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# Polymer Composites with Enhanced Mechanical and Thermal Properties by Orientating Boron Nitride Flakes

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# Polymer Composites with Enhanced Mechanical and Thermal Properties by Orientating Boron Nitride Flakes

Xiao Zhang<sup>1,\*</sup>, Jian Zheng<sup>1,a</sup>

Shijiazhuang Campus, Army Engineering University, Shijiazhuang, 050003, China

\*Corresponding author e-mail: zxleo@foxmail.com, <sup>a</sup>zhengj2020@163.com

**Abstract.** In this study, a BN/PVDF composite was prepared by hot press method. The dispersion of BN is uniform, dense and oriented in PVDF. The thermal conductivity and tensile performance of the composite are largely enhanced by the strategy. The thermal conductivity is tuned to 0.57 W/(mK), enhanced by 307 % compared with pure PVDF.

## 1. Introduction

Heat management has become more and more important for the utilization of electrical devices [1]. In some condition, low effective heat removal can cause the damage of electrical devices, even the destruction of the whole system. Therefore, to make sure the successful application of devices, the unwanted heat has to be removed [2, 3]. It has been demonstrated that composites embedded with high thermal conductive fillers are the useful strategy for heat removal [4, 5]. Currently, the common thermal conductive fillers include metal particles of Ag or Cu, carbon nanotubes, graphene and boron nitride [6-9]. As we know, thermal conductivity is the key parameter to evaluate the heat transfer ability, which should be enhanced to apply in the high power devices. On the other hand, the high thermal conductivity depends on the connected pathway in the composites that used in electrical devices, for example the thermal interface materials. Because of this, constructing the connected pathway for the rapid transfer of heat, is the effective approach to increase the value of thermal conductivity.

Among the thermal conductive fillers, two dimensional materials, such as graphene nanosheets boron nitride flakes, and graphite flakes have attracted a plenty of attentions because of their high specific area, low density and superb thermal conductivity. Compared with other two dimensional fillers, boron nitride has a great advantage of insulation. Therefore, regarding boron nitride as the composite filler results insulated composite for electrical devices, which is significantly important for electronic packing. In addition, a lot of studies have been conducted to obtain the effective heat transfer pathway of boron nitride, for example three dimensional (3D) network [10]. However, it has a complex process and not suitable for the industrial production. Hot press [11] is a common method to fabricate uniform composites with dense and oriented inner structure, which can be consider as the way for fabricating boron nitride/polymer composite with oriented boron nitride distribution, by which the enhanced thermal conductivity can be expected.

Herein, we tried to fabricate a boron nitride/polymer composite with oriented boron nitride dispersion, which is obtained through hot press process. The thermal conductivity of composite is tested, which is demonstrated to be remarkably enhanced by filling boron nitride. The mechanical



properties are also measured at the same time, and we can see that the composite has been clearly reinforced compared with pure matrix.

## 2. Experimental Section

### 2.1. Materials

Boron nitride (BN) is provided by J&K Chemical Ltd. Shanghai China. Poly(vinylidene fluoride) (PVDF) is purchased from Shanghai Dongfu Chemical Technology Co., Ltd. Ethyl acetate is obtained from Xilong Scientific Co., Ltd., Shantou, China.

### 2.2. Fabrication of BN/PVDF composites

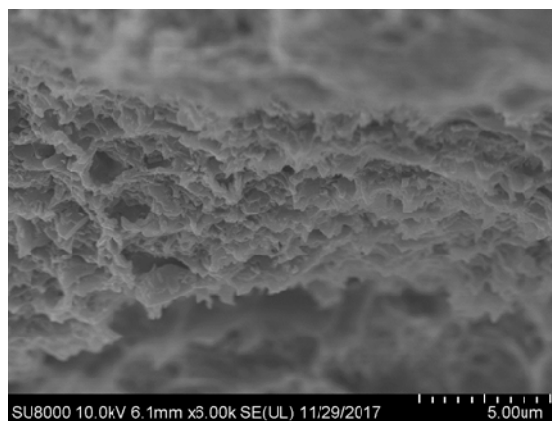
BN flakes are first mixed with ethyl acetate, and then the mixture is put in stirring machine for speedy stirring, followed by strong ultrasonication for about 1 hour. After that, the PVDF polymer is added into the mixture, and the mass ratio of PVDF and ethyl acetate is 1:10. Then we stir the mixture for about 15 min, and after this, it is put into oven to remove the ethyl acetate at 80 °C. Then the achieved composite is cut into the same shape and stacked together. The composite is hot pressed under 120 °C for 2 hours. Finally, the PVDF composite with oriented BN is obtained.

### 2.3. Characterization

Morphology and structure of the composites were observed by scanning electron microscope (SEM, SU-8010, and Hitachi). Tensile properties were obtained on tension machine (Instron 5980) under the loading rate of 10 mm/min. Thermal conductivity can be calculated by the formula as follows:  $\lambda = \alpha \rho C_p$ , where  $\lambda$ ,  $\alpha$ ,  $\rho$ , and  $C_p$  refers to thermal conductivity, thermal diffusivity coefficient, materials density, and specific heat capacity of materials, respectively. Among them, the thermal diffusivity coefficient was obtained on a laser flash diffusivity instrument (DXF-500, TA Instruments). The density of composite was measured by an automatic density analyzer (PEAB, XS105DU, and METTLER TOLEDO, Switzerland). The specific heat capacity test was performed in a differential scanning calorimetry instrument (DSC Q20, TA Instrument).

