Preparation and Properties of Graphene Flexible Membrane

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Abstract. Graphene material has excellent electrical, thermal and mechanical properties, and the flexible film prepared by it can be widely used in intelligent wearables, industrial temperature control, biomedicine, home heating and other fields. In this paper, graphene paste was used to prepare textile substrate and non-substrate graphene flexible film, and its tensile strength, elongation at break, resistivity, hardness, modulus and other parameters were tested. The results show that the graphene flexible film has smooth appearance, good electrical conductivity and good mechanical strength, and is a good choice for smart wear and industrial parts gasket applications.

Keywords: graphene; flexible membrane; tensile strength; modulus.

1. Introduction

Graphene is a new material with sp^2 hybrid connected carbon atoms tightly packed into a single two-dimensional honeycomb lattice structure [1-2]. In 2004, physicists successfully separated graphene from graphite by micromechanical stripping[3]. Graphene has excellent optical, electrical and mechanical properties, and has important application prospects in materials science, micro and nano processing, energy, biomedicine and drug delivery, and is considered to be a revolutionary material in the future[4-5]. The common production methods of graphene powder are mechanical stripping, oxidation-reduction method, SiC epitaxial growth, and chemical vapor deposition (CVD) for film production [6-11]. At present, graphene materials mainly include single-layer graphene, multi-layer graphene, graphene oxide, reduced graphene oxide, and graphene quantum dots, in addition, there are also composite materials after graphene modification[12]. Because of its excellent physical and chemical properties, graphene is a good choice for the preparation of composite materials. Graphene flexible membrane is a kind of flexible material prepared by graphene and other materials, which has broad application in industrial temperature control, smart wear, smart home, biomedical and other fields. According to the use scenario and requirements, graphene flexible membrane can be used with or without substrate, the substrate can be selected PET film, PI film, non-woven fabric and textile cloth. Among them, most fields such as smart wear and smart home are based on textile substrates, and graphene slurry is coated on textile cloth to form a flexible graphene membrane, which generally requires better thermal conductivity and better mechanical properties. In the industrial field, the baseless graphene flexible membrane can be used as a flexible gasket for parts, which is widely used because of its good conductive and mechanical properties. No matter which kind of graphene flexible membrane, its use environment has certain requirements for its mechanical properties. In this paper, two kinds of textile graphene flexible membrane and non-substrate graphene flexible membrane were prepared and their properties were tested.

2. Experimental section

2.1 Reagent materials and instruments

Reagent materials: graphene powder, waterborne polyurethane resin, graphene special dispersant, leveling agent, defoamer, film forming agent, etc.

Instruments: high speed mixing and dispersing machine, automatic screen printing machine, microscope, four probe tester, material tester, etc.

2.2 Dispersion of graphene powder

The calculated amount of graphene powder was weighed and slowly added to the dispersion solvent. The container containing graphene was placed in an ultrasonic cleaner for 2h and stirred with a glass rod every half hour. Then weigh the calculated amount of PVP according to PVP: graphene powder mass ratio 5:1, add PVP to the graphene solution, and then ultrasound for 2h, stirring every half hour with a glass rod. Parameters of ultrasonic cleaner: working frequency 40 KHZ, ultrasonic power: 700 W.

2.3 Preparation of flexible graphene membrane for textile substrates

The graphene dispersion, graphite, leveling agent, defoamer and slow drying agent were added to a certain amount of polyurethane resin according to the ratio, and the stirring was started for high-speed dispersion. After the viscosity was stable, the stirring was terminated to obtain the graphene paste. The flexible graphene membrane was prepared by screen printing method. Clean the substrate, cut it according to the established size, fix it on the printing table, select different mesh plates for printing, dry in the oven at 80 ° C for 20 minutes, and then wind up, that is, the graphene flexible film is prepared.

2.4 Preparation of baseless graphene flexible membrane

The graphene dispersion, graphite, leveling agent, defoamer and slow drying agent were added to a certain amount of polyurethane resin according to the ratio, and the stirring was started for high-speed dispersion. After the viscosity was stable, the stirring was terminated to obtain the graphene paste. Using wire drawing process, 200 micron wire drawing rod was selected to prepare the slurry wet membrane. After drying at 80℃ and 20 min in the oven, the graphene flexible film was prepared.

