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ENHANCED ELECTRICAL AND THERMAL PROPERTIES OF EPOXY-GRAPHITE NANO SILICON CARBIDE COMPOSITES

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Abstract

Recent researches focused on the electrical and thermal properties characterization of polymer nanocomposites used as dielectric materials for energy storage and thermal stability. High-performance polymer materials with low dielectric

constant and dielectric loss factor have been widely used in high-speed communication networks. Frequency dependence of dielectric constant and dielectric loss in pure epoxy, epoxy-graphite, and epoxy-graphite with various weight fractions of nano silicon carbide are studied in the frequency up to 5MHz. The value of decreased with increasing frequency indicates that the major contribution to the polarization comes from orientation polarization while the conductivity increased. The electrical properties are sensitive to the homogeneity of graphite and nano silicon carbide dispersion in the epoxy matrix. The thermal properties of the nanocomposite were highly affected leading to an enhancement of the thermal conductivity and thermal effusivity of the material. It is found that addition of thermal conductivity enhancement filler is a more effective method to improve thermal conductivity.

Keywords: Epoxy , Graphite , Nano silicon carbide, dielectric constant , dielectric loss, Thermal stability, electrical properties.

1.Introduction

Polymers are often insulator materials due to chain chemical bonding and order formation [1]. They have some beneficial properties such as high adhesion, good mechanical properties, they are also less expensive than other thermosets and have better chemical resistance. However, due to its cross-linked structure, the higher thermodynamic properties are irrelevant to the manuscript and have higher electrical and thermal resistances [2]. Therefore, this study focuses on transforming Epoxy resins enhance thermal conductivity by incorporating different weight fractions of Gr, SiC, and hybrid (Gr-SiC) particles. Gr is a hexagonal form of carbon, which is inexpensive, low in density, has electrical conductivity and good thermal properties [3]. The multilayer has an installed level and has covalently interconnected atomic bonds. The three electrons are still the fourth free electron. This explains the electrical and thermal properties [4] ..Because of its strong thermal conductivity and low thermal expansion coefficient, SiC micro filler is a good choice for high temperature and high power applications [5]. Polymer nanocomposites are materials in which non-organic nanoparticles (typically 1-100 nm in at least one dimension) are disseminated in an organic polymer matrix to improve the polymer's performance attributes [6]. As the particle gets smaller, an increase in the surface area to volume ratio results in an increase in the dominance of the behavior of atoms on the particle surface area over the behavior inside the particle . Depending on the combination of matrix-nanofillers a variety of polymer nanocomposites can be produced even on demand [7]. Because polymer interfaces operate as charge carrier trapping sites, research into their effects on charge carrier formation, transit, and storage in polymer systems is critical. One of the most convenient and sensitive approaches for examining polymer structures is to examine dielectric constant and dielectric loss as a function of temperature and frequency [8].

Experimental 2

2.1. Materials Selecting a Template

Graphite powder micro particles (GE) provide by EG INDUSTRY Co, LTD GUILIN FACTORY in china autam Post an powder Graphite with High Purity of 1.82 g / cm3 density and low-volume granular 15um and particulates of Silicon carbide (SiC),as in figure1, equipped with the Sky Spring Nano company, cubic crystalline materials with a grain of size 40nm and a purity of up to 99% ,and with expansion coefficient <0.15 Matrix is epoxy resin (Sikadur-52)

2.2. Sample Preparation and Characterization

A Teflon mould was fabricated to give specimens of 1 mm thick and 40 mm diameter which is coin shaped as shown in Figure 1. Before casting, clean the mold thoroughly. Samples are prepared using a hand casting for electrical and thermal testing made of Teflon according to applied to Astm 6025 I EC, received (tolerance: 1 mm, disc diameter 40 mm) and fixed on a Teflon substrate, as in table 1. Mixing samples with a fraction (pure epoxy weight) Nano silicon carbide (0%) and epoxy resin by (100%), then hardener added 15 g and mixed for 5 minutes and then poured into the mold. And the second sample we prepared epoxy by 96.77% epoxy and added graphite 3.33%, which is a fixed value for all samples, and it is placed in magnetic max for a period one hour, then add the hardener according to the prescribed weight and we continue mixing for 5 minutes and pour the sample into the casting mold, which is the same procedure for the other samples, as in Table 1. all specimens are placed in an oven at a temperature of 30 °C for ten days to obtain post cured samples as in figure1. The specimen was fixed between two electrodes to determine the dielectric constant, and dielectric loss factor , at frequencies ranging from 2 up to 5 MHz .

