A Study on Carbon/Graphite Coating for the Heat Dissipation of Photovoltaic Module

Un-Yong Eom, Seung-Kuk Seo, Jae-Hong Kim, Gwang-Ju Lee, Seung-Kuk Seo, Ji Eun Ha, Jae-Seung Roh

School of Advanced Materials and Systems Engineering, Kumoh National Institute of Technology, Gumi, Gyeongbuk 730-701

1. Introduction

With the exhaustion of fossil fuel and the rising of environmental problems including CO2 emission, solar energy is attracting great attention. Solar energy is free of pollution while being an infinite energy source at the same time. However, solar energy has demerits such as relatively lower energy conversion efficiency compared to other energy sources. In addition, the energy conversion efficiency of photovoltaic power generation deceases further because the temperature of the system rises due to the heat generated by the system itself in the process of producing electricity and surrounding atmospheric conditions. This temperature rising becomes a major cause of the reduction of the life and performance of the system [1, 2]. It is reported that the temperature of a photovoltaic module increases by 1℃, the efficiency decreases by around 0.5% [3]. Therefore, the thermal emission of photovoltaic power generation systems is very important. The efficiency and lifetime of photovoltaic modules should be increased by introducing efficient cooling systems. In cooling systems for the heat emission of photovoltaic power generation systems, the water spraying is mainly used but this method requires costs to install, maintain and repair the system and continuous power consumption.

This is a study on the possibility of carbon materials coating as a solution for the thermal emission problem for photovoltaic power generation systems.

2. Experimental procedure

Carbon black, cokes, natural graphite and amorphous graphite powders were used after ball milling followed by sieving. The average size of the powders was 13~18㎛ measured using a particle size analyzer (MASTERSIZER200, MALVERN INSTRUMENT Co.). The crystallinity of the produced powders was measured using a Raman spectroscopic analyzer. The basic properties of the carbon and graphite powders used in this study are shown in Table 1.

Each powder and the organic binder were stirred for three hours at 50℃ to make a paste and each of the produced paste was coated on an aluminum sheet sized 40x40x3(mm) and dried for 30 minutes at 150℃.

Thermal emissivity was measured at 50℃ using a FT-IR Spectrometer (M2400-C, MIDAC, USA) and the thermal emissivity values of the aluminum sheet and the carbon and graphite coating layers were compared with those of Black bodies(emissivity=1.0).

To measure the heat emission effects of carbon and graphite coatings, each sheet was heated in an oven up to 150℃ and stabilized for around 15 minutes and then they were cooled down. The temperature was measured continuously until the sheet was cooled down to 40℃ using thermocouples.

Table 1. Summary of the raw powders properties

Carbon Types	Average Size	Shapes	Id/Ig by Raman
Carbon black	14㎛	Spherical	0.91
Cokes	14㎛	Random	0.79
Natural graphites	18㎛	Flaky	0.12
Amorphous Graphites	13㎛	Random	0.29

3. Results and discussions

3.1 Thermal emissivity

Fig 1 shows the radiation properties of carbon materials in the state of powder. Carbon black, cokes natural graphite and amorphous graphite powders show high radiation properties close to 0.9 in the entire area of 5~20㎛ and in particular, it was identified that they had high radiation properties of at least 0.8 even for short wavelengths.

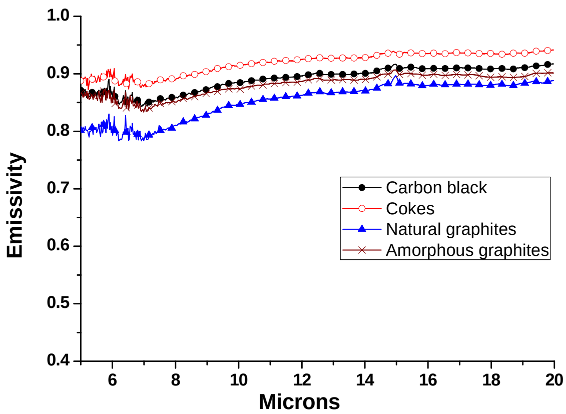

Fig 1 Emissivity curves of raw powders at 50℃.

Fig 2 shows the radiation properties of aluminum sheets coated with each powder mixed with organic binders. At 50℃, at least 0.8 of thermal emissivity was obtained from all the carbon or graphite coating layers. The thermal emissivity decreases in the order of carbon black > cokes > amorphous graphite > natural graphite showing the same tendency as that of carbon materials in the state of powder.