3. Results and analysis

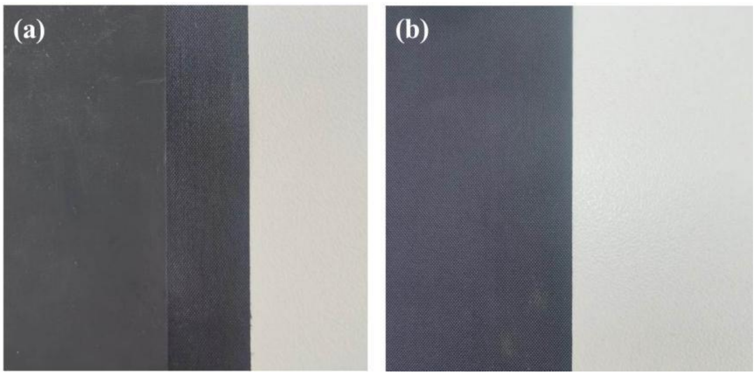

Fig. 1 Flexible graphene membrane for textile substrates

The photo of flexible graphene membrane for textile substrates is shown in Figure 1. In order to clearly see the appearance of the material, we photographed the edge of the flexible membrane against a white background. The surface of the woven fabric in Figure 1 (a) can be seen coated with graphene membrane, and the left side can be seen that the appearance of the film is black, and the black in the middle is the textile cloth. The graphene membrane is well combined with the textile fabric. Figure 1 (b) is the other side of the textile substrate graphene flexible membrane, which is not coated with paste and is the textile cloth itself.

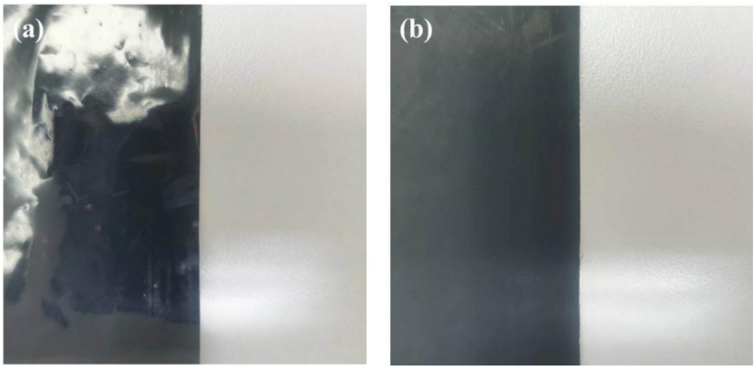

Fig. 2 Non-substrate graphene flexible membrane

Fig. 2 is a baseless graphene flexible membrane with a dense black appearance and a smooth bright surface on one side of the membrane, which is somewhat reflective in the photo. The other surface is matte. The membrane has excellent flexibility and can be bent and twisted at will. The thickness of the film is about 90 μm.

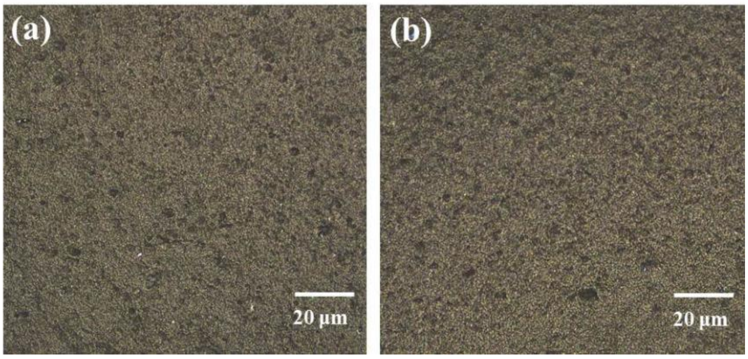

Fig. 3 The magnified image of the surface for flexible graphene membrane

Figure 3 is a surface enlargement of the flexible graphene membrane. Figure 3a is the surface of the textile substrate flexible membrane, and Figure 3b is the surface of the non-substrate flexible membrane. There is basically no difference in the appearance of the two figures, because the two flexible graphene membrane are just different substrates, and the composition of the slurry is the same. There are some pores on the surface as shown in Fig.3, which is due to the solvent is volatilized during the heating process.

Graphene flexible membrane is mainly used in smart wear, smart home and other fields, tensile property is one of the main properties that need to be concerned, which directly determines the reliability and life of the material. Tensile strength usually refers to the ability of a material to resist breaking during static tension or the maximum tension that a material can withstand without breaking. It is measured by taking a section made of the measured material, pulling it to break, and dividing the maximum load by the cross-sectional area of the material to obtain the tensile strength. Therefore, the tensile properties of the flexible membrane are tested in this paper, and the results are shown in Tab.1 and Tab.2.