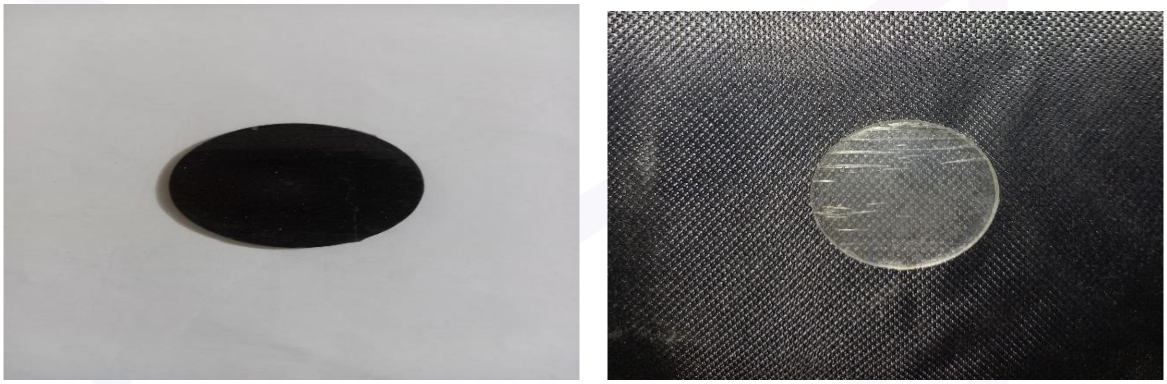

Fig 1.: Specimens are remove d from the mold

Table 1. The specimens, the amounts used, and the percentages for each Weight ratios

Weight ratios							
Material	**Sample1**	**Sample2**	**Sample3**	**Sample4**	**Sample5**	**Sample6**	**Sample7**
Epoxy polymer	**100%**	**96.77%**	**95%**	**94.16%**	**93.33**	**92.5%**	**91.66%**
Graphite	**0%**	**3.33%**	**3.34%**	**3.34%**	**3.34%**	**3.34%**	**3.34%**
Silicon carbide	**0%**	**0%**	**1.66%**	**2.5%**	**3.34%**	**4.16%**	**5%**
Total ratio	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

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3.3-Results and Discussion

3.1- FTIR Analysis.

Fourier (FTIR) infrared spectroscopy was used as shown in Figure (2) to analyze the functional groups and molecular bonds in nanocomposites. Expansion in many regions of the spectra The FTIR spectrum shows very wide and strong bands observed at 3375cm-1, This is attributed to the hydroxyl groups' stretching vibration (O-H). The peak at 2921 cm-1 assign to the vibrational stretching of the aldehyde group(C-H) In addition to that, the peak at (1731 cm-1) is for carbonyl group (C = O, C = C) where (C = C) is called the aromatic bond, and a group of frequency ranges at 1244 to1032 cm-1belongs to one carboxyl group (C-O), also appeared many flexural vibrations in addition to elongation and extension at a group of finger print at a range of frequencies ranging from 823 to500 cm-1 or less than 600 cm-1 [9].

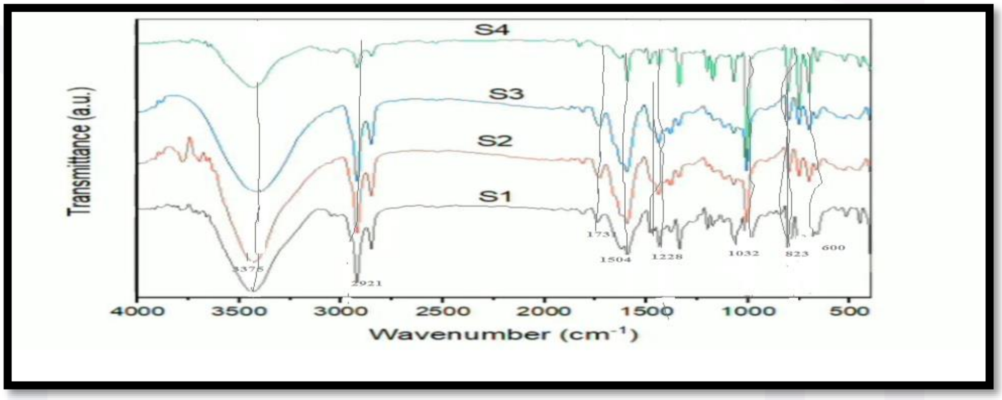

Fig (2) : spectra FTIR: Fourier transform

2-Electrical properties:

