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COMPOSITE FILMS MADE OF BARIUM FERRITE FIBERS AND POLY (VINYLIDENE FLUORIDE) HAVE INTERESTING MAGNETIC AND DIELECTRIC CHARACTERISTICS

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Abstract

To make composite films, poly(vinylidene fluoride) (PVDF) resin was dissolved in *N,N*-dimethylformamide, and then different amounts of *M*-type barium ferrite fibers (1, 5, 10, 20, 30 wt%) were added. Composite films of BaFe₁₂O₁₉ and polyvinylidene fluoride (PVDF) were analyzed using a combination of scanning electron microscopy and X-ray diffraction. It is shown that 1 μm diameter BaFe₁₂O₁₉ fibers with an aspect ratio (length/diameter) of 50 experience a structural transition from the *α* to the *β* phase when they are immersed in PVDF resin. Magnetization measurements performed on sheets of BaFe₁₂O₁₉/PVDF composite material using a magnetometer that vibrates demonstrate the material's unusual magnetic characteristics. Increasing the BaFe₁₂O₁₉ concentration of the composite films raises the saturation level of magnetization and dielectric loss, but has no effect on the coercion and dielectric constant. Composite films made of BaFe₁₂O₁₉ and polyvinylidene fluoride (PVDF) may display electrical, mechanical, and magnetic characteristics of both phases.

Keywords : Fibers made of barium ferrite. PVDF stands for poly(vinylidene)fluoride. Mixture films. Possessing a magnetism. Dielectric property

Introduction

The extraordinary piezoelectric and piezoelectric characteristics of poly(vinylidene) fluoride (PVDF) and its copolymers have attracted a lot of attention during the last three decades [1-3]. Polyvinylidene fluoride (PVDF) is more varied than the majority of polymeric materials [4, 5] owing to the existence of at least four crystalline phases. The *β*-PVDF phase significantly improves piezoelectric, pyroelectric, and dielectric properties. As a matrix material, PVDF has showed tremendous promise. Magalhes et al. [6] used an isothermal crystallization technique to create

electro active *β*-PVDF membranes. Despite differences in nano clay form and composition, Dillon et al. [7] shown that PVDF-nano mud nanocomposites that may be produced. Crystallization is and melting temperatures of PVDF have been shown to increase once nano clay is included into the molecular structure. There is a wealth of information on PVDF's creation and characterization, however current PVDF compounds don't have the right mix of qualities needed by the IT industry.

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Stable hexagonal magneto plum bite (M-type) structure in barium ferrite ($\text{BaFe}_{12}\text{O}_{19}$) is responsible for the material's high magnetic loss tangent, coercive force and energy, and degree of uniaxial magneto crystallographic anisotropy. The magnetic mechanisms of hysteresis loss, domain wall resonance, and residual loss make barium ferrite a strong candidate for application in millimeter-wave devices such as circulators and isolators [8, 9]. Isolators and circulators serve vital tasks, but they may be difficult to implement in preexisting microwave systems. To get over this problem, you may either employ blocks or make thin or substantial films with identical performance as blocks. Chen et al. [11] employed screen printing to produce thick, durable sheets of barium ferrite. Thick sheet with a eminence ratio of 0.95 and a strong saturation magnetization may be made by hot press sintered barium ferrite at $1,200\text{ }^{\circ}\text{C}$. Barium ferrite is a ceramic, which makes it difficult to create continuous films out of it.

The development of combinations of an inorganic and polymeric substances is crucial if films are to perform a wide range of functions. Nano hybrid of barium titanate (BaTiO_3) and polyvinylidene fluoride (PVDF) were produced by Kobayashi et al. [12] to create thin films with a high dielectric constant. These BaTiO_3 /PVDF composite sheets exhibited a dissipation factor of 0.05 despite their high dielectric value (104 hertz). Unfortunately, $\text{BaFe}_{12}\text{O}_{19}$ /PVDF composite film research is still in its infancy. According to our findings, the dielectric and magnetic characteristics of composite films made of solution-cast $\text{BaFe}_{12}\text{O}_{19}$ and polyvinylidene fluoride (PVDF) are enhanced. SEM (scanning electron microscopy) and X-ray diffraction (XRD) were used to examine the structure and morphogenesis of the composite films. Researchers looked at their dielectric and magnetic qualities. There are likely several sensing uses for these $\text{BaFe}_{12}\text{O}_{19}$ /PVDF composite sheets.

