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A PC Chemical Material Made of Modified Monolayer Boron Nitride and Its Performance Analysis

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This paper sheds new light on the effects of single-layer Boron Nitride (SBN) for vehicle interiors and exteriors on the mechanical and friction properties of polycarbonate (PC). First, the SBN is prepared by modifying the Hexagonal Boron Nitride (HBN) with the silane coupling agent KH550. PC, PC-g-MAH and SBN are evenly mixed by a high speed mixer. Next, an injection molding machine is used to prepare the PC/SBN composite material for vehicle interiors and exteriors by the melt blending mode. The findings suggest that SBN has a toughening and strengthening effect on PC when it is less than 1.6wt%, and the surface hardness and wear resistance of PC/SBN are also improved; when the boron nitride filling volume is higher than 1.6wt%, the mechanical strength and friction properties of PC/SB weaken instead. When the filling volume of SBN is 1.6wt%, the tensile and impact strengths of PC/SBN reach the peaks, i.e. 35.28MPa and 34.76kJ/m2, respectively, and 10.8%, 18.88% as high as that of pure PC; at this time, the friction factor and wear rate of PC/SBN are 14.3% and 32.3%, respectively, lower than that of pure PC.

1. Introduction

Along with the development of modern technology, the polymer materials have found wider and wider application, but the people also set a higher request to the properties of polymer materials in the application. Polycarbonate Cool (PC), as an excellent thermoplastic with mechanics properties, heat resistance and dimensional stability, has often been used as vehicle interior and exterior materials. But unfortunately, the PC has high melt viscosity, requires a high processing temperature, cumbersome forming process and is very sensitive to notches, so that itis often used with other micro nanoparticles, polymers, to improve their machining properties and getting rid of its notch sensitivity (Peng et al., 2005; Bledzki et al., 2012). Furthermore, PCs, if used for vehicle part and component package, interiors and exteriors, plastic gears and other special application domains, are required to have a certain abrasion resistance (Lu et al., 2011; Asuke et al., 2014; Lu and Wang, 2016). It is therefore of great significance to explore the PC friction properties.
As a non-oxide material, boron nitride is an isoelectronic body, for example, carbon (C_2). It has graphite-like crystal structure, and diamond-like hardness, as well as thermal stability and chemical stability. Thanks to its excellent properties such as high thermal conductivity coefficient, oxidation resistance, self-lubricating, corrosion resistance and high thermal shock resistance, etc., it has been widely used as high specific strength composites, high performance aerospace friction material, special optoelectronic material and semiconductor material, etc. It has so far been recognized as one of composite with the vast market potential (Zhou et al., 2011; Gao et al., 2013; Gao, 2012).
This paper discusses how to prepare the PC/SBN composites for vehicle interiors and exteriors by the melt blending mode, and expounds what the wear mechanism and mechanical properties of PC composites under SBN filling conditions seem. Providing the clues to the future application of PC composites in vehicle interiors and exteriors.

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2. Test

2.1 Raw materials

PC: R20, Formosa Chemicals & Fiber Corporation;
Boron nitride: average particle size < 5mm, Weifang Bond Special Materials Co., Ltd.;
Maleic anhydride grafted PC: WJ-5D98, Dongguan Zhangmutou Jinyunlai Plastic Materials Company;
Coupling agent: KH550, Grade BR, Guangzhou Chaoshun Chemical Co., Ltd.;
Absolute ethanol: Analytical grade, Tianjin Chemical Materials Co., Ltd.;
Vegetable oil: castor oil;

2.2 Major equipment and instruments

Injection molding machine: MA900, Haitian Plastic Machine Group Co., Ltd.;
Vacuum drying oven: DHG-9053A, Shanghai Hecheng Instrument Manufacturing Co., Ltd.;
Electronic universal sample machine: WDW-200, Jinan Xinshi Jin Test Machine Co., Ltd.;
Mixer: SHR10A, Zhangjiagang Yi Plastic Machinery Co., Ltd.;
Friction testing machine: QG-700, Lanzhou Zhongke Kaihua Technology Development Co., Ltd.;
Hardness tester: HR2150A type;
Electron diffraction microscope: JEOL-2010, Japan;
Transmission electron microscopy: JEM-2200FS, Japan;
Impact testing machine: ZBC7000, MTS Industrial Systems (China) Co., Ltd.;

