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Dispersion Analysis of Silicon Carbide Nanoparticles in Polyvinyl Alcohol Polymeric Matrix by Electronic Microscopy Techniques

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Polymer nanocomposites comprise an exciting area that is increasingly attracting the attention of researchers all around the world due to the interesting properties exhibited such as mechanical, physical, and chemical properties, allowing applications in different areas including aeronautical [1], automotive [2], biomedical [3], optoelectronics [4], energy storage [5], supercapacitors [6], and sensors [7], among others. Silicon carbide (SiC) nanoparticles exhibit high hardness and strength, high resistance against corrosion, low thermal expansion coefficient, and high thermal conductivity, among others [8], when mixed with some polymer matrices, especially with polyvinyl alcohol (PVA), SiC nanoparticles exhibit better optical, electrical, thermal, and mechanical properties [9]. However, some authors had found some dispersion problems of SiC nanoparticles on PVA because they form agglomerates due to van der Waal forces and their poor interfacial adhesion with polymer matrices. Because of the above, the dispersion and the interfacial functionalization [10] of nanoreinforcements into a polymeric matrix are a very important challenge for this type of nanocomposites. Thereby, this study is focused on the dispersion degree analysis of SiC nanoparticles into a PVA matrix by scanning electron microscopy (SEM) and transmission electron microscopy (TEM) techniques. Thus, a solution mixing technique was used for the PVA-SiC synthesis. The SiC nanoparticles were added to the PVA solution at 0.5 and 1.0 wt.%. Magnetic stirring (600 – 800 rpm) was used to homogenize the SiC into the PVA solution. Then, the PVA-SiC mixture was subjected to severe agitation employing a high-frequency ultrasonic lance (40% of maximum power) during 3 h. The PVA-SiC solution was poured into an acrylic mold and dried for 7 days at room temperature to allow it to cure. For the dispersion quantification, a statistical model free-path distance was used [11]. For this, the distances between nanoreinforcements were measured on the SEM and TEM images.

Figure 1a and Figure 1b show SEM and TEM images for SiC nanoparticles. Figure 1a evidences an irregular morphology of the nanoparticles with different sizes (~ 80-100 nm). Additionally, the TEM image in Figure 1b evidences the morphology seen in SEM images, and a selected area electron diffraction (SAED) pattern confirms the crystallographic characteristic of the Beta-SiC nanoparticles.

Figure 2 shows the dispersion degree quantification of the Beta-SiC nanoparticles into the PVA matrix by SEM images. The SiC nanoparticles are seen well dispersed into the matrix without cluster formation. The results shown in Figure 2b evidence an average spacing between SiC nanoparticles of 0.159 µm and a dispersion degree $D_{0.1}$ of 12.5%. Additionally, about 12.2% spacing data are in the range of 0.128 – 0.148nm, according to the methodology used [11]. The same analysis was done for the TEM

images (Figure 3), and the results showed an average spacing between SiC nanoparticles of 37.5 nm and a dispersion degree $D_{0.1}$ of 7.1%. The TEM images evidence a lower dispersion degree than SEM images due to the fact that SEM images do not show sub-superficial nanoparticles as TEM images evidence.

In general, these images show a good dispersion of SiC nanoparticles into PVA; in addition, no SiC clusters were observed, which allows promoting a good load transference between the polymeric matrix and SiC, which in turn should produce good mechanical properties. Additionally, the PVA promotes the dispersion between nanoparticles due to its polar nature [11] allowing a good dispersion of the nanoreinforcements.

