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THERMAL CONDUCTIVITY PERFORMANCE OF SILICON RUBBER ENHANCED BY ALUMINUM NITRIDE POWDERS

J. CHEN[a], H. ZHANG[b]

[a]*Faculty of Materials, Xi'an University of Science and Technology, xi'an, 710054,China*

[b]*Faculty of Materials, Guangdong University of technology, Guangzhou,510006, China*

A new insulating thermal conductive rubber was prepared using aluminum nitride nano-powder as filler and silicon rubber as matrix. The effects of filler content and particle size on the thermal conductivity dielectric constant thermal stability were analysized, and the morphology and dispersion propriety of the filler were investigated by Scanning electron microscopy. The results show that The larger particles give rise to a higher thermal conductivity of composites, at the same time the thermal conductivity of the composites increase with increase of aluminum nitride filler fraction. When the particle size is 60 nm, the thermal conductivity of composites at 40% volume fraction is about 3.5times that of pure silicon rubber matrix. The dielectric constant increase with the increase of filler volume fraction, and the volume resistivity decrease with the increase of filler volume fraction.

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1. Introduction

Recent advancement in electronics technology has resulted in the miniaturization of transistors, allowing more transistors to be crammed and integrated into a single device[1],. Therefore it is essentially crucial to use high thermal conductivity materials in order to dissipate heat generated in devices. These materials also need low dielectric constant for fast propagation and low coefficient of thermal expansion for resistance to thermal fatigue[2]. Various materials have been developed for electronic packaging applications, These materials can be in the form of thermal greases[3], gels thermal epoxies even thermally conductive rubbers. All these materials are polymer base materials and filled with high thermal conductive fillers such as aluminum nitride, born nitride, alumina and silicon carbide reinforced polymer materials have been used extensively as electronic packaging materials[4].

heat dissipation is very important for the performance，reliable and further miniaturization of transistors[5]. Therefore it is essentially crucial to use high thermal conductivity materials in order to dissipate heat generated in devices[6]. These materials also need low dielectric constant for fast propagation and low coefficient of thermal expansion for resistance to thermal fatigue[7]. Various materials have been developed for electronic packaging applications, These materials can be in the form of thermal greases[8] , gels thermal epoxies even thermally conductive rubbers. All these materials are polymer base materials and filled with high thermal conductive fillers such as aluminum nitride, born nitride, alumina and silicon carbide reinforced polymer materials have been used extensively as electronic packaging materials[9].

Zhu[10] use Al_2O_3, CuO, TiO_2 and Fe_3O_4 as filler prepared nanofluids. They found that the Fe_3O_4 nanofluid with the highest thermal conductivity, 4% volume of fractions exhibit 38% enhancement.

In this study. Elastomeric silicon rubber were produce by adding aluminum nitride nano-powders. It is well known that the aluminum nitride is fracture resistant and chemically nonreactive materials with low coefficient of thermal expansion, which make this material a clear candidate for the integration chip with silicon-based electronics.

2. Experimental

2.1 Materials

AlN particles of diameter less than 500nm manufacture at Sinocera company (he bei province, China) were used as the filler. Commercial silicon rubber supplied by Dow Chemical Pacific was used as the matrix material.

2.2 Preparation

The mixtures of aluminum nitride particles and xylene were blended by ultrasonication wand. After 30 min add silicon rubber into mixture liquid continue stir dissolved with ultrasonic. The solvent xylene was removed in a vacuum oven at 60 ^{o}C. Then the as made material was load in a custom-made stainless mold to vulcanization, the vulcanization conduction is 160 ^{o}C，pressure 10MPa. After 1h heat the sample was made.

Measurement

Phase and crystal structure analysis of the sample is measured by XRD ,Japan's RIGAKU X-ray diffraction (Cu Ka radiation), scanning range :10-80^{o}, scan speed 8^{o} • min^{-1}. Thermal conductivity of the composite was measured using a Natzsch thermal measurement system(LFA-427,German), and was calculated from thermal diffusivity equation :

$$K=\alpha\rho C_p \tag{1}$$

where K is the thermal conductivity, α is the diffusivity of the sample, ρ is the density, C_p is the specific heat capacity under constant pressure.

3. Results and discussion

3.1 microstructure of compsites

The shape and grain size of AlN powder were showed in Fig.1 . It can be seen that the powder is diamond-like, flakes and other irregular shapes, with the diameter less than 10μm. Fig2 is the SEM image of cross-section of origin silicon rubber ,we can see that there are many dimples in the cross-section, due to viscoelastic, the cross-section of the rubber is not smooth . Fig.3 shows the typical microstructure of the AlN-composites. The AlN particles are essentially surrounded by rubber in the sample contain 50 phr fillers, with the increase of fillers, some connectivity between adjacent filler particles formed in small region.