Experimental

Barium ferrite fiber spinning has begun. In our prior work [13], we outlined the steps necessary to turn organic gel precursor into beryllium ferrite fibers and provided examples of each. The primary analytical reagents used were citric acid, sodium citrate, and nitric and fulvic acids. Using magnetic stirring, the citric acid and metal nitrates in the deionized water were brought to the correct stoichiometric ratio. After 20-24 hours of magnetic stirring at room temperature, the solution's excess water had evaporated in a state of vacuum at $60\text{-}70\text{ }^{\circ}\text{C}$. After extracting the gel

fibers, they were dried in a vacuum oven at $80\text{ }^{\circ}\text{C}$ for approximately 24 hours. To create the ferrite fibers, the material was calcined in an alumina crucible devoid of nitrogen for two hours at $900\text{ }^{\circ}\text{C}$. Fibers in calcined barium ferrite have a diameter of about $1\text{ }\mu\text{m}$ and a length-to-diameter ratio that is around 50, as shown in scanning electron micrographs (SEMs) (Figure 1).

Composite films are made by fusing two separate films together; in this case, a $\text{BaFe}_{12}\text{O}_{19}$ film and a polyvinylidene fluoride (PVDF) film. After purchasing the PVDF from Shanghai's East The element fluorine Chemicals Co., Ltd., I never again had to worry about maintaining its pristine condition. DMF (N,N-dimethyl formamide) was used to produce chemical solubility. Following these steps, films of $\text{BaFe}_{12}\text{O}_{19}$ and PVDF were created. The combination of high-quality PVDF powder and DMF heated to $50\text{ }^{\circ}\text{C}$ using a magnetic stir bar.

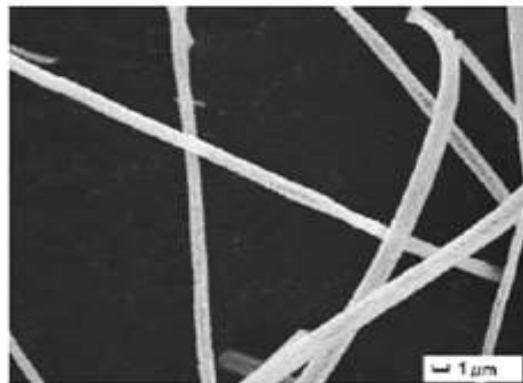


Fig. 1 SEM morphology of barium ferrite fibers calcined at $900\text{ }^{\circ}\text{C}$

Twenty percent by weight of PVDF was applied initially. The first use of ultrasonic energy to this method was the dispersion of barium ferrite fibers in dimethylformamide (DMF). Shaking the mixture for 5 hours helped guarantee that the barium ferrite fibers used to make $\text{BaFe}_{12}\text{O}_{19}$ /PVDF were evenly distributed throughout the PVDF solution. Composite film compositions varied widely, with $\text{BaFe}_{12}\text{O}_{19}$ contributions ranging from 0 to 30 percent by weight. After casting the $\text{BaFe}_{12}\text{O}_{19}$ /PVDF suspension onto a mold, the solvent was evaporated for an hour in a vacuum oven at $70\text{ }^{\circ}\text{C}$. Varying the $\text{BaFe}_{12}\text{O}_{19}$ concentration results in $\text{BaFe}_{12}\text{O}_{19}$ /PVDF film composites with a thickness of 0.5 mm to 0.7 mm .

Characterization

Using CuK radiation with a BrukerD8 Advanced powder diffractometer, XRD patterns of fibers and

composite films were made. Through scanning electron microscopy (SEM) analysis of fibers and composite films, we identified many intriguing morphological features utilizing a Jeol JSM-5600LV. A room-temperature vibration sample magnetometer (VSM) was used to examine the magnetic characteristics of the composite films. Under regulated conditions, the dielectric characteristics of composite films were evaluated at 1 kHz utilizing a Huizhou TH2828 LCR digital meter.

