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## Low activity tabbing pastes for passivated surface

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### Abstract

The PERC solar cell technology increases conversion efficiency by adding a dielectric passivation layer at the rear side of the cell. This requires back-side tabbing paste to maximize the protection of this dielectric layer from damage during the metallization step. We have developed a novel silver back-side tabbing paste for mono- and multi-crystalline PERC solar cell wafers. The new tabbing paste helps PERC to realize its higher efficiency and longer term reliability. In this paper we report our new generation backside tabbing paste for PERC application. The new generation tabbing paste contains new glass chemistry which minimizes the reaction between tabbing paste and passivation layer, showing  $>2$  mV Voc gain. New tabbing paste also demonstrates higher aged adhesion  $> 3N$ .

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*Keywords:* low activity; tabbing paste; passivated surface; PERC; high Voc; aged adhesion

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### 1. Introduction

By introducing and utilizing PERC (Passivated Emitter Rear Cell) technology [1], solar cell manufacturers are able to significantly increase their average output cell conversion efficiency while lowering cost per watt [2]. The PERC solar cell technology increases conversion efficiency by adding a dielectric passivation layer at the rear side of the cell. This dielectric layer reduces electron recombination, therefore improving the solar cell's ability to capture light at longer wavelengths. This requires solar cell paste metallization to maximize the protection of this dielectric layer from damage during the metallization step. For the formation of the rear contact of PERC cells, we have developed a

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novel silver back-side tabbing paste for mono- and multi-crystalline PERC solar cell wafers. The new tabbing paste helps PERC to realize its higher efficiency and longer term reliability. This paste contains new inorganic chemistry, imparting controlled reaction between Ag paste and the dielectric layer to maintain the passivation layer under the metallized area whilst at the same time showing improved cell efficiencies, as well as excellent solderability and higher aged adhesion.

## 2. Experimental section

In this paper, commercial available mono-crystalline p-type PERC solar cells with sheet resistance of 85  $\text{ohm}/\square$  were used to test new PERC tabbing paste electrical performance. Rear side tabbing pastes were first printed using a standalone semi-automatic ASYS screen printer, with a segmented 4 busbar (BB) design. Silver deposit on BB is about 2.8-2.9  $\text{mg}/\text{cm}^2$ . Second, a commercial available PERC aluminum paste, Toyo ALSOLAR TLCO-06C, was printed to form localized BSF through laser openings. Last, Heraeus SOL9631C was printed on the front side of the cells with a Baccini printer. After each printing step, cells were dried in a box oven at 150°C for 10 min. The wafers were fired with a Centrotherm belt furnace at a peak firing temperature of 785°C measured by a Dataloger. A typical firing profile is illustrated in Figure 1, for the furnace setting at 380-400-400-480-800-850 at belt speed of 6500 mm/min. I-V test was completed with a h.a.l.m. cetisPV-Celltest2. Adhesion test was done with ST-RX N002 PV Pull Tester made by Mogrl Technology. Pull test was performed at 180 degree angle at speed of 300 mm/min. Fired wafers were then hand soldered using a Vectech SD150 hand soldering gun. Soldering was conducted at different soldering tip set temperatures, and with Sn60Pb40 ribbon from different suppliers to test pastes soldering window. The soldering ribbon is 0.25 mm thick, and 1.2 mm wide. Cell microstructure was examined with JEOL JSM-7600F scanning electron microscopy (SEM) equipped with a field emission gun. SEM samples was etched with HNO<sub>3</sub> and HF solution to remove bulk silver and glass layer, respectively.