It is clearly that the AlN powders are surrounded by silicon rubber. The particles dose not interconnected. The thermal conductivity of AlN is about 180 W/m K, which is much greater than that of silicon rubber 0.20 W/m K, When the samples are heated, just as current flows where the resistance is low, so heat will tend to flow through the AlN particles. Then thermal conductive channels can be formed in the composites.(illustrated in the graph Fig.3)

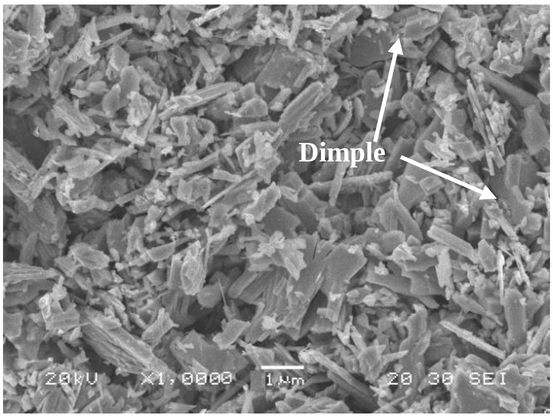

Fig.1 SEM image of the AlN fillers

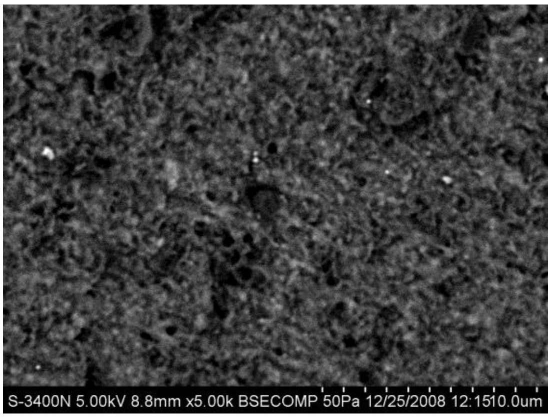

Fig.2 SEM image of the silicon rubber AlN composites

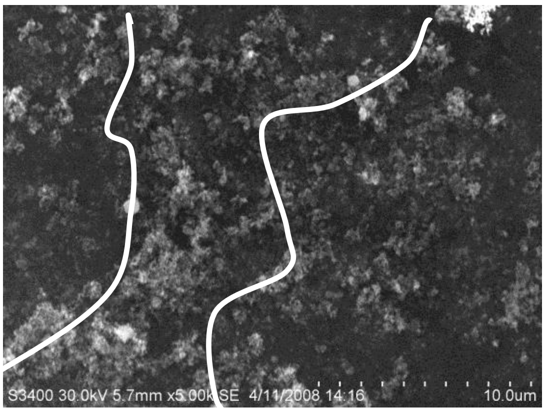

Fig. 3 thermal conductive channel of composite

3.2 The relationship between thermal conductivity of composites and AlN filler fractions of composites and AlN filler size

The relationship between the thermal conductivity of the composite at room temperature and average particle sizes of AlN fillers is shown in Fig.4. where the upper curve(a) is the sample contain 30phr AlN fillers and the lower(b) is the one contain 8phr AlN. From the chart we can see that with the increasing of AlN particles size the thermal conductivity increased. The increase of in the thermal conductivity of composite with increasing fillers particle size could be due to large filler has a small thermal interface resistance.

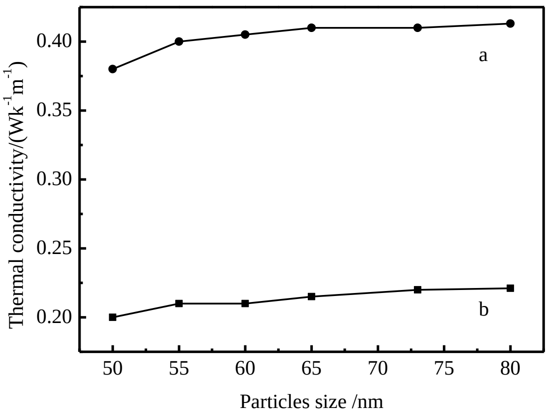

Fig.4 relationship between the thermal conductivity of composites and the size of the filler

The AlN fillers size has a close relationship to the thermal conductivity of the composites. When AlN particles are dispersed into silicon rubber matrix different size of will result in a different dispersion.

3.3 The relationship between thermal conductivity and dispersion fraction.

The relationship between the thermal conductivity of the composite at room temperature and the fraction of AlN fillers is shown in Fig.5 where the upper curve is the sample contain mean diameter of 80nm fillers and the lower is the one contain mean diameter of 50nm one.