3.2.1 Loss factor

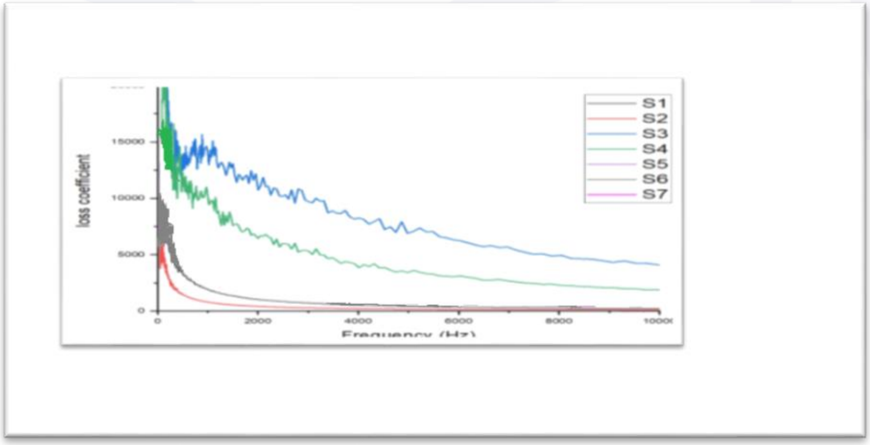

Fig 3. The loss factor –frequency for all specimen

Figure 3 shows the table of loss factor. All samples exhibit the same behavior and the value of the loss factor decreases or decreases when the frequency value increases, due to the increase in dielectrics, where the values of the loss factor remain for The specimens (pure epoxy,0, wt%) very close or almost constant (5.48, 5.38, wt%) respectively compared with pure epoxy, due to the natural frequency of the dipoles(vibration of the active functional groups in the compound) is equal to the frequency of the acting electric field, resulting in high vibration energy and thus a large energy loss, and there was a sharp increase in the loss factor in Ep / Gr compounds by (1.66 and2.5 wt%) by(6.77,10.62%) of nano silicon carbide as It is shown in Table (2), Figure (3) shows the angular loss coefficient with the change in frequency, where we notice that the angular loss coefficient decreases slightly at low frequencies Then it starts to decrease significantly at high frequencies and after frequency (2×103). We also note from the figure that all the measured models are good insulating materials at high and low frequencies [10].

Table 2.The loss factor and the log of the frequency

Epoxy-Sic	Loss factor	The percentage increase
Pure Epoxy	255.11	5.48%
Epoxy\Gr3.34%-0%Sic	100,19	5.38%
Epoxy\Gr3.34% -1.66%Sic	245.56	6.77%
Epoxy\Gr3.34%-2.5%Sic	186.82	10.62%

3.2.2 Dielectric constant:

Figure (4) in the low frequencies and then after the frequency 3 × 106 MHz the curve begins to behave in a stable and constant manner. This is due to the fact that at the beginning of the frequency the polarization processes are the polarization of the vacuum charge Figure 4, we note that the highest value of the sample dielectric constant (1.66, 2.5%) and these results are close to what was proven by the researchers [11]. The sample morphodogy charactrize by FESEM

