ISSN: 2414-1895 DOI: 10.6919/ICJE.202209_8(9).0059

Study on Properties of Hybrid Silicone Used in Photovoltaic Modules

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Abstract

In this paper, the effect of mixing black and white organic silica gel with the same composition in different proportions on the properties of the mixed silica gel was studied. The results show that the filler carbon black in the black silica gel has a reinforcing effect on the performance of the white silica gel. The results show that the filler carbon black in the black silica gel has a reinforcing effect on the performance of the white silica gel. With the increase of the proportion of black silica gel, it helps to improve the curing hardness, tensile strength and bonding strength of the mixed silica gel. Black and white mixed silica gel can still maintain good performance and meet the production and use requirements of photovoltaic modules.

Keywords

Silica Gel; Filler; Carbon Black; Reinforcement; Tack Time; Cure Hardness; Tensile Strength.

1. Introduction

With the development of the economy and the progress of society, people put forward higher and higher requirements for energy, and the search for new energy has become an urgent task facing human beings. Solar power generation has attracted the attention of various countries because of its advantages of no pollution, no noise, environmental protection and beauty, and it can avoid the damage to vegetation and the environment when laying cables long-distance [1]. In the past ten years, photovoltaic technology, as the most concerned new energy type, has achieved leapfrog development, the photoelectric conversion efficiency has been continuously improved, and the cost per kilowatt-hour has dropped rapidly. In the future, photovoltaics will become the most competitive energy form [2].

In this huge expansion of the solar photovoltaic industry, silicone sealants and potting compounds have also developed rapidly. The main application field of silicone sealant is the bonding and sealing of solar photovoltaic module frame and backplane junction box, and the main application of silicone encapsulant is junction box potting[3]. Organ silica is a highly active adsorbent material with adsorptive, thermally stable and stable chemical properties. As an important part of the current solar photovoltaic module bonding and sealing, it must also have good weather resistance, adhesion and flame retardancy in the outdoor environment, which promotes the continuous modification of silica gel for photovoltaic modules [4].

Fillers such as carbon black as silica fillers have been developed from the initial single reinforcing agent to functional fillers such as electromagnetic wave shielding materials [5], antistatic materials [6], and sensitive materials. The composite material not only has the excellent heat resistance, cold resistance, radiation resistance, flexibility and aging resistance of silicone rubber, but also has the

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electrical conductivity and piezoresistive properties of metal [7]. The amount of carbon black and the chemical properties of the surface and its dispersion in the silicone rubber matrix all affect the physical properties of the composites. In this work, organic silica gel with or without carbon black filler is used as the matrix material to study the influence of different proportions on its performance, and to judge whether the mixed silica gel meets the production and application standards of photovoltaic modules according to the test results.

2. Experimental Section

2.1 Experimental Materials and Equipment

The main experimental materials and equipment are shown in Table 1 and Table 2 respectively.

Table 1. Information on experimental materials.

Name	Ingredient/Model	Content/%	Manufacturer
Black Silicone	Hydroxy-terminated polydimethylsiloxane Calcium carbonate Fumed silica Ketooximosilane	40-65 35-50 3-10 3-6	Chengdu Guibao Science & Technology Co., Ltd.
	Carbon black	0.5-1	
White Silicone	Hydroxy-terminated polydimethylsiloxane Calcium carbonate Fumed silica Ketooximosilane	40-65 35-50 3-10 3-6	Chengdu Guibao Science & Technology Co., Ltd.
Backplane	FPF	/	Jolywood (Suzhou) Sunwatt Co., Ltd.

Table 2. Information on experimental equipment

Name	**Model**	**Manufacturer**	**Application**
Shore hardness tester	Type A	40-65	Hardness Testing
Electronic tensile testing machine	WDS-05	Jinan Sida Testing Technology Co., Ltd.	Tensile Strength /Elongation at break
Electronic digital caliper	/	Shanghai Henglaing Measuring Tool Co., Ltd.	Thickness measurement
Experimental trench	10×20×0.2 cm	Self made	Sample making

2.2 Sample Preparation

The black silica gel and white silica gel are uniformly mixed into five states according to the mass ratio, as shown in Figure 1: ① Black: White = 10: 0, pure black; ② Black: White = 8: 2, dark black; ③ Black: White = 5: 5, dark gray; ④ Black: White = 2: 8, gray; ⑤ Black: white=0:10, white.