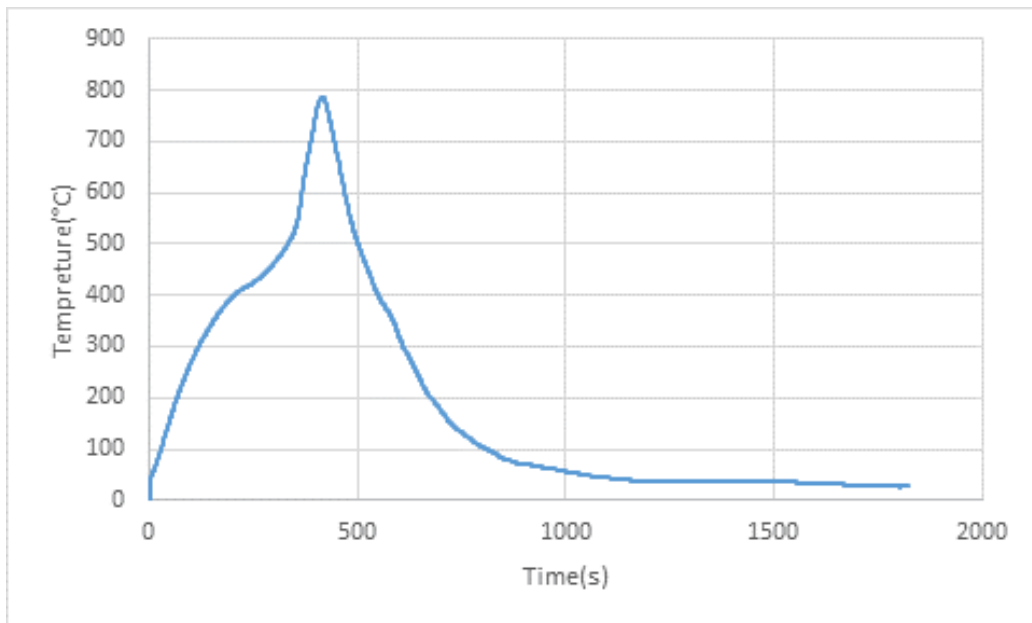


Fig. 1. Typical temperature profile of a co-firing cycle used. The measurement was performed using a Dataloger. The measured peak wafer temperature is 785°C.

## 3. Results and discussion

Our last generation tabbing paste showed great adhesion and good compatibility with different PERC Al pastes. However, it still showed damage on SiN<sub>x</sub> capping layer which caused loss in Voc. To improve the Voc, new glass

chemistry with controlled reactivity with SiNx was developed. Table 1 showed different paste composition. In compared to last generation paste (paste A in table 1), new generation tabbing pastes not only adopted a new glass chemistry (B1 in table 1), but also developed and incorporated a second glass (A2 or B2 in table 1). The main function of the second glass A2 or B2 is to regulate the reactivity of first glass A1 or B1 and further protect SiNx layer.

Table 1. Paste composition

Paste	A	B	C	D	E
1st glass	A1	A1	B1	B1	B1
2nd glass	--	A2	A2	B2	B2
Silver	A3	A3	A3	A3	B3

To study the paste reactivity with SiNx layer, SEM was used to observe the SiNx damage after metallization step. Figure 2 showed HF etched SEM images of different pastes on passivated mono-crystalline PERC wafers. From SEM images, control paste A (Fig.2a) showed significant SiNx damage and Ag precipitation after metallization step, which resulted in a low Voc in solar cell (Fig. 3). Incorporating a second glass frit A2, the reactivity of glass A1 with passivation layer was dramatically reduced. Paste B showed much less SiNx damage and silver precipitation than paste A (Fig. 2b). First glass A1 was further modified to glass B1, to reduce its reactivity with silver. Paste C showed reduced silver deposition on Si in both size and amount (Fig. 2c) in compared with paste B. In paste D, we further optimized both first and second glass chemistry, new generation tabbing paste D showed lowest reactivity with passivation layer, the SiNx damage was controlled to minimum level, hardly seen under SEM (Fig. 2d).