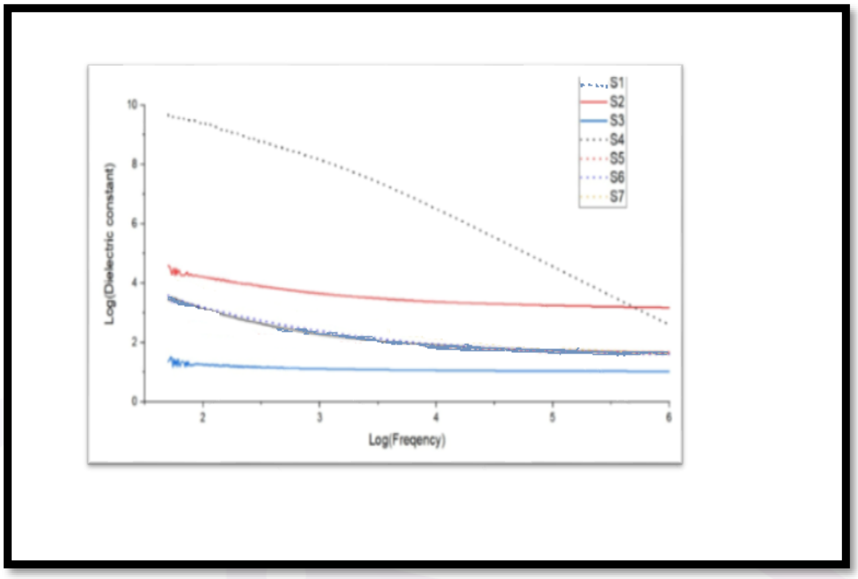

Fig 4. Dielectric constant vs. frequency (Hz) for epoxy-SiC composites

3.3- Thermal properties:

Figure 5 (S1, S2, S3, S4) depicts the importance of TGA-DSC in characterizing and identifying the many phase transitions seen in thermal studies of SiC nanocomposites. The glass transition temperature (Tg) is a second-order transition frequently observed in polymer systems. It is defined as the change associated with the difference in molecular mobility and relaxation time in amorphous materials. Glass temperature is a time-temperature relationship that is a bidirectional transition between glassy and rubbery states caused by changes in system pressure, temperature, or humidity. Due to the unbalanced nature of the glassy state and the fact that the verification process occurs over a large temperature range, Tg is a state transition rather than a phase transition due to the imbalanced nature of the glassy state and the fact that the verification process occurs across a large temperature range. The amount of nanofiller in the samples appears to affect their thermal stability. The maximum temperature 113 °C is 38°C, and reduces between 43°C and 66 °C with increasing nano carbide silicon from 0 to 2.5 wt%. Interestingly, with SiC, the shape of the changes significantly, with a temperature at a maximum weight loss rate that is related to the amount of 0 wt% have the ability to alter the mass transport barrier, resulting in more convoluted routes for volatile products to escape during thermal breakdown and encouraging slightly improved thermal resistance. According to TGA data, the addition of Nano Carbide Silicon to the matrix may prevent heat even better than the addition of 2.5wt and 1.66 wt% SiC particles These results are agree to what the researchers found in the reference [12], [13] and [14].