Volume 8 Issue 9, 2022
DOI: 10.6919/ICJE.202209_8(9).0059

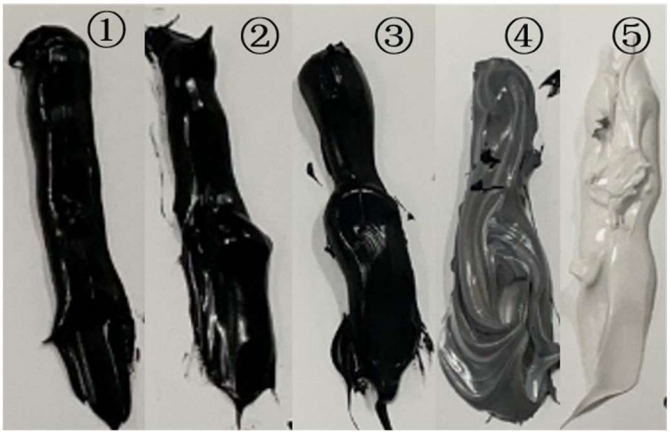

Figure 1. Appearance pictures of mixed silica gel in different proportions

2.3 Test Content

Surface drying time: Use a glue gun to extrude the silica gel on the test plate into a long strip, record the time until the surface of the silica gel does not stick to light touch, and test according to GB/T 134.77.5-2003;

Curing depth: Under the environment of 23±2℃/50±5%RH, extrude thin strips on the test plate, after curing for 24h, cut the thin strips horizontally, and measure the cured thickness of silica gel displayed in the cross section;

Cured hardness: Use a thin sheet sample cured for 7 days to test, the thickness of a single layer is not less than 1.5mm, the thickness of multiple layers is not more than 3 layers, the thickness is not more than 6mm, and the hardness is tested with a Shore hardness tester;

Tensile peel strength: according to GB/T 134.77.8-2002 test;

Tensile strength: according to GB/T 528-2009 test;

Elongation at break: Experiment according to GB/T 528-2009.

3. Results and Discussion

3.1 Influence of the Ratio of Black and White Silica Gel on the Surface Drying Time

Table 3. Surface dry time and 24-hour curing depth of mixed silica gel with different proportions

Black:White	10:0	8:2	5:5	2:8	0:10
Dry time /min	29	28	25	19	14
24 hour cure depth /mm	2.3	2.5	2.6	2.9	3.1

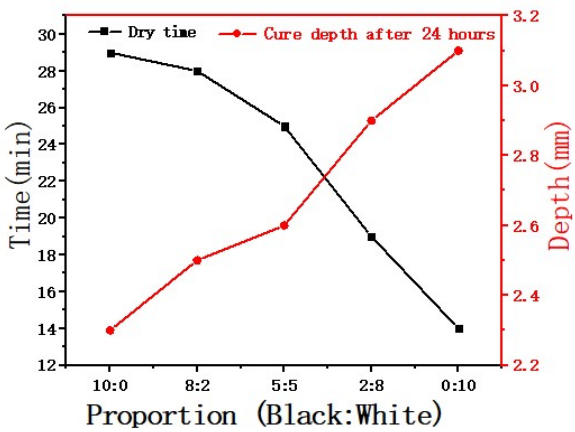

Figure 2. Trends of surface drying time and 24 hours curing depth of mixed silica gel with different proportions

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The five well-mixed samples were extruded on the test board with a glue gun, and the test board was cured at 30% humidity and 18°C, the data are shown in Table 3. As can be seen from Figure 2, the surface drying time of the five mixed states of silica gel is between 10-30min, and the curing depth in 24 hours is not less than 2.0mm, which meets the test standard of GB/T 134.77.5. With the decrease of the proportion of black silica gel, the surface dry time was shortened from 29 min to 14min, and the curing depth in 24 hours was increased from 2.3 mm to 3.1 mm. This shows that the incorporation of white silica gel accelerates the curing degree of the mixed silica gel. As a functional material, carbon black has the effect of reinforcing and increasing in rubber materials, which is why black silica gel is more viscous than white silica gel. At the same time, carbon black has the effect of absorbing moisture. The decrease of carbon black content in silica gel reduces its ability to absorb moisture [7].