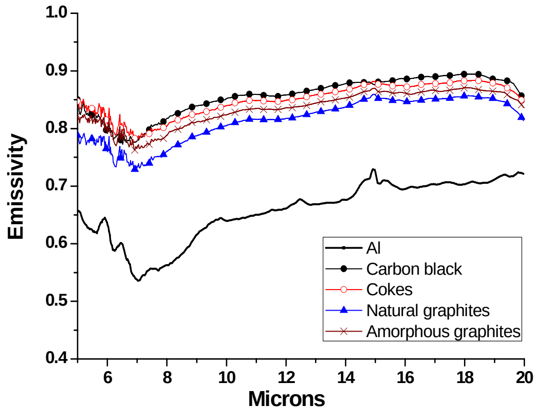

Fig. 2. Emissivity curves of coated powders at 50℃.

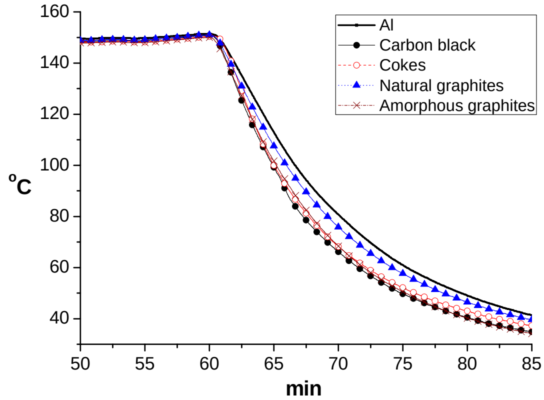

Fig. 3. Comparison of cooling rate as a function of coating condition.

Table 2 shows the results of the thermal emissivity values of raw powders before coating and the thermal emissivity values of their coating layers on aluminum sheets. The reason why the thermal emissivity values of the coating layers were a little lower is considered to be the effect of the binder used for joining to cover the material powder. The thermal emissivity of the coating layer of flake shaped natural graphite was the lowest. This is considered that the orientation of natural graphite particle affects thermal emissivity.

Table 2. Result of thermal emissivity at 50℃

Carbon Types	Emissivity	
	before coating (raw powders)	after coating (coated powders)
Carbon black	0.890	0.877
Cokes	0.893	0.870
Natural graphites	0.850	0.834
Amorphous graphites	0.856	0.854

3.2 Effect of heat release

Fig 3 shows changes of cooling rates in relation to carbon and graphite material coatings. When aluminum sheets and the sheets coated with each carbon and graphite materials were heated to 150℃ and then cooled down to 40℃, those sheets were cooled down faster than aluminum sheets non-coated. The cooling rate decreased in order of carbon black > amorphous graphite > cokes > natural graphite and in the case of the sheet coated with carbon black which showed highest cooling rate. The time taken to be cooled down from 150℃ to 40℃ was around 6 minutes faster compared to an uncoated aluminum sheet. When 7 minutes had passed after commencing the cooling, the temperatures of the two sheets were different by up to 16℃. This is concluded that the carbon or graphite coating with high thermal emissivity affected the cooling rate of aluminum sheets.

4. Conclusion

Carbon black, cokes, natural graphite and amorphous graphite powders were mixed with an organic binder and coated on aluminum sheets and the thermal emissivity of each powder before coating and that of the coating layers were compared with each other.

1. The thermal emissivity of carbon black and cokes powders showed high radiation properties close to 0.9 in whole range of 5~20㎛ wavelength and when each power was coated on an aluminum sheet. The thermal emissivity of the aluminum sheet which had been 0.63 increased to at least 0.8.

2. When carbon black was coated on an aluminum sheet, the thermal emissivity was shown to be 0.877 and thus the highest value could be obtained which was not much different from the thermal emissivity (0.890) of the powder material.

3. The sheets coated with carbon or graphite materials showed higher cooling rates than aluminum sheets. In the case of the sheet coated with carbon black that showed the highest cooling rate, the time taken to be cooled down from 150℃ to 40℃ was faster by around 6 minutes compared to uncoated aluminum sheets. When 7 minutes had passed after the beginning of cooling, temperature differences of 16℃ at the maximum were shown.

It is expected that heat emission coating using carbon and graphite powder is used independently or in combination with the cooling method for photovoltaic power generation systems. Therefore the energy conversion efficiency and lifetime of photovoltaic power generation systems could be improved.

5. Reference

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