2.3 Sample preparation

Add 300g ethanol solution to a 500ml flask and dropwise add 3g silane coupling agent KH550 for a water bath at 50 °C, stir it for 20min, add 100g HBN powder, continue to stir it for 2h; then, make a strong ultrasonic dispersion for 30min, and centrifuge it at 7000r / min, separate it for 15min; Finally, the suspension liquid is collected and frozen for dryness to obtain a solid white powder as modified HBN (Coleman et al., 2011; Pan et al., 2014).
The PC/SBN composite is prepared by a melt process. Let the materials in Table 1 dry off in a vacuum oven for 4-5 hat 85 °C, weigh the materials by the ratio of Table 1 and add them to a high-speed mixer, dropwise add 1-2 drops of vegetable oil, stir it for 20 min, and then uniformly mixture is poured into the injection molding machine (at the temperature zone 1 190 °C, zone 2 210 °C, zone 3 230 °C, nozzle 230 °C), after melting at a high temperature, it is molded into a standard test strip for the relevant performance test.

Table 1: Components of the PC/SBN composite materials

Number	PC	PP-g-MAH	SBN	Mass fraction of SBN
1	100	15	0	0%
2	100	15	0.58	0.5%
3	100	15	1.4	1.2%
4	100	15	1.87	1.6%
5	100	15	2.35	2%
6	100	15	2.95	2.5%
7	100	15	3.56	3%

2.4 Sample test

Impact strength: in accordance with the GB/T 1843-2008, from each set of samples, 80mm × 10mm × 4mm (L×W×H), to be tested, 5 samples (no notch) are randomly chosen for the test to average the values;
Tensile strength: in accordance with the standard GB/T 1040.1-2006, the sample is dumbbell type, the tensile rate is 2mm/min, and 5 samples per test is averaged;
Rockwell hardness: in accordance with the GB/T9342-1988, the indenter steel ball D is 12mm, the loading time is 20s, and the pressure is 588N;
Friction property: The friction and wear properties of the composite are measured on a QG-700 friction tester. The mate part is a GCr15 stainless steel ring with an outer diameter of 40 mm. The spline size is 30 mm × 6 mm × 7 mm. Test conditions: room temperature, dry-type friction, 200N load, 30min, the sliding speed of the friction pair is 0.4m/s; before the test, the sample is polished by 600 mesh water sandpaper, and the mean roughness *Ra* of the sample surface is 0.1-0.18μm. The test result is the average of the 5 tests.

3. Results and discussion

3.1 SBN characterization

As shown in Figure 1 and 2, the TEM and ED of the modified HBN are given, respectively. it is obvious that the graphite-like structure HBN is stripped into a nearly transparent mono flake, so that it can be said that the modified white powder is similar to SBN; in the figure, the sample appears as a single crystal in a selected area, which basically coincides with the structure of the SBN.