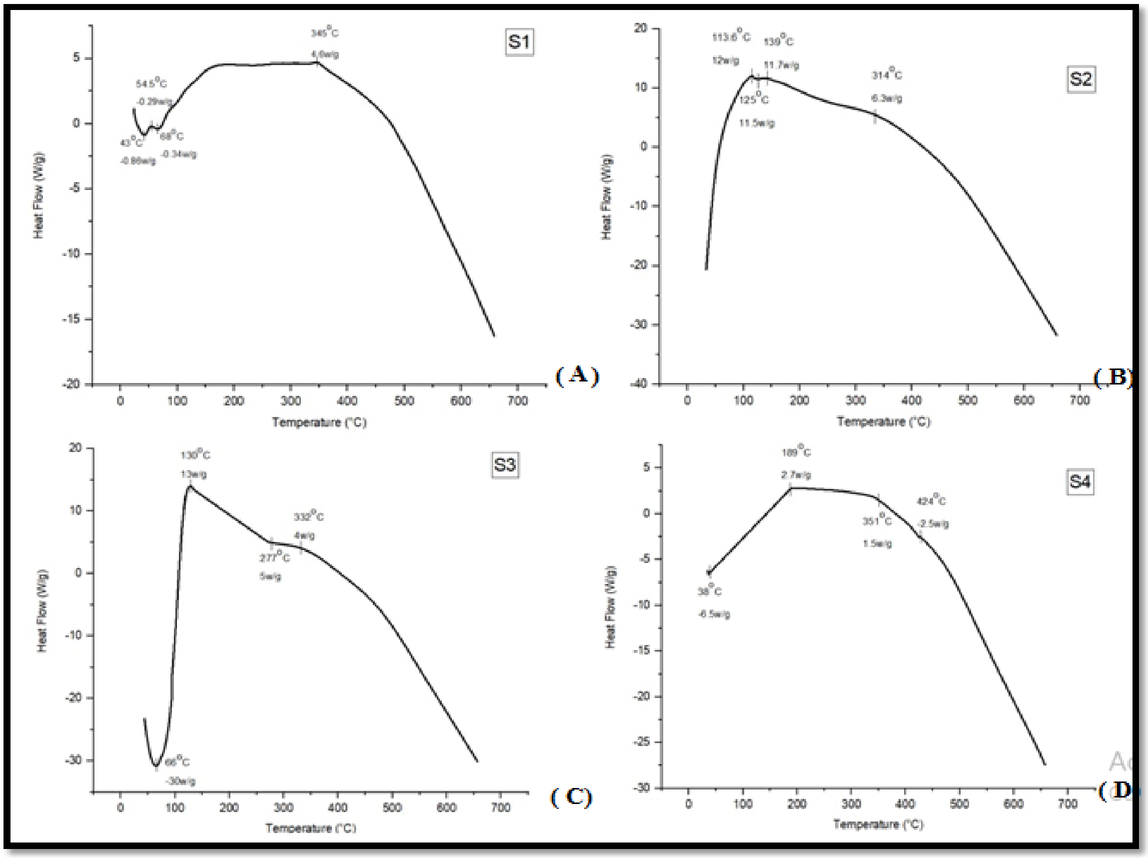

Table 3- Shows the DSC results to all specimens.

Epoxy - Sic	Glass transition Tg (°C)	Crystallization HCC(°C)	Melting Tm(°C)
Pure Epoxy	43 °C	54.5 °C	68 °C
Epoxy\Gr3.34%-0%Sic	113 °C	139 °C	125 °C
Epoxy\Gr3.34% -1.66%Sic	66 °C	130 °C	277 °C
Epoxy\Gr3.34%-2.5%Sic	38°C	189 °C	151 °C

3.4 Scaning Electron Microscope:

Figure 6 shows an SEM image of the composite showing well-dispersed graphite and nanoparticles in the polymer matrix. The morphology depicted in this figure is a non-porous continuous matrix, which increases flexural strength and electrical conductivity, as shown in Figure 6. The polymer does not contain nano-silicon carbide, but does contain graphite and epoxy. Therefore, this composite material has a very transparent high porosity.. A graphite layer's structure is also presented in detail. The voids are decreased when nano silicon carbide is introduced as a 2 filler, resulting in a denser texture. This can be clearly seen in Fig. 6A–B. The dosage of nano-silicon carbide is 1.66, and , 2.5, respectively, in the forms Cand D . By increasing the amount of nano silicon carbide, the texture of nanocomposite becomes denser and more holes are filled. Consequently, in Fig. 6D, It contains 2.5 percent nano silicon carbide, The highest density compared to the other numbers can be observed. Where it was found that there is a difference in the Figure and size of جnanoparticles that differ from each other through the size, which can be clearly seen in the figures, and that the rate of the size of nanoparticles may lead to an increase whenever the ion is replaced by the pion in the crystal lattice, and this is what the researchers found[15].

