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Boron Nitride Powders for High Thermal Conductivity Insulation Resin Sheets

1. Introduction

Demand for power modules, which are used in industrial and automotive inverters, has been extremely high in the application for hybrid electric vehicles (HEV) and electric vehicles (EV) in recent years. Although ceramic-type insulated heat dissipation substrates had been used for power modules until recently, a changeover from ceramic materials is now in progress as a result of the development of high thermal conductivity insulation resin sheets using boron nitride fillers. Mizushima Ferroalloy Co., Ltd., a wholly-owned subsidiary of JFE Steel Corporation, developed and commercialized a series of aggregate hexagonal boron powders (HP-40 Series) as fillers for use in high thermal conductivity insulation resin sheets for high output power modules.

2. Main Features of Aggregate Boron Nitride

Hexagonal boron nitride (h-BN) is a white ceramic material with a layered structure similar to that of graphite, and is used as a raw material for cosmetics and in various industrial applications owing to its good lubricity, heat resistance, electrical insulation property and thermal conductivity[1, 2]. Because h-BN has high thermal conductivity, a low dielectric constant and excellent stability (hygroscopicity resistance) in comparison with other ceramic materials used for heat dissipation parts such as heat dissipation insulation sheets and heat dissipation substrate materials, it is a promising filler material.

h-BN displays a planar shape and has anisotropic thermal conductivity originating from its crystal structure, as its in-plane thermal conductivity is high (200 W/m-K) while its through-plane thermal conductivity (thermal conductivity in the thickness direction) is low (2 W/m-K). However, when h-BN was filled in resins and formed into sheets without modifying its planar shape, it was not possible to increase the through-plane thermal conductivity of the resin because the planar particles oriented in the in-plane direction in the sheet. To solve this problem, Mizushima Ferroalloy developed aggregate BN powders with a random orientation of planar h-BN. It is possible to increase through-plane thermal conductivity by producing an aggregate powder and filling the resin while maintaining this morphology.

We originally produced an aggregate BN powder (FS-3) by granulating planar BN powder particles in a spherical shape using an organic binder, followed by high temperature synthesis. Recently, we reviewed the raw materials and production method with the aim of improving the filling property in resins, and developed a new series of aggregate BN powders (HP-40 Series) with added high crystallinity, an appropriate void ratio and a disaggregation property by forming the aggregated state by high temperature synthesis followed by crushing. **Photo 1** shows SEM images of an aggregate BN powder (HP-40MF100). As features of the developed products, the particles that comprise HP-40 are thicker and have a smaller aspect ratio than the planar particles that made up the original granulated aggregate powder (FS-3). For this reason, the developed product has a structure that enables easy filling of resins in comparison with the granulated aggregate powder, and heat dissipation is improved by a suitable disaggregation property.

Table 1 shows the composition, particle size, property values (representative values) and SEM images of the aggregate BN powders sold by Mizushima Ferroalloy. The aggregate BN powders sold by this company are the above-mentioned HP-40 Series and FS-3 with planar particles granulated to a spherical shape. The HP-40 Series includes HP-40MF100 and HP-40J2, in which the particle size of the aggregate powder is

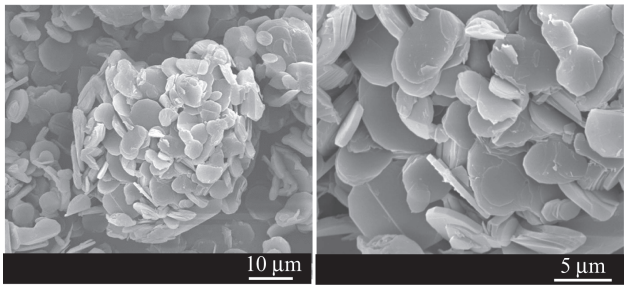
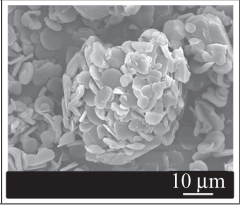
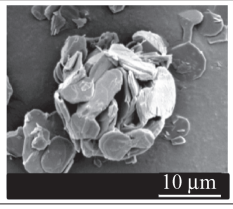
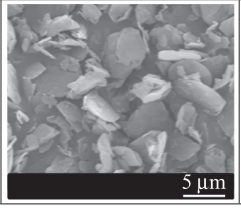
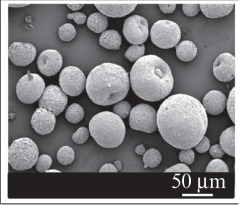


