threshold value does not increase solvent removal rate

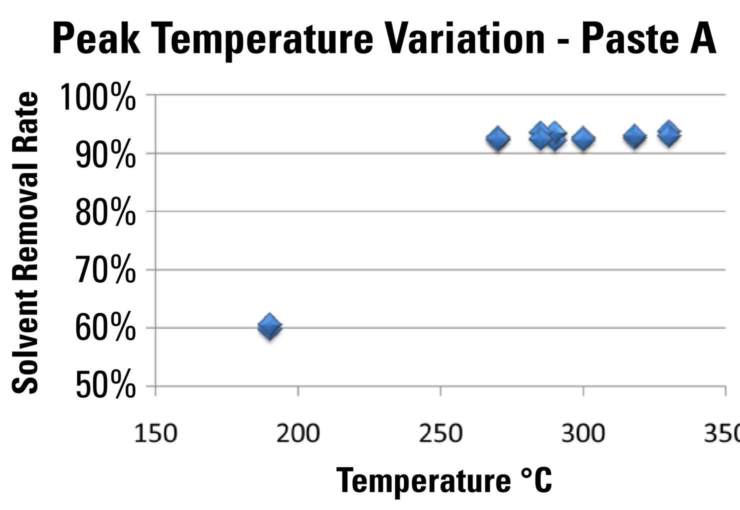

Figure 2: Impact of temperature on solvent removal rate of difficult to dry Paste A

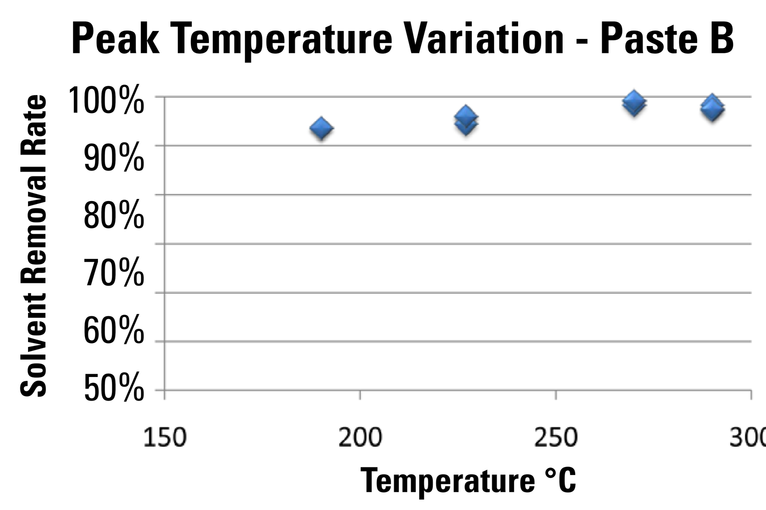

Figure 3: Impact of temperature on solvent removal rate of easy to dry Paste B

Influence of Residence Time

Residence time is determined by the belt speed and the length of the dryer. Since the length of the dryer usually cannot be changed and the belt speed is given by the line speed, residence time is a parameter that is generally fixed and cannot be used for process optimization.

Difficult to dry paste A:

- Traditional dryer : Minimum residence time 20s (figure 4)
- DriTech : Minimum residence time 10s (=belt speed 12700 mm/min) (figure 5)
- Increasing residence time above threshold value does not increase solvent removal rate
- Means of heating is key for efficient drying
- Hybrid heating technique of the DriTech represents a technology leap in drying efficiency