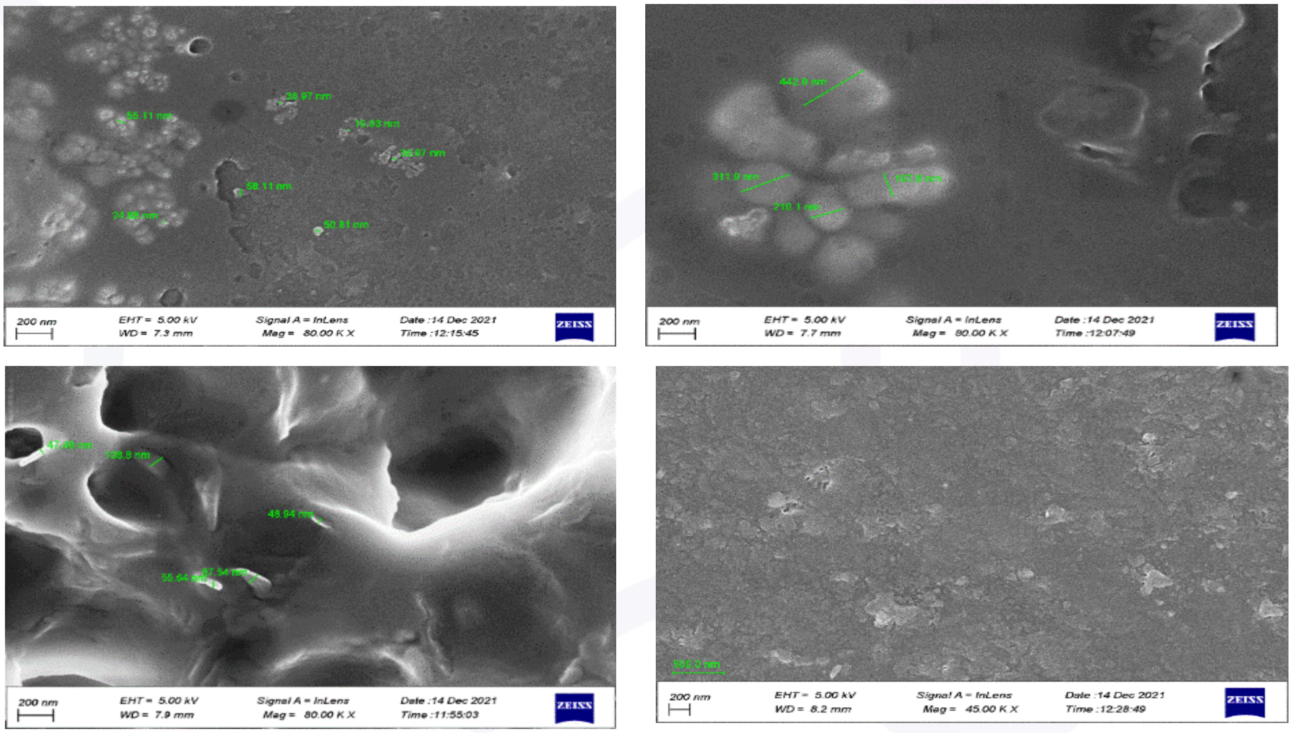

Fig 6.. SEM pictures ofEp\ Gr and SiC particles. (a) pure Epoxy ;(b) Ep\ Gr particles (c)1.66% SiC\Ep\Gr particles.;(d) 2.5%SiC\Ep\Gr particles

Conclusions

The following conclusions from the comparative study of electrical properties and thermal of properties epoxy/ Nano silicon carbide composites;

1- Electrical properties:

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a- the dielectric constant increased in the Nano silicon carbide weight fractions composites (1.66, and 2.5wt%) respectively, and the dielectric constant decreased in the Nano silicon carbide weight fractions composites (1.66wt%)

b- The loss factor increased in the Nano silicon carbidefractions composites (pure epoxy, 0 ,1.66,2.5, wt%) by(5.48,6.77, wt%) respectively, due to relaxation time .The highest lo weight ss factor in (2.5wt%)specimen by percentage increase(10.62%) ,and the loss factor decreased in the Nano silicon carbide weight fractions composites (0wt%) by(5.38%)

2-Tharmal properties : Increasing the fill (SiC) leads to an increase in the glass transition temperature (Tg), which reaches a maximum of about 113c and a minimum of about 38c when adding a nanomaterial (SiC) at a ratio of 1.66wt and 2.5wt

3-The scanning electron microscope (SEM) measurements of the surface morphology of the nanocomposites films, which are homogeneous and cohesive with the aggregates or pieces randomly scattered on the upper surface, show typical SEM images of the nanocomposites with different concentrations of silicon carbide nanoparticles. It was found that it is smoother, more homogeneous and coherent in the image (B) in Fig. (6). Despite the gradual growth of the proportion of nanoparticles in polymer mixtures, the surface shape changes. The appearance of numerous aggregates or pieces of spherical particles on the surface of nanocomposites films indicates a homogeneous growth mechanism. It becomes softer with increasing concentration of both nanoparticles.

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