

# ***The Influence of Silver Powder Specific Surface Area on the Performance of Photovoltaic Silver Paste***

## **1. Introduction**

Photovoltaic silver paste is an indispensable core component of solar cells, and its quality directly affects the solar cell performance. Silver paste is typically coated onto the front and back of the cell in a grid formation and adhered by rapid heating (sintering), and the silver grid serves as a highly conductive electron network. Usually, silver powder accounts for 70-90% of the paste by weight, therefore silver material properties will directly affect the overall performance of photovoltaic silver paste. Shape, particle size, dispersion, and specific surface area affect the properties of silver powder.<sup>(1,2)</sup>

Two of the common silver particle shapes are:

- ✓ Spherical – good dispersibility
- ✓ Flake – higher surface area and density

Photovoltaic silver paste is often applied to both the front and back of the solar cell to complete the electrical circuit, but each side serves a different purpose. The front side of the solar cell faces the sun and is designed for light adsorption and current collection, and the back side of the cell is typically designed to house electrical connections. Front-side silver paste is typically comprised of spherical silver powder due to the improved dispersibility and narrow particle size distribution to ensure high photoelectric conversion and stability, and back-side silver paste is often comprised of larger silver flakes for improved electrical contact and lateral conductivity.<sup>(3)</sup>

The front-side silver particle size affects the specific surface area and dispersibility of the silver powder. Smaller silver particles result in larger specific surface area and higher surface activity, which allows for low-temperature sintering of the silver paste. During the sintering process, silver welding to the solar cell surface is likely to occur, which helps to form a dense conductive film and improve conductivity. However, if the silver particles are too small and the specific surface area too large, they may agglomerate during sintering. This reduces the continuity of the electrical network and limits conductivity.<sup>(4)</sup>

If the front-side silver particle size is too large, the specific surface area and the relative contact area will be too small, resulting in increased contact resistance and lower surface activity. Therefore, selecting silver powder with an appropriate particle size is crucial.

Spherical silver particles in the range of 1-3  $\mu\text{m}$  with specific surface area between 0.4-1.0  $\text{m}^2/\text{g}$  are typically used in the front side of the solar cell. Silver powder within this particle size range has good fluidity, good conductivity, a controllable rough surface, and can significantly improve the adhesion of the paste.<sup>(5)</sup>

In summary, the specific surface area of silver powder affects the performance of photovoltaic silver paste. Different silver particle shapes have different surface areas and serve unique functions. A larger specific surface area is not always better, because an excessively large specific surface area of spherical silver powder can adversely affect the performance of the silver paste. Therefore, selecting silver powder with an appropriate specific surface area is critical for enhancing the performance of conductive silver paste.

## 2. Experiment

The specific surface areas of three different front-side silver materials, A, B, and C, as well as one back-side silver material, D, were measured. The specific surface area of the silver powder was measured using the **AMI Sync 400** specific surface area and pore size analyzer from AMI. Approximately 8-10 grams of each silver powder sample were weighed and loaded into static sample tubes for testing. Nitrogen adsorption isotherms were measured at liquid nitrogen temperature, with pressure ranging from 0 kPa to 30 kPa. Two tests were conducted for each type of silver powder material.

## 3. Results and Discussion

Figure 1 shows the adsorption isotherms of the four types of silver powder. As can be seen from the figure, the nitrogen adsorption capacity is relatively low for both front-side (Fig. 1a-c) and back-side (Fig. 1d) silver powders. However, since back-side silver typically uses flake-shaped silver powder, its adsorption capacity is greater than that of front-side silver, a phenomenon demonstrated in Figure 1d. To verify the stability of the materials and the instrument, repeatability tests were conducted for each type of silver powder. The isotherms obtained from three BET tests for each of the four silver powder materials, shown in Figure 1, almost completely overlap, which strongly confirms the high stability of both the materials and the instrument.

Table 1 presents the specific surface area test results of the silver powders performed in triplicate. For front-side silver A, the average specific surface area was 0.55 m<sup>2</sup>/g. For front-side silver B, the average specific surface area was 0.53 m<sup>2</sup>/g. For front-side silver C, the average specific surface area was 0.53 m<sup>2</sup>/g. The relative standard deviations (RSD) of the three tests for the three materials were 0.53%, 0.24%, and 0.72%, respectively, all of which are less than 1%. This indicates excellent stability of both the materials and the **AMI Sync 400**.