## 3. Results and discussion

### 3.1. Morphologic and structure characterization of the composite



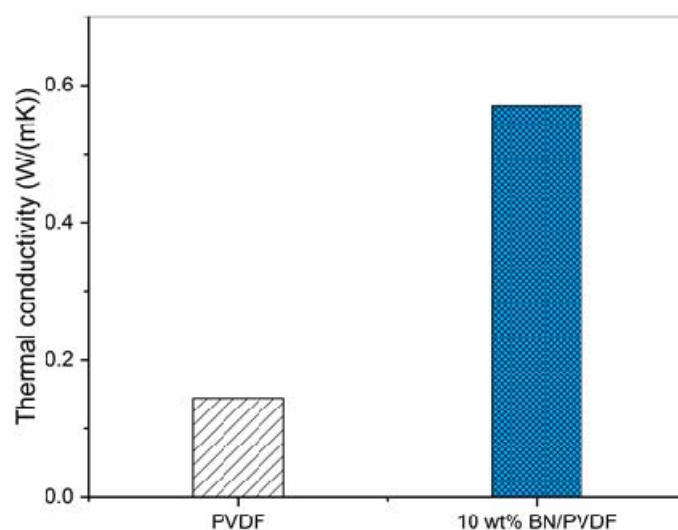
**Fig. 1.** SEM image of CNTs/PVDF composite

Fig. 1 presents the structure of BN/PVDF composite. We can see that the BN flakes are uniform distributed in PVDF polymer. Although the nanoscale BN flakes usually aggregate in the polymer matrix, the phenomenon cannot be found in this composite. The structure obviously demonstrates that

hot press can decrease the aggregation of BN and causes the homogenous dispersion. Besides, it can be seen that the BN flakes are press together and contact each other, which is very helpful for enhance the efficiency of heat transfer. In addition, most of the BN flakes disperse along the direction vertical to the direction of hot press loading. As we all know, the oriented direction can enhance the efficiency of heat transfer. Therefore, we can expect that the thermal conductivity can be obviously increased by this method. Moreover, this dense and oriented distribution of BN can also attributed to the reinforcement of mechanical properties, such as Young's modulus and tensile strength.

### 3.2. Thermal conductivity of composite

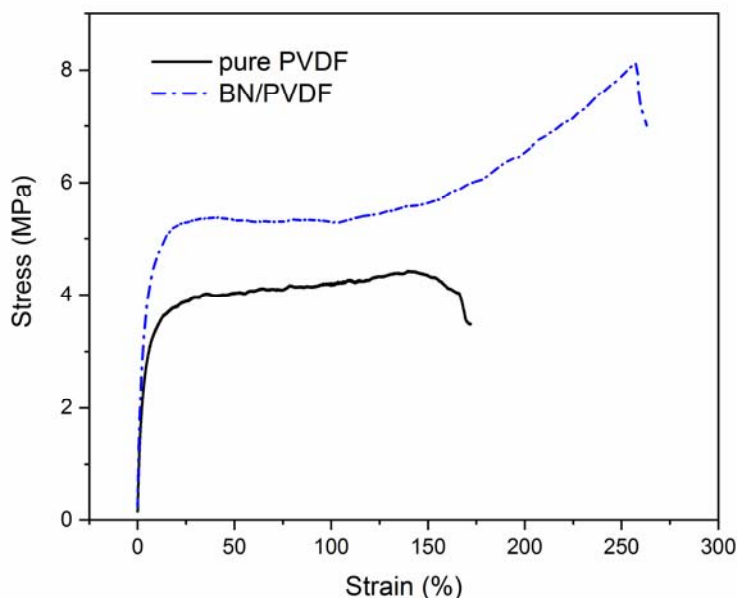
Fig. 2 shows the thermal conductivity results of pure PVDF and BN/PVDF composite. We can see that BN/PVDF composite has the much higher thermal conductivity value than that of pure PVDF, which can indicate the effects of BN flakes. The thermal conductivity of BN/PVDF composite reaches to 0.57 W/(mK) which is enhanced from the value of 0.14 W/(mK) of pure PVDF. The thermal conductivity enhancement is 307%. It can be attributed to the high thermal conductivity of BN flakes and the dense structure of fillers in the composite. Meanwhile, the composite possesses a low filler content of 10 wt%. Therefore, the contacted BN flakes already construct the effective heat transfer pathway. In addition, the oriented pathway further enhances the speedy of heat transfer, which can further increase the thermal conductivity. Thus the hot press method can regard as a useful approach for increasing the thermal conductivity of composites.



**Fig. 2.** Thermal conductivity of pure PVDF and BN/PVDF composite

### 3.3. Mechanical properties of composite

Tensile properties of pure PVDF and BN/PVDF composite are shown in Figure 3. From the tensile stress-strain curves, we can see that the mechanical properties of BN/PVDF composite is obviously enhanced compared with pure PVDF. Not only the Young's modulus, but also the tensile strength is increased significantly. Therefore, the oriented dispersion of BN flakes in PVDF matrix, which is obtained by hot press, is demonstrated to be very useful for reinforcing the polymer matrix, for example PVDF.



**Fig. 3.** Tensile stress-strain curves of pure PVDF and BN/PVDF composite

#### 4. Conclusion

In this study, the BN/PVDF composite was successfully fabricated through hot press strategy. The dispersion of BN flakes in composite exhibits oriented and dense structure, which can be attributed to the enhancement of thermal conductivity and mechanical properties. The thermal conductivity of composite is tuned to 0.57 W/(mK), enhanced by 307 % compared with pure PVDF. Meanwhile, the tensile properties are also largely increased.

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