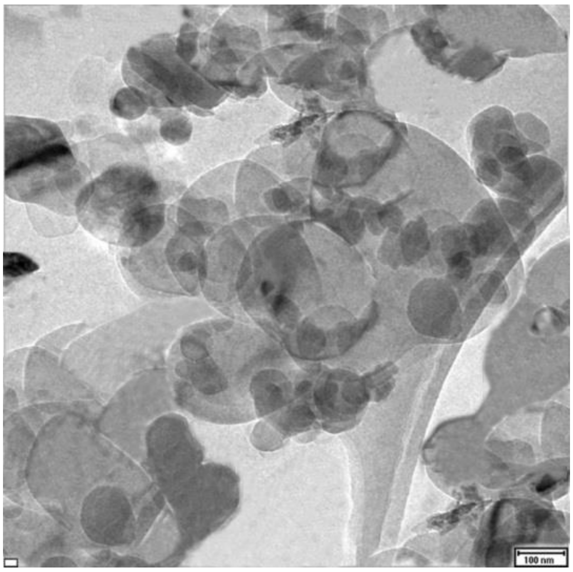

Figure 1: The TEM image of SBN

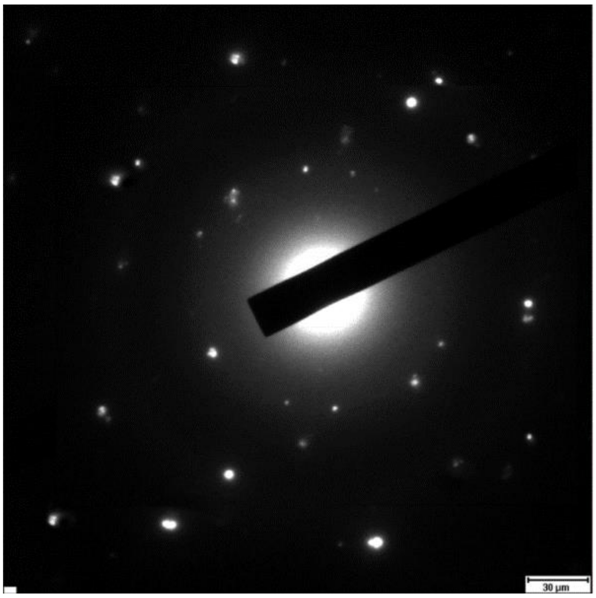

Figure 2: The ED diagrams for SBN

3.2 Mechanical properties of PC/SBN composites for vehicle interiors and exteriors

As shown in Figure 3, the mass fraction of SBN has different effects on the impact and tensile strengths of PC/SBN composites for vehicle interiors and exteriors. It can be seen that SBN has a certain enhancement effect on the tensile and impact strengths of PC. When the mass fraction of SBN is 1.6%, the tensile strength of the composite reaches a maximum of 35.28 MPa, 10.8% higher than that of pure PC. As the mass fraction of SBN continues to increase, the tensile strength of PC/SBN composites shows a downward trend; when it increases to 1.6%, the impact strength of the composite builds up to the maximum 34.76kJ/m2, 18.88% higher than that of pure PC. Then, with the continuous addition of SBN, the impact strength of PC/SBN composites also shows a downward trend; in the figure, it can be seen that, as the dose of SBN increases, the tensile and impact strengths of PC/SBN composites all show first increase and then decrease, and the peaks appear at critical positions. The main reason for this phenomenon may be such that boron nitride fully exerts its physical properties, absorbs and transfer the stress, consumes and delivers the energy when the dose of SBN is low. Furthermore, the SBN lamella layer exhibits “pinning” and hindrance to the PC macromolecular chain, and prevents the crack produced by stress from development, thus increasing the tensile strength and toughness of composite (Zhang et al., 2012; Gao et al., 2014); when the filling volume of SBN is large, on the one hand, high content of boron nitride may agglomerate in the PC substrate, forming defects between interfaces, and on the other hand, mutual slip between the lamella layers of boron nitride of high content causes a decrease in tensile and impact strengths of the PC/SBN composite.

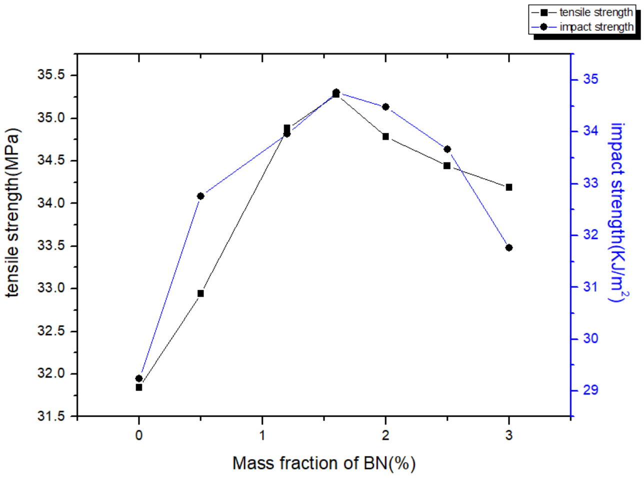

Figure 3: Influence curve of Single-layer boron nitride mass fraction on impact strength and tensile strength of composite materials

3.3 Friction property of PC/SBN composites for vehicle interiors and exteriors

As shown in Figure 4, it is a curve of the wear rate and friction coefficient of PC/SBN composites as a function of the dose of SBN. As the dosage of SBN progressively increases, the wear rate of PC/SBN composites generally shows a phenomenon of first decrease and then increase. When the mass fraction of SBN is 1.6%, the wear rate of composites declines to the bottom, that is, 32.3% lower than the pure PC; in addition, as shown in the figure, the overall trend of effect of boron nitride at different mass fractions on the friction coefficient of the composite is similar to that on the wear rate, that is, decreasing first and then increasing. When the mass fraction of SBN is 1.6%, the friction coefficient of the composite reaches a minimum of 0.372, 14.3% lower than that of pure PC. It is mainly rooted in the fact that: when the proper amount of SBN is filled into the PC substrate, on the one hand, SBN has a certain "pinning" effect on the PC macromolecular chain, which reduces the slippage and breakage of the PC macromolecular chain, and the SBN also has a heterogeneous nucleation effect on the PC, which improves the hardness of the composite material and indirectly increases the friction non-deformation resistance of the composite material; on the other hand, during the friction process, the SBN on the friction surface bears the load before the PC substrate, while boron nitride can improve the wear resistance of the composite material to certain extent thanks to its superior physical properties; furthermore, the friction surface temperature of the composite material increases over the time due to the friction environment, and the PC substrate is easy to adhere to the friction surface of the composite material, resulting in fatigue friction, so that its friction coefficient and wear rate are reduced; when the mass fraction of SBN is too high, boron nitride is easily agglomerated in the composite material, which weakens the interfacial bonding strength between boron nitride and PC substrate. During the friction process, part of the boron nitride will be tripped off friction surface of the composite material and forms an abrasive which directly acts on the composite material, thereby leading to an increase in the friction coefficient and the wear rate of the composite material (Yang, 2018).