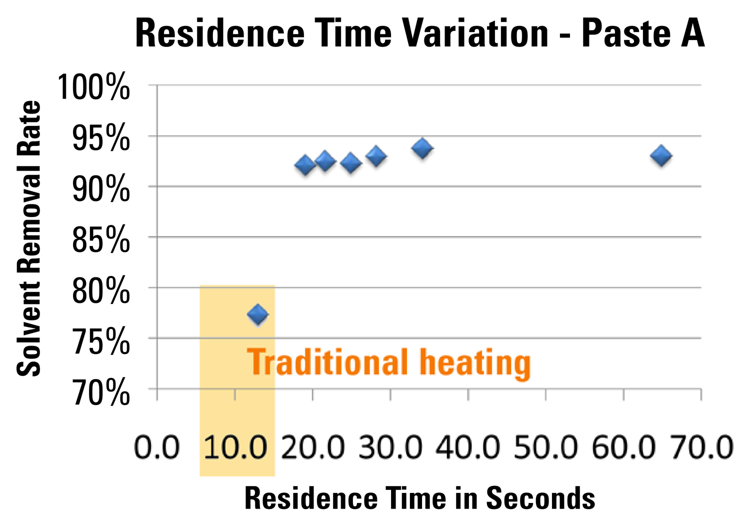

Figure 4: Impact of residence time on solvent removal rate for difficult to dry Paste A with a traditional heating mechanism

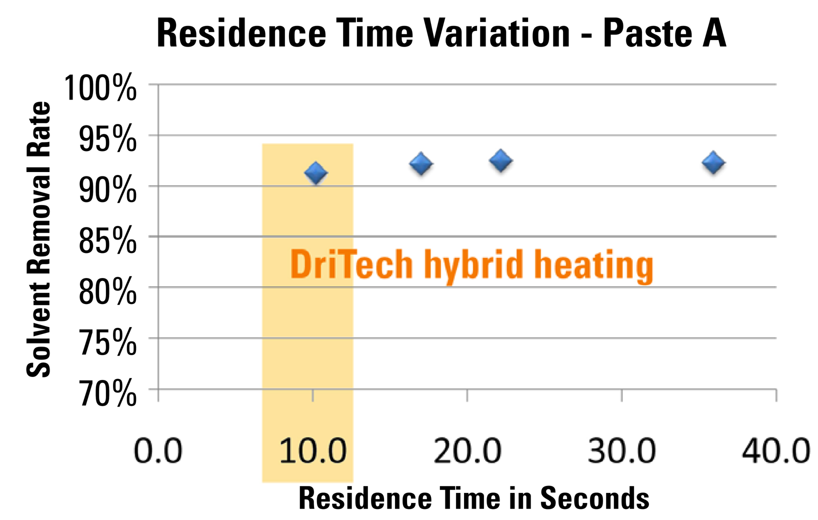

Figure 5: Impact of residence time on solvent removal rate for difficult to dry Paste A with novel DriTech hybrid heating

Easy to dry paste B:

- DriTech hybrid heating method enables a reduction in residence time to as little as 6s (= belt speed of 20000 mm/min)