Photo 1 SEM photograph of aggregate BN powder (HP-40MF100)

† Originally published in *JFE GIHO* No. 47 (Feb. 2021), p. 80−81

Table 1 Characteristics of agglomerates boron nitraide powder

Properties			Grade			
			HP-40MF100	HP-40J2	HP-40J11	FS-3
Composition	BN	%	99.9	99.9	99.9	99.9
	T.C	ppm	0.01	0.01	0.01	0.01
Particle size	D10	µm	10	4.5	2	40
	D50	µm	36	16	4	65
	D90	µm	98	35	10	100
Specific surface		m^2/g	1.8	3.2	10	9.5
Bulk density		g/cm^2	0.85	0.85	0.40	—
SEM						

Those are typical values and not spec values.

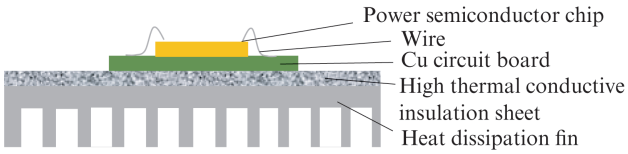


Fig. 1 Typical application of high thermal conductive insulation sheet for power module

adjusted by crushing, classification, etc. after high temperature synthesis, and HP-40J11 having constituent particles pulverized to the size of constituent particles. These products can be used as required by the filler application, such as the thickness of the heat dissipation resin sheet. The particle size can also be adjusted by pulverizing, classification, etc. to meet the requirements of the intended application.

3. Example of Use as Filler for Heat Dissipation Application

High expectations are placed on aggregate BN powders as high thermal conductivity materials with heat dissipation and insulation properties on the same level as ceramic materials for use in the heat dissipating insulation sheets of power modules, as illustrated in **Fig. 1**. High thermal conductivity insulation sheets improve the heat dissipation of power modules, enabling downsizing and higher capacity.

Photo 2 shows a cross-sectional photograph of a prototype sheet (filling rate: 50 vol.%) produced by the Functional Material Research Dept. of the Steel Research Laboratory of JFE Steel by mixing an aggregate BN powder (HP-40MF100) in an epoxy type resin and forming under a high pressure, high temperature atmosphere. While retaining their original morphology,

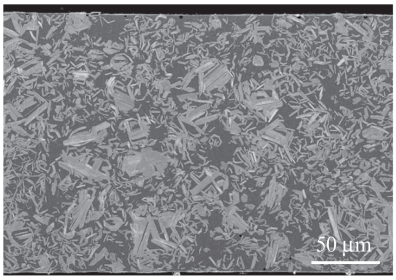


Photo 2 Cross section of thermal conductive insulation resin sheet with aggregate BN powder (HP-40MF100)

the constituent particles of the aggregate BN powder in the resin sheet have not oriented in the in-plane direction, and the resin has also filled the interior of the aggregated particles, resulting in forming without generation of voids. The produced sheet (filling rate: 50 vol.%) has thermal conductivity of 10 W/m-K or higher and a withstand voltage of 10 kV or higher.

4. Conclusion

The series of aggregate BN powders developed by Mizushima Ferroalloy are used as fillers in high thermal conductivity insulation resin sheets of automotive and industrial power modules. With larger capacity and higher voltage power modules predicted in the future, these new aggregate BN powders are expected to be useful as products that meet customer needs.

References

1) Funahashi, T.; Koitabashi, T.; Uchimura, R.; Koshida, T.; Yoshida, A.; Ogasawara, T. Development and Application of High-Purity Hexagonal Boron Nitride (h-BN) Powder. Kawasaki Steel Technical Report. 1993, no. 28, p. 17–25.

2) Fundamentals and application of boron, borides and related materials. 16th International Symposium on Boron, Borides and Related Materials. CMCpublishing, 2008, 366p.

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