Results and discussion

Validation of X-Ray Diffraction's Usefulness Three different materials, (a) pure BaFe₁₂O₁₉, (b) BaFe₁₂O₁₉/PVDF composite films with 30 wt.% BaFe₁₂O₁₉, and (c) PVDF, are shown in XRD patterns in Figure 2. The X-ray diffraction patterns (Fig. 2a) of fibers made from barium ferrite exhibit the characteristic peaks at $2\theta=30.3, 32.2, 34.1, 37.1, 40, 5,65,$ and 63.0 for M-type BaFe₁₂O₁₉ (JCPDF No.84-0757), confirming the formation of a single M-type ferrite phase.

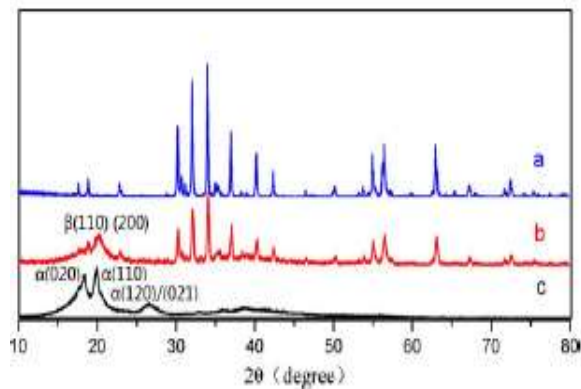


Fig. 2 XRD patterns of BaFe₁₂O₁₉ (a), BaFe₁₂O₁₉/PVDF composite films with 30 wt% of BaFe₁₂O₁₉ (b), and pure PVDF (c)

Two hours of intense heat at 900 degrees Fahrenheit. Figure 2c shows that the three prominent peak at 18.4, 19.9, and 26.6 correspond well to -phase PVDF [7]. Narrow peaks in PVDF indicate a large crystallite size. Figure 2b shows that the barium ferrite fibers, which may contain -PVDF [14], have a high peak at a value of 20.4. The composite film consists of the binary phases for M-type barium ferrite & -PVDF. The distributed barium ferrite fibers have been linked to a peculiar phenomenon: a phase change from - to -PVDF within the PVDF matrix. A similar effect was found by Dillon et al. [7] when studying PVDF/nano clay nanocomposites.

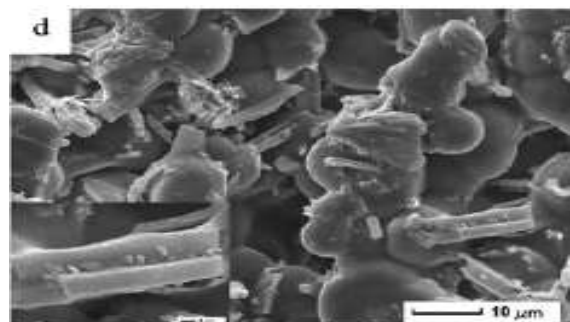
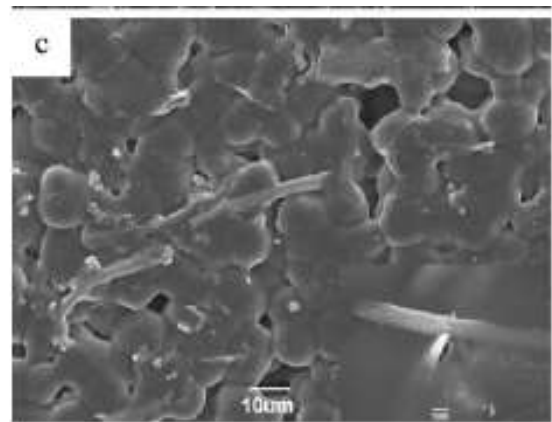
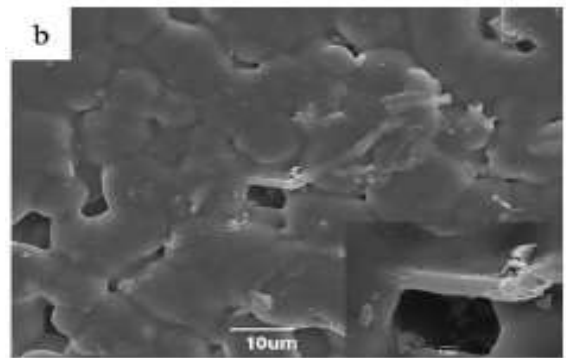
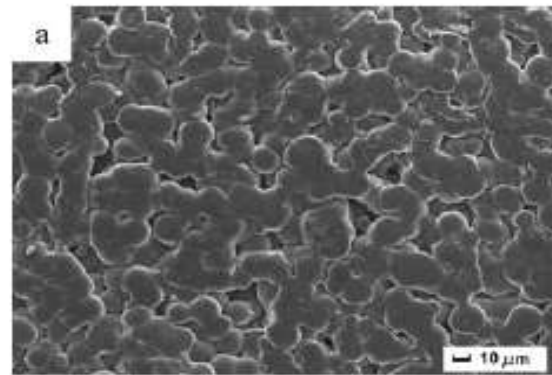