Sample	Specific Surface Area Test #1 (m <sup>2</sup> /g)	Specific Surface Area Test #2 (m <sup>2</sup> /g)	Specific Surface Area Test #3 (m <sup>2</sup> /g)	Average (m <sup>2</sup> /g)	RSD (%)
Silver powder A	0.55	0.55	0.54	0.55	0.53
Silver powder B	0.53	0.54	0.53	0.53	0.24
Silver powder C	0.52	0.52	0.53	0.52	0.72
Silver powder D	0.80	0.80	0.80	0.80	0.27

Table 1: Specific surface area results for silver powders A-D, experiments performed in triplicate

Furthermore, the specific surface areas of the three front-side materials are very close, with silver A slightly larger than silver B, which is very slightly larger than silver C. Based on the specific surface area results, it is predicted that front-side silver A will exhibit the best performance.

Silver powder D is a back-side silver material, primarily composed of flake-shaped silver powder. The average specific surface area was  $0.80 \text{ m}^2/\text{g}$ , and the RSD was 0.270%, indicating excellent stability. The specific surface area of sample D is significantly larger than that of front-side silver powders A-C, which enhances its conductivity compared to spherical silver powders. However, the poor fluidity of flake-shaped silver powders limits its use to a back-side silver material.

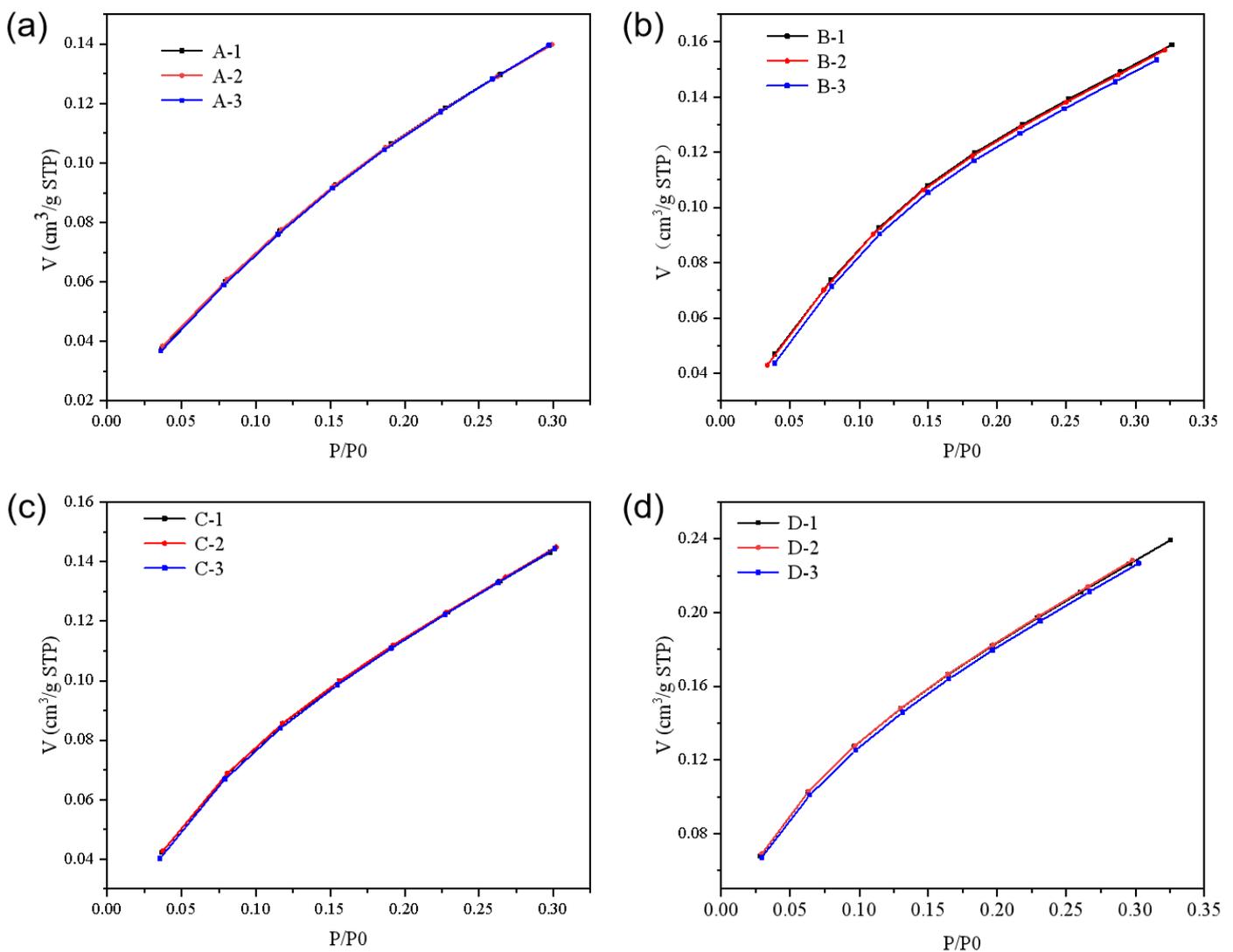