3.2 Influence of Black and White Silica Gel Ratio on Curing Hardness

Put the mixed silica gel sample into the glue gun, squeeze it into the self-made 10cm×20cm experimental groove, the groove depth is 2 mm, cover it with a layer of plastic wrap, take a flat glass plate and press it on the experimental groove to make the excess mixed silica gel Just overflow the groove. Remove the glass plate and place it in the natural environment for 24 hours. After the surface is cured, remove the plastic wrap and continue to cure for 144 hours until the mixed silica gel is completely cured. The curing hardness test is carried out, The data are shown in Table 4. It can be seen from Figure 3 that with the decrease of the mixing ratio of black silica gel, the curing hardness of the mixed silica gel decreases from 53HA to 48HA, which shows that the increase of black silica gel is beneficial to the improvement of the curing hardness of silica gel. The curing hardness of the five mixed states of silica gel is about 50HA, which is in line with the test standard of GB/T 531.1 (40-60HA). The analysis shows that with the increase of the proportion of black silica gel, the amount of carbon black increases, the physical and chemical interaction occurs between the filler particles and the base rubber, and the entanglement and adsorption of the rubber molecular chains to the filler particles make the rubber molecules and segments The activity is blocked, and the relative slippage of the molecular chain is more difficult. Therefore, adding an appropriate amount of carbon black can not only reinforce the rubber but also improve the stress relaxation properties of the composites.

Table 4. Curing hardness after 7 days of mixing silica gel with different proportions

Black:White	10:0	8:2	5:5	2:8	0:10
Hardness /°	53	52	52	51	48

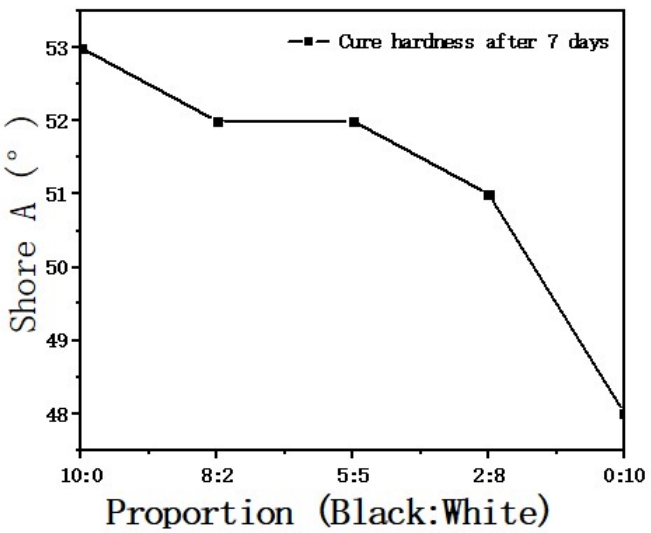

Figure 3. The curing hardness trend after 7 days of mixing silica gel with different proportions

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3.3 Effect of Black and White Silica Gel Ratio on Tensile Strength and Elongation at Break

Use the experimental groove to prepare the silica gel sample, and use the dumbbell cutter to make the dumbbell-shaped sample according to the GB/T 528-2009 inspection specification (the sample thickness is 2.0mm ± 0.2mm, type 1 standard). It can be seen from Figure 4 that the tensile strength of the mixed silica gel is positively correlated with the proportion of black silica gel, and the elongation at break is negatively correlated with the proportion of black silica gel. This is consistent with the increase in the amount of filler in the silica gel, the viscosity, density, Shore A hardness and tensile strength of the rubber increase but the elongation at break decreases. The data show that the tensile strength and elongation at break of the silicone rubber in the five mixed states meet the test standards of GB/T 528.

Table 5. Tensile strength and elongation at break after complete curing of mixed silica gel with different proportions

Black:White	10:0	8:2	5:5	2:8	0:10
Tensile Strength /MPa	2.92	2.75	2.63	2.58	2.52
Elongation at break /%	260.29	267.12	286.51	320.89	340.28

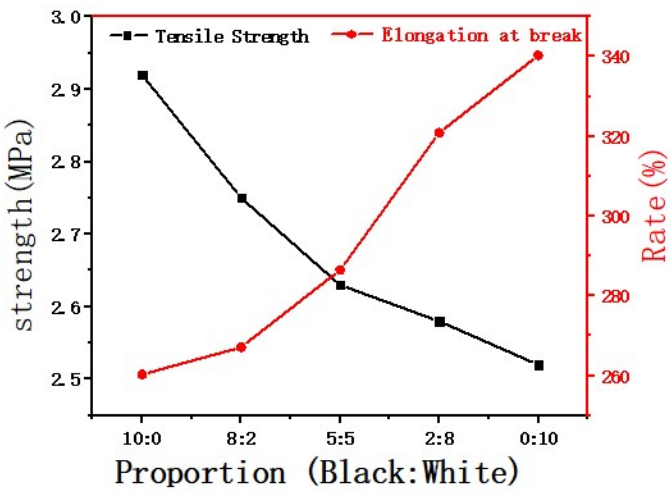

Figure 4. Trends of tensile strength and elongation at break after complete curing of mixed silica gel with different proportions