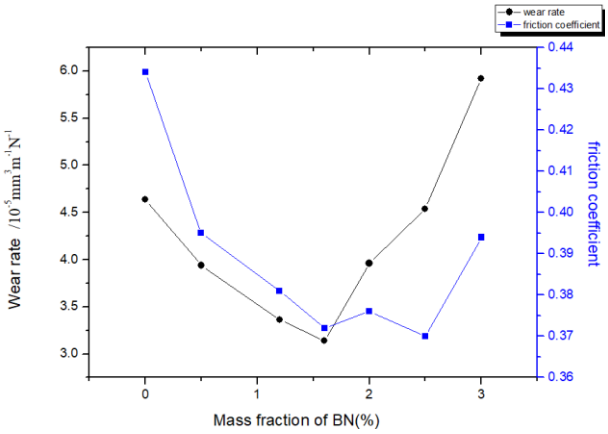

Figure 4: Influence curve of Single-layer boron nitride mass fraction on wear rate and friction coefficient of composite materials

3.4 Hardness of PC/SBN composites for vehicle interiors and exteriors

As shown in Figure 5, it is a curve of the surface hardness of PC/SBN composites as a function of the dosage of SBN. It is obvious that the surface hardness of PC/SBN composites increases first and then decreases as the dosage of SBN multiplies. When the mass fraction of boron nitride is 1.6%, the hardness value reaches the maximum 115HRR, 11.65% higher than that of pure PC. When the mass fraction of boron nitride is more than 1.6%, the surface hardness of the PC/SBN composite material shows a decrease trend. The main reason is such that: on the one hand, the physical properties of SBN itself improve the bearing capacity of the composite; on the other hand, boron nitride has heterogeneous nucleation effect, which improves the crystallization degree of PC; and when the mass fraction of boron nitride gets too more, it tends to agglomerate to reduce the bonding power on the interface with substrate or form crystal defects during crystallization, which thus reduce the surface hardness of the composite (Han et al., 2015; Wei et al., 2018).

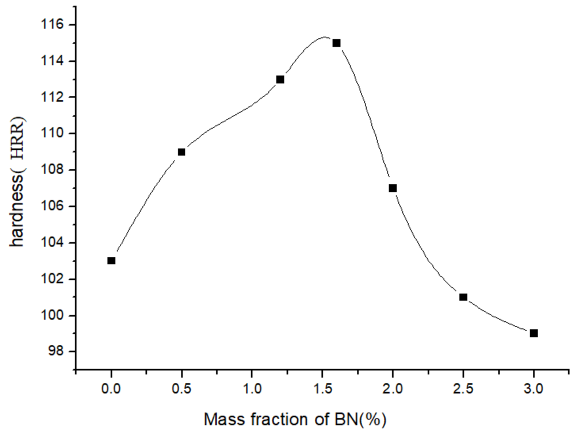

Figure 5: Influence curve of Single-layer boron nitride mass fraction on surface hardness of composite

4. Conclusion

(1) The SBN can improve the mechanical strength of the PC/boron nitride composite. When boron nitride is 1.6%, the impact and tensile strengths of the PC/SBN composite material peak to 34.76KJ/m^2 and 35.28 MPa, respectively. However, when the SBN is more than 1.6%, both of PC/boron nitride show a downward trend;
(2) The SBN can improve the friction property of composite materials. When the mass fraction of SBN is 1.6%, the friction factor and wear rate of PC/SBN material are 14.3% and 32.3% lower than that of pure PC. However, when the mass fraction of SBN exceeds 1.6%, the friction process will cause the SBN to fall off and form abrasive wear, which will increase the wear rate instead, but reduce the wear resistance of the composite.

(3) The surface hardness of PC/SBN composites increases first and then decreases as the dose of SBN gets more. When the mass fraction of boron nitride is 1.6%, the hardness value peaks to 115HRR, and is 11.65% higher than that of pure PC.

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