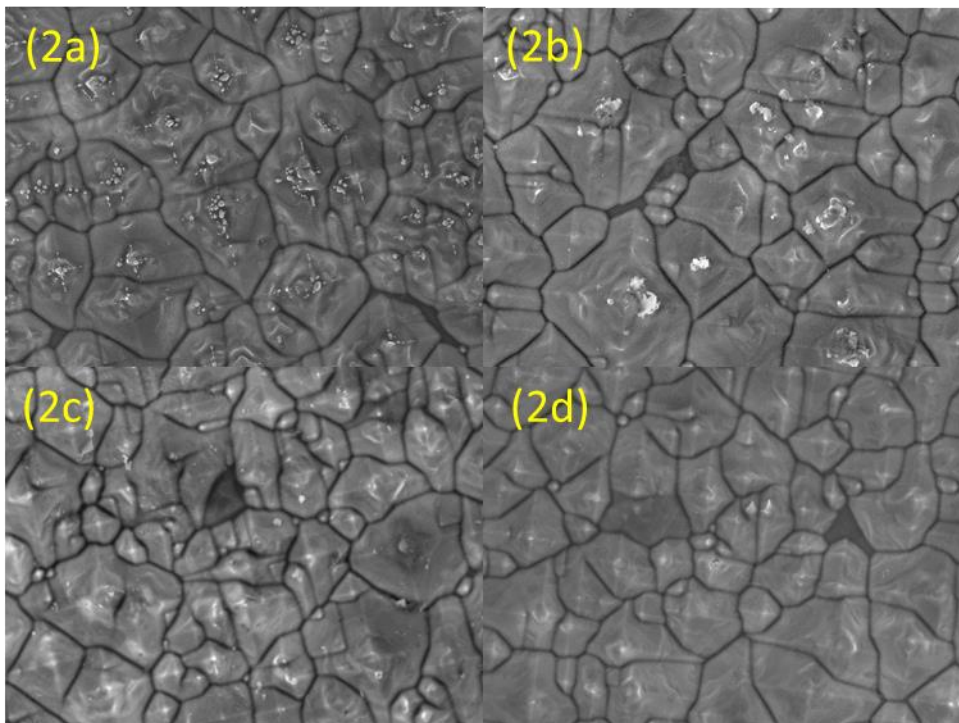


Fig. 2. SEM images of HF etched silicon wafers with different low activity pastes printed and fired on passivated p-type mono crystalline wafers. 2a: paste A; 2b: paste B; 2c: paste C; 2d: paste D.

The degree of SiNx damage and amount of Ag precipitation directly affect paste performance in Voc. Figure 3 showed the Voc boxplot of paste A, C and D as tabbing pastes on mono-crystalline PERC cells. We obtained > 2 mV

Voc gain from both paste C and D with new glass system. Paste D which had least reactivity with SiNx observed under SEM showed highest Voc.