In the process of heat transfer, the heat will transformed from one side to another side, when the fillers content is low rubber matrix will form thermal resistance, it called thermal interface resistance. Small particle size has large surface area, that means large thermal interface resistance. When the content of AlN filler increases, the thermal interface resistance decreased. Obviously, the use of the AlN filler fraction may be an effective way to increase the thermal conductivity of composites.

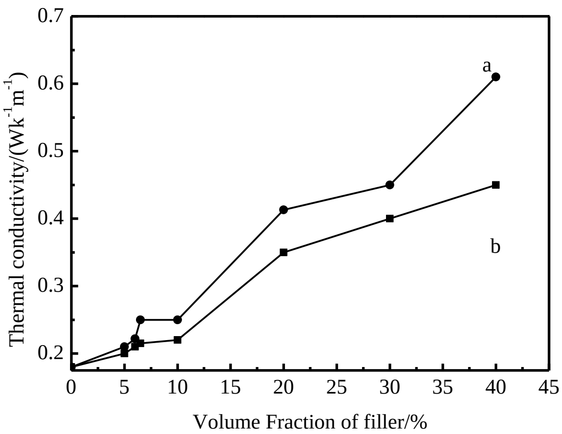

Fig.5 Thermal conductivity of the composites in different filler fraction

3. 4 The relationship between dielectric constant ,volume resistivity and volume fraction of filler

As is shown in the Fig. 6, dielectric constant increased with the increase of filler volume fraction in the composite, while the volume resistivity decrease. The sample contains 40fr filler dielectric constant increase to 7.8 from initial 4. At the same time, the volume resistivity decrease from $4.8\times10^{13}\Omega\cdot$cm decrease to $1.1\times10^{12}\Omega\cdot$cm. We inferred that the dielectric constant of filler is larger than that of matrix, so with the increase of filler the dielectric constant. This theory also applies volume resistivity.

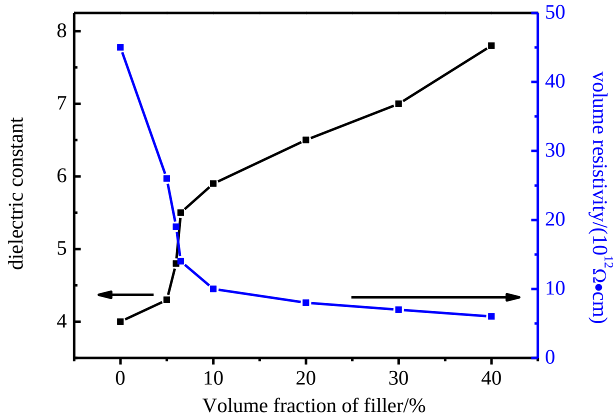

Fig. 6 dielectric constant and volume resistivity of composites

4. Conclusions

We investigated the thermal conductivity of AlN-silicon rubber composites. Both particles size and filler fraction have significant effect on the thermal conductivity of the silicon rubber matrix. The larger particles give rise to a higher thermal conductivity of composites, at the same time the thermal conductivity of the composites increase with increase of aluminum nitride filler fraction. When the particle size is 80 nm, the thermal conductivity of composites at 40% volume fraction is about 3.5times that of pure silicon rubber matrix. The dielectric constant increase with the increase of filler volume fraction, and the volume resistivity decrease with the increase of filler volume fraction.

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References

[1] H.rish.ikesh panchawagh. Aplication of MEMS Technology for Cooling of Electronic Components [R]. Report. 18 April ,2000.
[2] J.P. Gwinn, R.L. Webb, Microelectronics Journal **34**, 215 (2003).
[3] M Grujicic, C L Zhao, E C. Dusel, Appl Surf Sci, , **246**, 290 (2005).
[4] E G Wolff, D A. Schneider Int J Heat Mass Transfer **41**(22), 3469 (1998).
[5] M Grujicic, CL Zhao, EC Dusel, Appl Surf Sci, **246**, 290 (2005).
[6] J Westwater, DP Gosain, S Tomiya, et al. J Vac Sci Technol B; **15**(3), 554 (1997).
[7] Reguer A, Bedu F, Dallaporta H, et al. ition. J Vac Sci Technol B **26**(1), 175 (2008).
[8] Haitao Zhu, Canying Zhang, Shiquan Liu Yaming Tang Yansheng Yin . App Phy Let

89, 023 (2006).
[9] L.C. Sima, S.R. Ramanana, H. Ismaila, K.N. Seetharamub, T.J. Gohc Thermochimica Acta **430,** 155 (2005).
[10] M A Zhu, D. Srivastava, nanotechnology, **12**(1), 21 (2001).