Fig. 3 Scanning Electron Micrographs of Polyvinylidene Fluoride (a) and Barium Ferrite (BaFe₁₂O₁₉)-Containing

Composite Films (b) of Varying Weight Percentages 5 (b); 10 (c); 30 (d)

Composite films of Ba Fe 12 O 19 and PVDF with 0%, 5%, 10%, and 30% barium ferrite are shown by SEM (scanning electron micro in Figure 3. Uncoated PVDF film (Fig. 3a) consists of spheres with spaces between them. When the amount of barium ferrite is decreased to 5 wt.% and 10 wt.%, the amount of film surfaces voids decreases (Fig. 3b, c), demonstrating a high degree of compatibility among the barium fibers with the PVDF matrix. However, if a lot of BaFe12O19 fibres (30 wt.%) are added to the composite film, the surface becomes rougher (Fig. 3d).

Magnetic properties

Figure 4 depicts the hysteresis loops for BaFe12O19/PVDF film composites with varying ferrite concentrations. Composite films made of BaFe12O19 and PVDF are distinguished by their high magnetic quality. Films having 30 wt.% barium ferrite fibres have a saturation magnetic field (Ms) of 13.1 emu g⁻¹, which is a linear rise from 1 to 30 wt.%. Consistent with the findings of Makled et al., the link among the two variables may be explained by the equation $m_s = ms$.

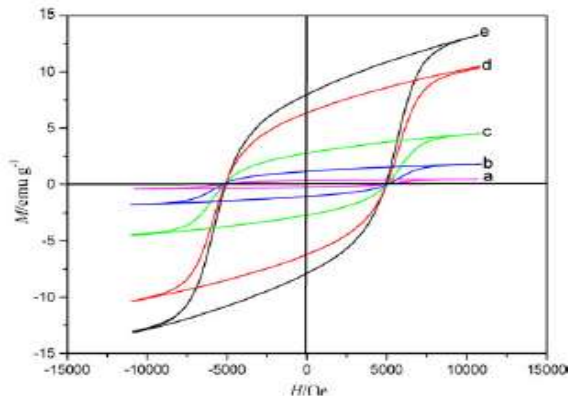


Fig. 4 Hysteresis loops of BaFe 1 kHz 12O19/PVDF composite films with different barium ferrite contents (wt%): a 1; b 5; c 10; d 20; and e 30

Values and percentages for partial saturation of magnetic fields (ms) [16]. In PVDF composite films, the saturation magnetization is significantly affected by the percentage of magnetization of magnetic BaFe12O19 fibers. The magnetic fibers are easy to isolate because the nonmagnetic PVDF disturbs the ferromagnetic order of the ferrite from a parallel structure. The PVDF matrix significantly weakens the magnetic field. The specific saturation magnetization of the composite increases with the addition of additional barium ferrite fibers, although it is still lower than that of pure barium ferrite. Although the coercivity (Hc) of

the composite films increases from around 5,045 to 5,144 Oe (Hc=5,001 Oe for pure BaFe12O19), the magnetization at saturation increases from 0 to 30% barium ferrite fiber content. There are several factors [17] that influence the coercivity of a composite film. These include the film's interfacial structure, composition, particles size and shape, magnetic asymmetry, and magnetostriction. The coercivity of the composite films is greater than that of pure BaFe12O19. The interface structure helps to shield the PVDF fibers from coming into touch with the barium ferrite ones. Similar to how adding not magnetic oxides to ferrites [18, 19] inhibits domain contact and domain misalignment, the not magnetic phase in PVDF increases coercivity.