Table 1. Tensile strength of flexible graphene membrane for textile substrates

item	1	2	3
tension stress(N)	158.19	163.21	163.35
ruptural deformation(mm)	45.141	45.193	48.544
breaking elongation(%)	15.699		
tensile strength(kN/m)	10.772		

Table 2. Tensile strength of non-substrate graphene flexible membrane

item	1	2	3
tension stress(N)	14.93	15.73	15.11
ruptural deformation(mm)	73.199	120.124	82.697
breaking elongation(%)	30.979		
tensile strength(kN/m)	1.017		

It can be seen from Table 1 and Table 2 that the elongation at break of the textile substrate graphene flexible membrane is 15.699% and the tensile strength is 10.772kN/m. The breaking elongation and the tensile strength are 30.979% and 1.017kN/m, respectively. The composition of the two graphene paste is the same, the main reason for the difference in performance is that the performance of the textile substrate graphene flexible membrane is mainly determined by the textile cloth, so if there are high requirements for tensile strength during use, it is necessary to choose the substrate with good tensile strength. The breaking elongation of the non-substrate graphene flexible membrane is better, but the tensile strength is lower. One of its important use scenarios is as an industrial gasket, which has certain requirements for its conductivity and hardness, so its resistivity, hardness and modulus are tested in this paper. The resistivity of non-substrate graphene flexible membrane is about 390 □ . The hardness and modulus results are shown in Fig. 4 and Fig. 5, repectively.

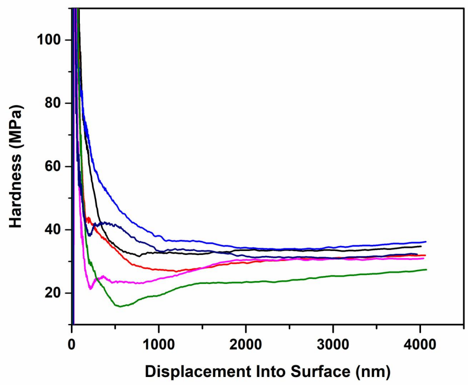

Fig. 4 The hardness of non-substrate graphene flexible membrane

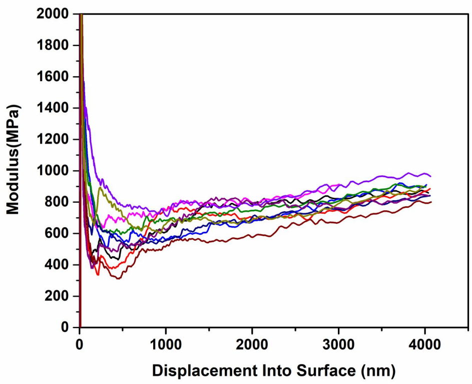

Fig. 5 The modulus of non-substrate graphene flexible membrane

According to the results in Fig.4 and Fig.5, ten times values are obtained for hardness and modulus. Thus, the mean hardness is 27.82 MPa and the mean modulus is 654.84 MPa. Hardness is the ability of a material to resist deformation or damage, and is a comprehensive index of mechanical properties. In general, the higher the hardness of the material, the higher the tensile strength and the better the wear resistance. Modulus is the ratio of stress and strain of a material under stress, which is the ability of the material to resist deformation. The larger the modulus is, the stronger the rigidity of the material and the stronger the bending and torsional resistance. Under the action of external forces, the material will undergo elastic deformation or plastic deformation. The greater the modulus, the stronger the elastic deformation ability of the material under the action of external forces, that is, the material has a strong resistance to stress, and the higher the ultimate strength. In our work, a relatively high modulus 654.84 MPa was obtained, and it’s a good choice for its application.

4. Summary

In this work, we successfully synthesized flexible graphene membrane for textile substrates and non-substrate graphene flexible membrane. The membrane shows dense structure and flexibility. Tensile strength of textile substrates membrane and non-substrate on is 10.772 kN/m and 1.017 kN/m, and the breaking elongation is 15.699% and 30.979%, respectively. The hardness of non-substrate graphene flexible membrane is 27.82 MPa and the modulus is 654.84 MPa. The samples show well properties for industrial application and also the smart wearable field.

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