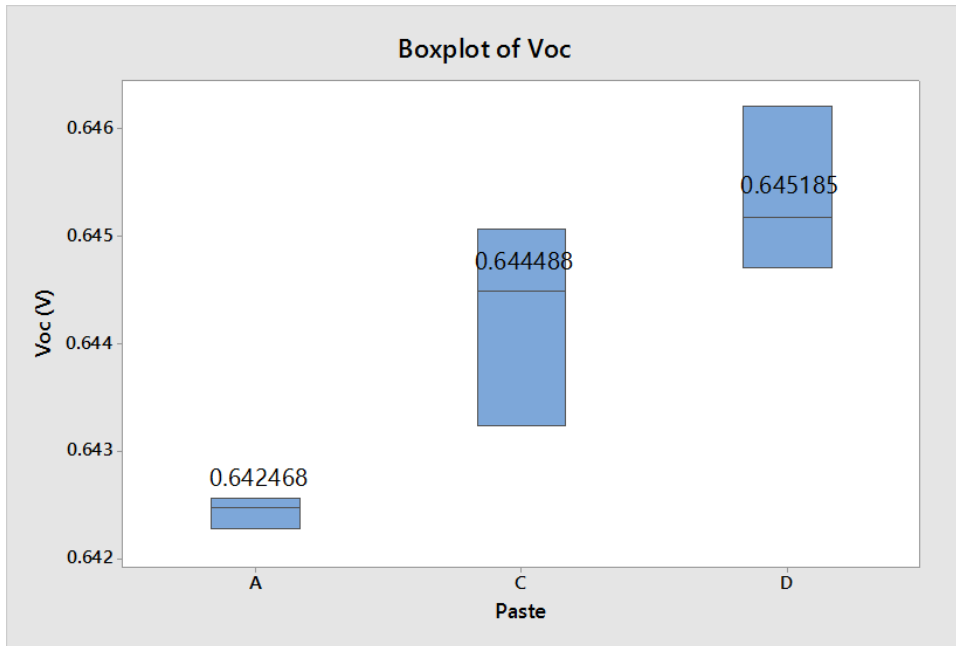


Fig.3. Voc of back side tabbing paste A, C and D printed on mono PERC wafers.

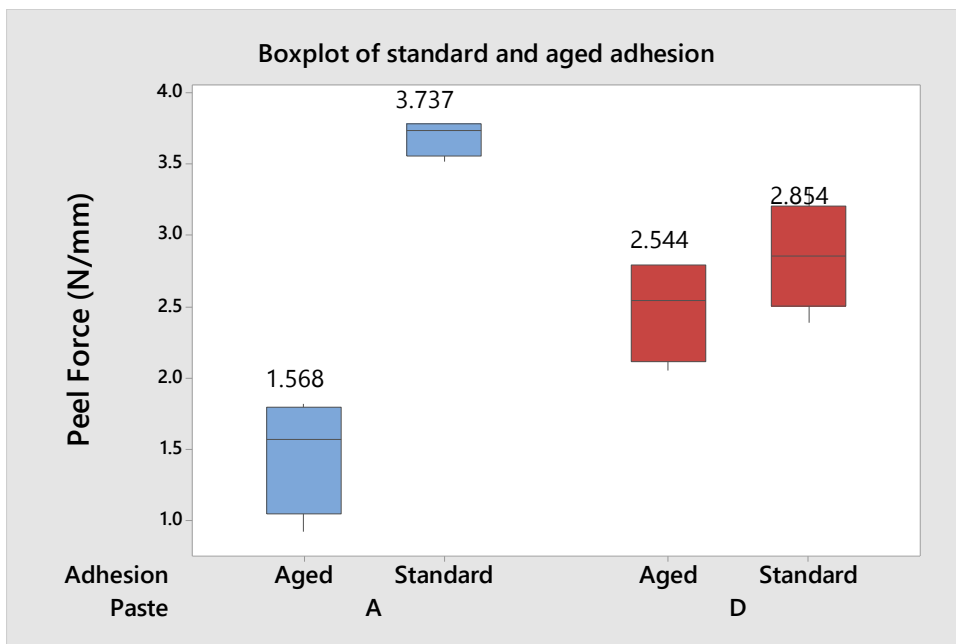


Fig.4. Adhesion of paste A and D printed on mono PERC wafers. Aged adhesion was tested after soldered wafer was left at 150°C for 1 hour. The peel force data were normalized to ribbon width of 1.2 mm.

Normally increasing efficiency achieved through minimizing the reaction between silver paste and passivation layer will result in decrease of adhesion at the same time. The low interaction between silver paste and passivation layer will reduce the cohesion between silver paste and wafer. However, our new generation paste is managed to keep the adhesion in the same level as the last generation paste. In addition, the new glass chemistry in paste D not only controls the interaction between Ag paste and passivation layer, but also controls the reaction between silver paste and solder which significantly increases the aged adhesion. Aged adhesion tests the adhesion after soldered BB undergoes a heat treatment. In this study, standard adhesion was tested after soldering, aged adhesion was tested after soldered BB was heat treated at 150°C for 1 hour. Figure 4 showed that the new glass chemistry enabled paste D with comparable standard adhesion, but much higher aged adhesion in comparison to control paste A. High aged adhesion leads to long term module reliability.