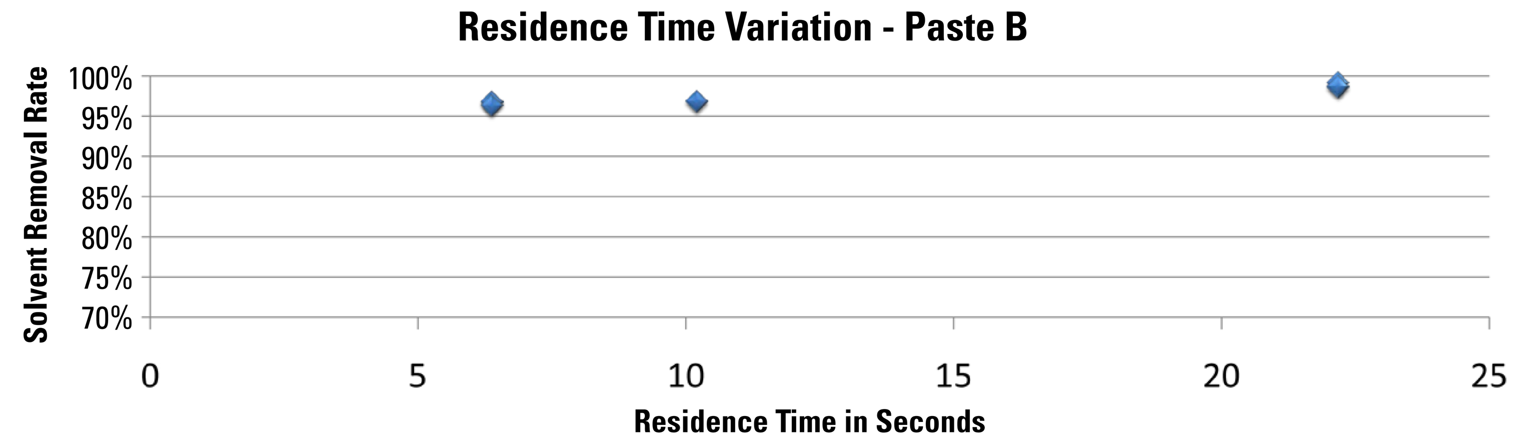

Figure 6: Impact of residence time on solvent removal rate for easy to dry Paste B

Mass Production Load

Continuous load conditions are challenging as there is danger of solvent vapor build-up inside the dryer. Such a solvent build-up can cause a decrease in drying efficiency.

- Traditional dryers lose drying efficiency during mass production load
- Exhaust flow management is key to avoid loss of drying efficiency
- DriTech with new exhaust management exhibits constant solvent removal rate during mass production load (figure 7)

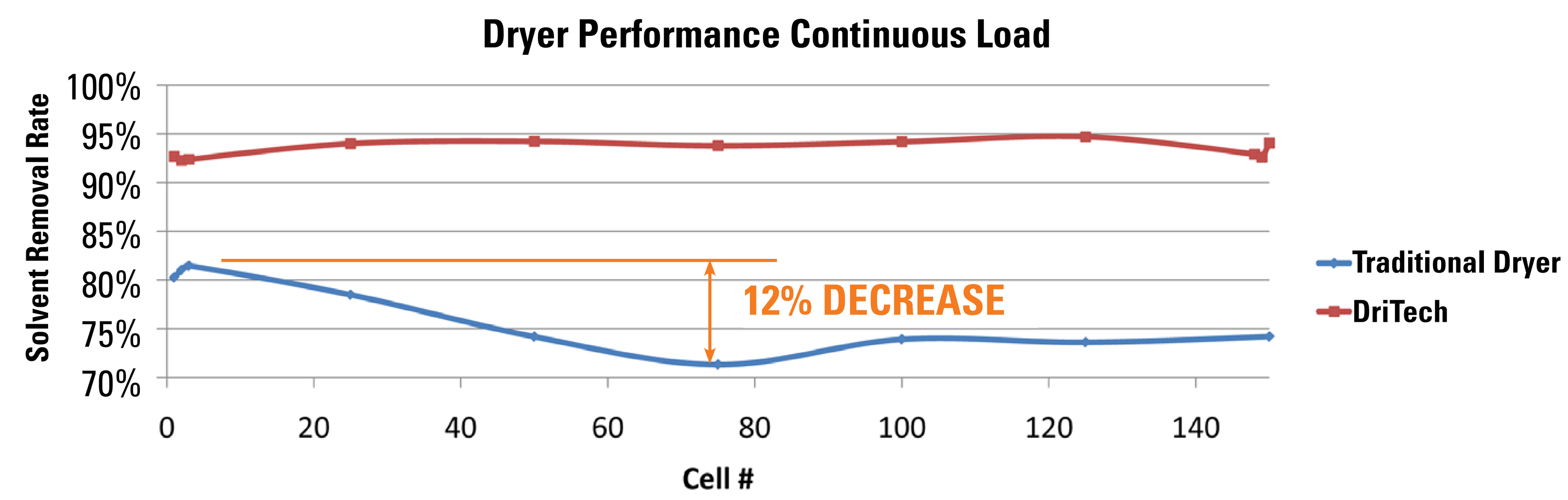

Figure 7: Comparison of drying performance during continuous load between traditional dryer and DriTech with optimized exhaust management

Conclusions

- There are great disparities in different aluminum pastes in terms of solvent content and solvent type
- Novel hybrid heating technique of DriTech significantly improves drying performance with dry aluminum pastes in as little as 6 seconds
- Exhaust flow management is crucial for constant solvent removal rate during mass production

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