Figure 1: (a) Isotherms from three BET tests of front-side silver A under pretreatment conditions of  $80^\circ\text{C}$  for 2 hours; (b) Isotherms from three BET tests of front-side silver B under pretreatment conditions of  $80^\circ\text{C}$  for 2 hours; (c) Isotherms from three BET tests of front-side silver C under pretreatment conditions of  $80^\circ\text{C}$  for 2 hours; (d) Isotherms from three BET tests of back-side silver D under pretreatment conditions of  $80^\circ\text{C}$  for 2 hours.

## 4. Conclusions

The specific surface area of silver powder is an important indicator for characterizing its performance in photovoltaic cells. The primary factor affecting the specific surface area of spherical silver powder is particle size, which must be carefully tuned for optimal stability and conductivity. The current industry standard "Spherical Silver Powder for Solar Cell Front-Side Paste"<sup>[7]</sup> specifies that the specific surface area of silver powder should be between 0.25 and 1 m<sup>2</sup>/g. In this study, the specific surface areas of three front-side silver powders and one back-side silver powder are all between 0.5-0.8 m<sup>2</sup>/g, which confirms that they meet the requirements of the industry standard. The consistent specific surface area measurements with low RSD values also showcase the precision and reliability of the **AMI Sync 400**, highlighted in Figure 2.

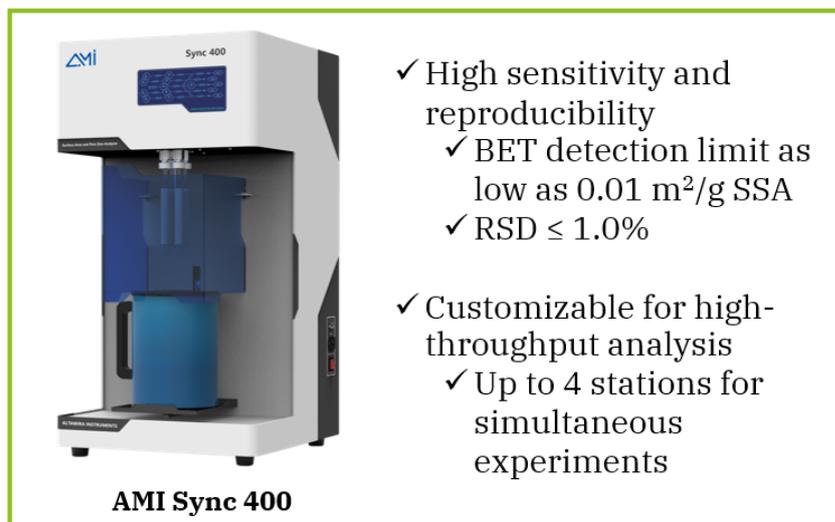


Figure 2: Highlights of **AMI Sync 400** physisorption analyzer

## 5. References

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