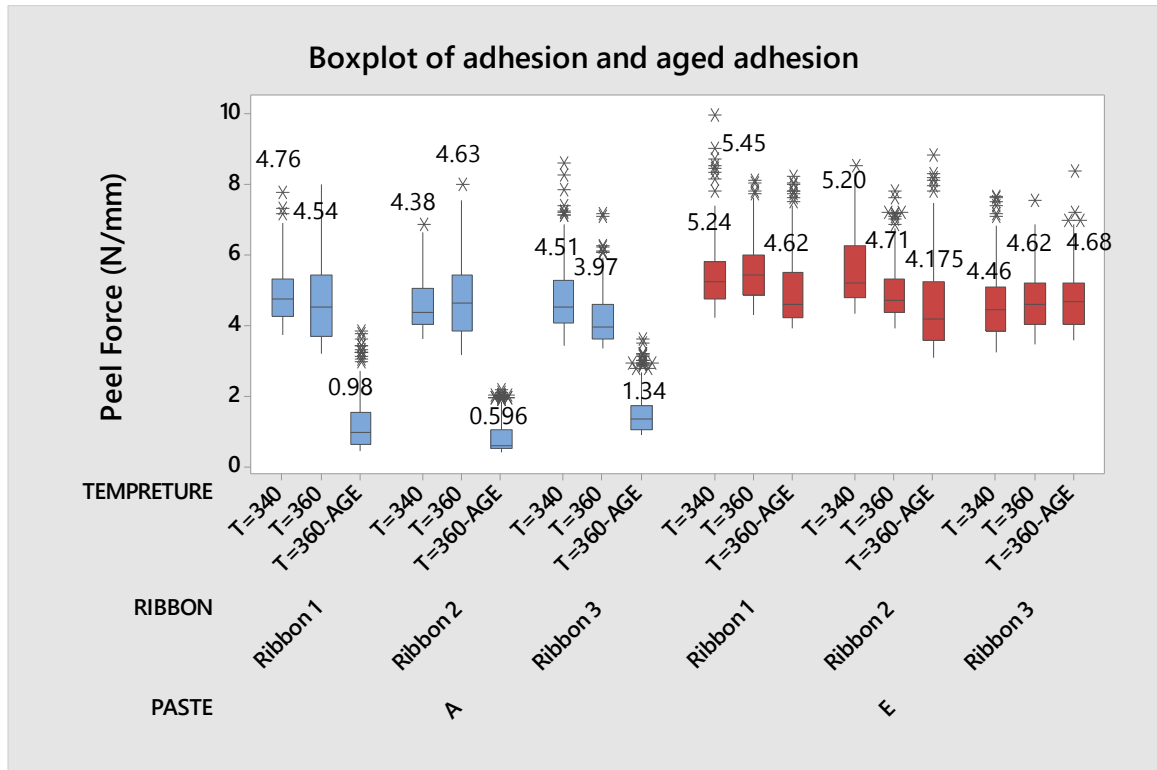


Fig.5. Adhesion of paste A and E printed on mono PERC wafers were tested with three different ribbons and at 2 different soldering temperatures of 340°C and 360°C, respectively. Aged adhesion wafers were soldered at 360°C. The peel force data were normalized to ribbon width of 1.2mm.

Higher aged adhesion and wider soldering window of new generation low activity PERC tabbing paste was not only observed on mono-crystalline PERC cell, but also realized on multi-crystalline PERC cells (Fig. 6). New generation paste E showed stable high adhesion with the soldering tip temperature varying from 280°C to 420°C on multi-crystalline PERC cells.