3.4 Influence of Black and White Silica Gel Ratio on the Peel Strength

Cut the backboard into a 1cm×20cm strip, lay it on the bottom of the self-made 10cm×20cm experimental groove, squeeze the five kinds of mixed silica gel samples on the strip backboard, and then add a layer of backboard to form a backboard/silica gel / The sandwich structure of the back plate, after covering the plastic wrap, the flat glass plate is squeezed until the excess mixed silica gel overflows the groove, and it can be completely cured, The measured peel strength data are shown in Table 6. From Figure 5, we can see that as the proportion of black silica gel in the mixed silica gel decreases, the peel strength between the silica gel and the backplane increases first and then decreases, and when the ratio is 5:5, the peel strength is the largest, and the five The silica gels in the mixed state all showed good bonding.

Table 6. Peel strength between different proportions of mixed silica gel and backing sheet

Black:White	10:0	8:2	5:5	2:8	0:10
Peel strength /N/cm	22.3	22	23	22.4	20

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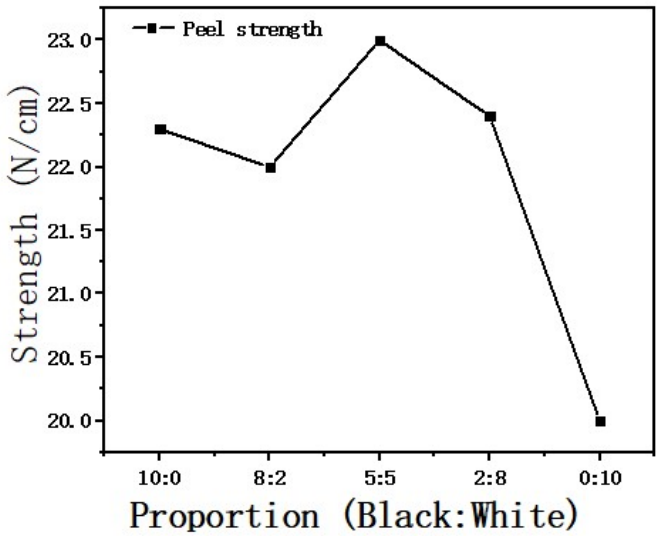

Figure 5. Peel strength between different proportions of mixed silica gel and backing sheet

4. Conclusion

(1) Among the black and white silica gel components selected in the experiment, only the amount of carbon black is different. The reliability of the five silica gels mixed in different proportions meets the use standard. (2) With the increase of the proportion of black silica gel, the surface drying time is prolonged and the curing depth is decreased, but the curing hardness, tensile strength and bonding strength are all improved, which is in line with the reinforcing effect of carbon black as a filler on silica gel. (3) Comparing the properties of the five mixed states of silica gel, we can find that the black silica gel has better performance overall than the white silica gel due to the incorporation of carbon black, which shows that the filler plays an important role in the modification of silica gel composite materials. From the perspective of the mixed use of black and white silica gel during the switching process, the mixed silica gel can still maintain good performance except for the gradient of the appearance color. Comprehensive consideration, the same composition and different colors of silica gel are mixed, the performance meets the use standard, and can be directly switched during use.

References

[1] Goetzberger A , Hoffmann V U . Photovoltaic Solar Energy Generation[J]. Springer Berlin Heidelberg, 2005.

[2] Park, Nam-Gyu. Perovskite solar cells: an emerging photovoltaic technology[J]. Materials Today, 2015, 18(2):65-72.

[3] Xue-Hua L I , Lin K H . Effect of Silane Coupling Reagent on Weathering Adhesion of Photovoltaic Sealant[J]. Adhesion, 2019.

[4] Zhang G , Rong Z . Silicone sealant for photovoltaic building[J]. China Building Waterproofing, 2010.

[5] Duan Y , Liu S , Guan H . Investigation of electrical conductivity and electromagnetic shielding effectiveness of polyaniline composite[J]. Science and Technology of Advanced Materials, 2016.

[6] Iqbal A , Frormann L , Saleem A , et al. The effect of filler concentration on the electrical, thermal, and mechanical properties of carbon particle and carbon fiber-reinforced poly(styrene-co-acrylonitrile) composites[J]. Polymer Composites, 2010, 28(2).

[7] Lux F . Models proposed to explain the electrical conductivity of mixtures made of conductive and insulating materials[J]. Journal of Materials Science, 1993, 28(2):285-301.