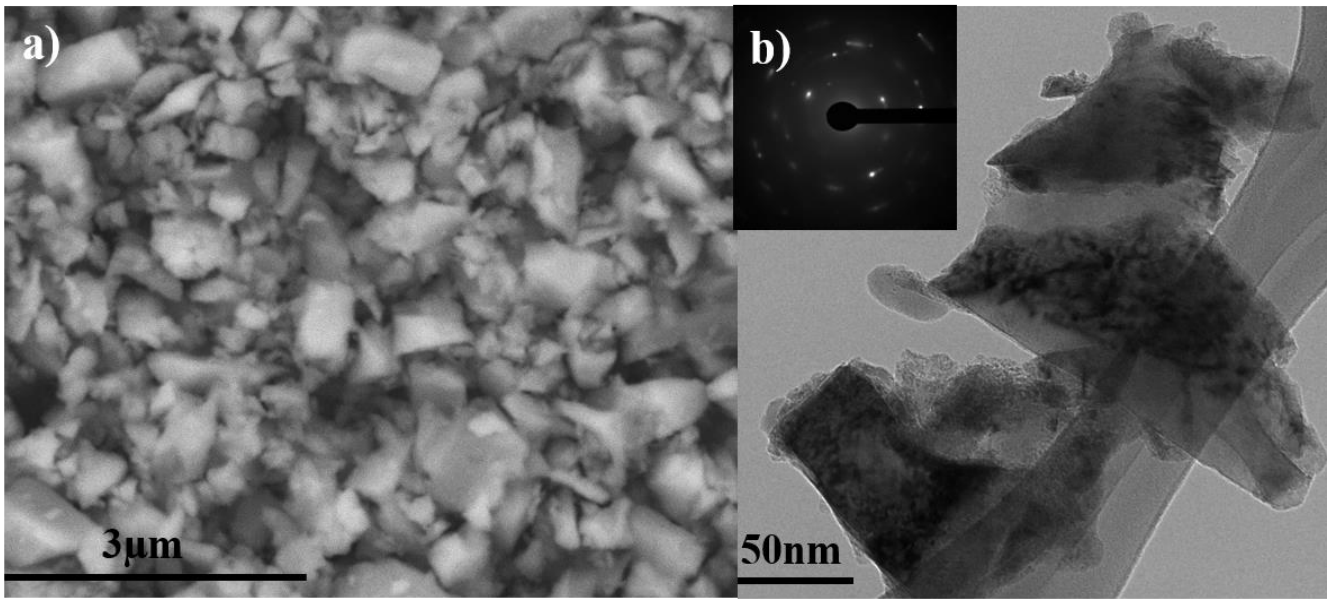

Figure 1. a) SEM image for SiC nanoparticles and b) TEM image for SiC nanoparticles with SAED pattern.

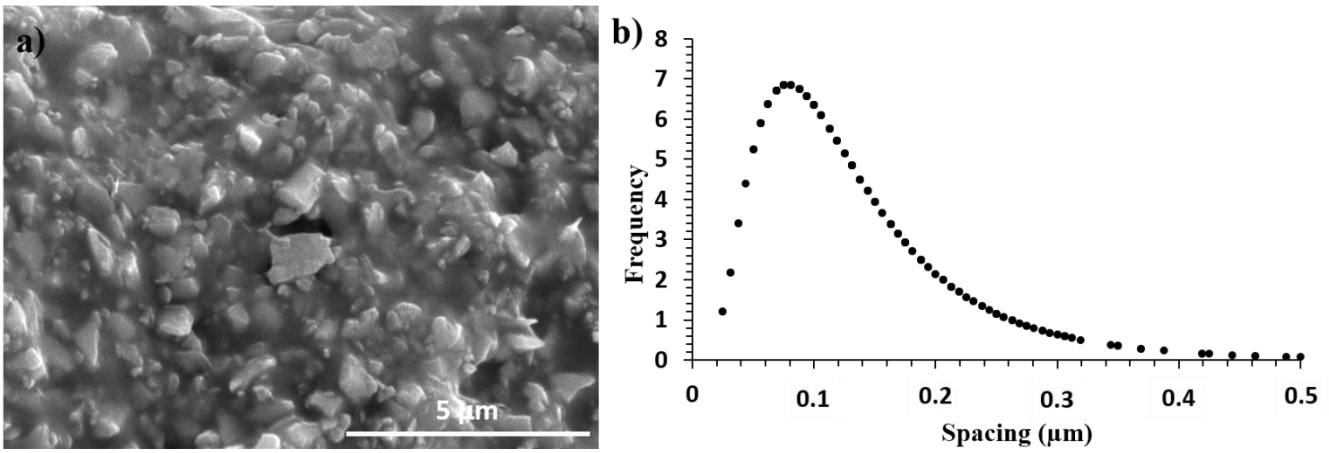

Figure 2. a) SEM images of PVA reinforced with SiC nanoparticles and b) frequency distribution of the SiC nanoparticles into the PVA matrix.

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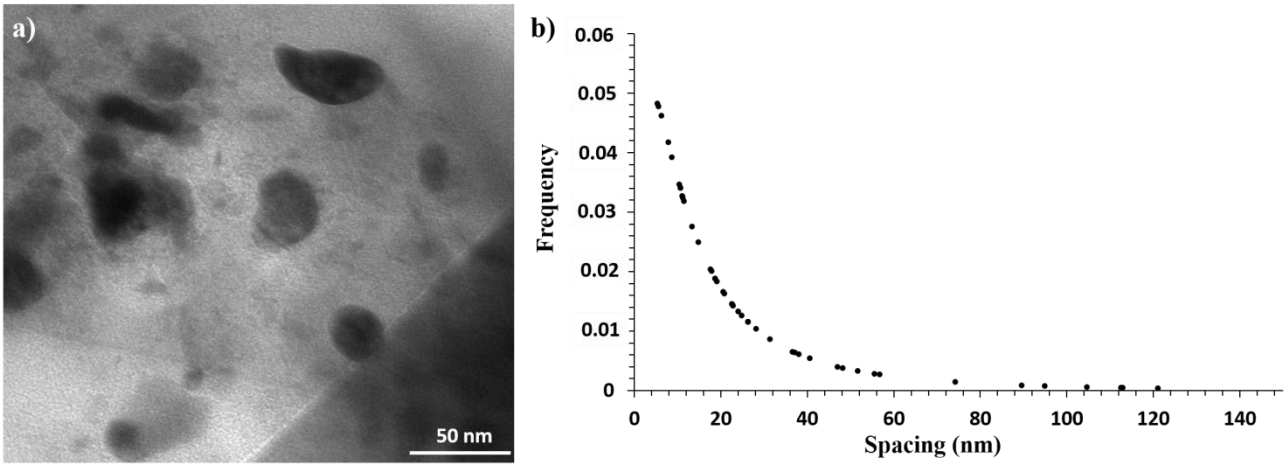

Figure 3. a) TEM images of PVA reinforced with SiC nanoparticles and b) frequency distribution of the SiC nanoparticles into the PVA matrix.

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