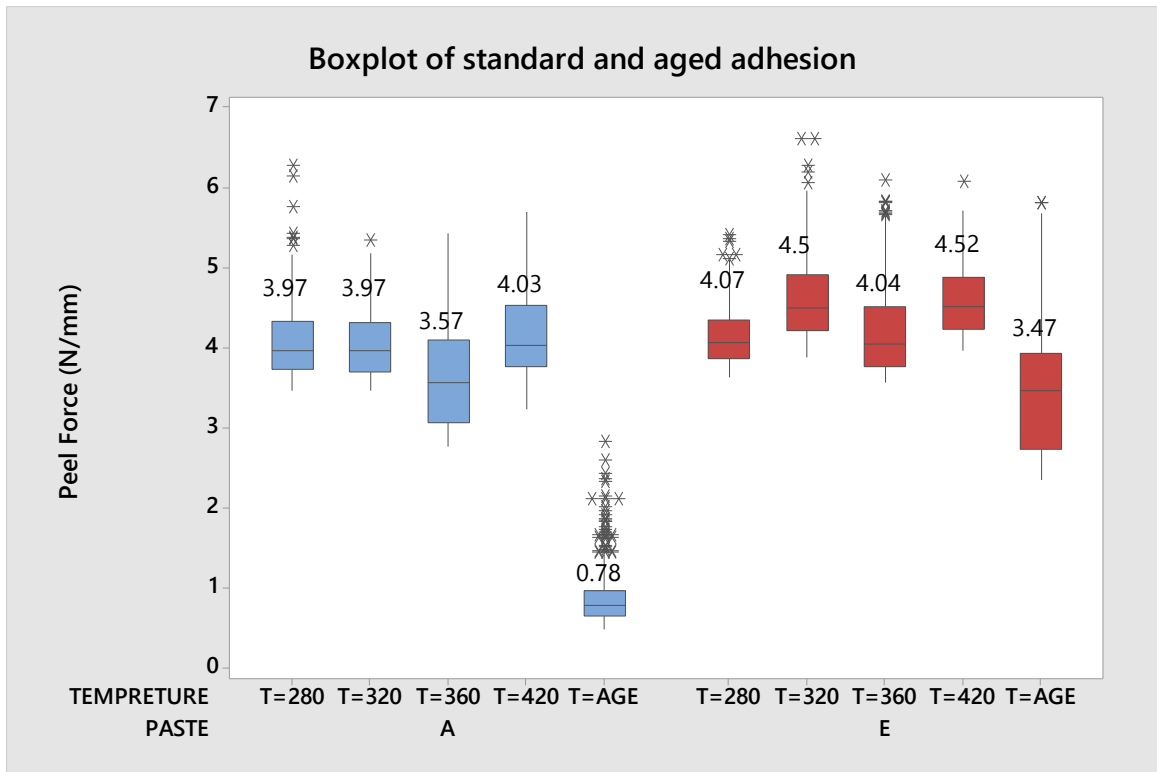


Fig.6. Adhesion of paste A and E printed on multi-crystalline PERC wafers were tested at four different soldering temperatures ranging from 280°C to 420°C. Aged adhesion wafers were soldered at 360°C. The peel force data were normalized to ribbon width of 1.2 mm.

#### 4. Conclusion

We developed new glass chemistry for PERC backside tabbing pastes to minimize the paste reactivity with SiNx passivation layer. Second glass helped to regulate the reactivity of first glass, both SiNx damage and silver precipitation were dramatically reduced. With the new glass chemistry, new generation tabbing paste achieved higher Voc, >2mV gain. In addition, the controlled interaction between new glass and silver offered higher aged adhesion leading to longer term module reliability. The adhesion of new generation tabbing paste was further improved through silver optimization. Paste E (BS21-1187) showed high adhesion and high aged adhesion with wider soldering window, on both mono-crystalline and multi-crystalline p-type PERC cells.

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