Dielectric properties

Figure 5 displays the relationship between BaFe12O19 concentration and the dielectric constant as well as the dielectric loss of BaFe12O19/PVDF composite films. having just minute quantities of BaFe12O19

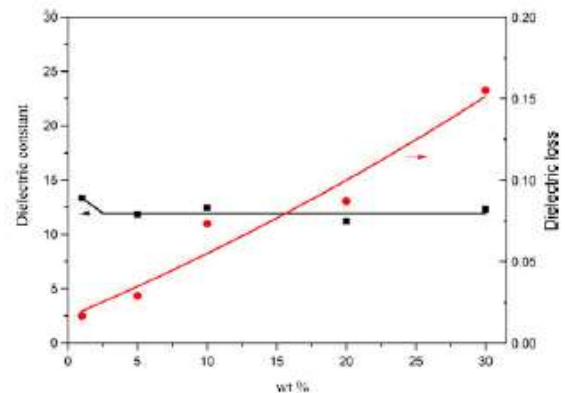


Fig. 5 Effect of barium ferrite content on dielectric constant and dielectric loss of BaFe12O19/PVDF composite films, measured at 1 kHz

Composite film dielectric constants are around 12.8 [20], much higher than pure PVDF's 7.7. It's well acknowledged that -phase PVDF possesses unrivaled dielectric characteristics. The aforementioned XRD analysis demonstrates that the collaboration among barium ferrite fibers for the PVDF phase change is responsible for this advancement. However, increasing the BaFe12O19 content up to 30 wt.% has no effect on the dielectric constant of the composite films, but has a significant impact on the dielectric loss, presumably because of the interaction between the interface and the porosity in BaFe12O19/PVDF composite films [21].

Figure 6 shows the frequency-dependent ($\log f$) variations in both the dielectric constant and the dielectric loss of BaFe₁₂O₁₉/PVDF composite film containing 10 wt.% barium ferrite fibers, from 50 Hz to 1 MHz. It has been shown that composite films with dielectric constant may be reduced by interface polarization [22]. On the other hand, the dielectric loss obviously rises from 50 kHz to 1 MHz, then progressively decreases to a minimum at about 10 kHz.

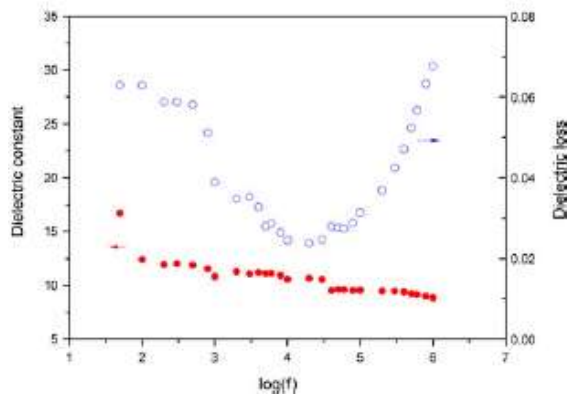


Fig. 6 Frequency dependence of dielectric constant and dielectric loss of BaFe₁₂O₁₉/PVDF composite films (10 wt% of BaFe₁₂O₁₉)

Conclusions

Using a solution casting approach, a BaFe₁₂O₁₉/PVDF composite film with tunable BaFe₁₂O₁₉ composition was successfully fabricated using M-type barium ferrite fibers & PVDF resin. Barium ferrite microfibers are dispersed throughout the PVDF matrix, as shown by scan electron microscopy and X-ray diffraction analyses. The composite films have a coercivity of around 5,045 Oe, which is more than the coercivity of pure BaFe₁₂O₁₉ (H_c=5,001 Oe). In composite films, the saturation specific magnetism and dielectric loss are enhanced by increasing the BaFe₁₂O₁₉ content, whereas their coercivity and dielectric value are decreased. The dielectric loss is small between 10 kHz and 1 MHz because the dielectric value drops off sharply at higher frequencies.

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