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Abstract: The influence of the reactive component (N-phenylmaleimide styrene maleic anhydride) on the blend morphology, the localization of functionalized multiwalled carbon nanotubes (MWCNTs), and the electrical resistivity of MWCNT filled blend systems of polycarbonate (PC) and poly(styrene-co-acrylonitrile) (SAN) was investigated. SAN, PC, amino-functionalized MWCNTs (Nanocyl® 3152) and the reactive component (RC) were melt mixed in a DSM Xplore microcompounder using different mixing sequences. The RC containing maleic anhydride (MA) groups is miscible with SAN and is assumed to act as linking agent to the functionalized MWCNTs. The morphology of the SAN/PC blends was studied depending on the concentration of the RC. Thereby co-continuous morphologies were found for all blends with 40 wt% SAN and 60 wt% PC. In all nonmodified blends the MWCNTs were localized within the PC phase. After the addition of RC the MWCNTs migrated completely into the miscible SAN-RC phase. Consequently, the electrical resistivities of the blends changed in dependence on the localization. Whereas the SAN/PC/MWCNT blends showed low electrical resistivity values, much higher values were found for SAN-RC/PC/MWCNT blends. This was assigned to a coupling or strong interaction of MA groups to the nanotubes disturbing electrical contacts and percolation between them. The occurrence of the MWCNT migration from PC towards SAN was found to be dependent on the concentrations of RC and MWCNTs. By adapting that ratio and the mixing strategy, the localization of the carbon nanotubes in the blend phases can be tuned. The investigations indicated that MWCNTs once coupled with the RC remain in the SAN-RC phase. Thus, a chemical reaction or strong interactions seem to be the driving forces for localization of the MWCNTs in the SAN-RC blend phase.

Tuning the localization of functionalized MWCNTs in SAN/PC blends by a reactive component

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Abstract

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Keywords

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1. Introduction

Blending polymers is an economic way to produce new custom-made polymeric materials with outstanding properties. The characteristics of the employed polymers can be combined, in some cases even synergistic effects are generated. Thereby, in biphasic immiscible polymer blends the property profile is strongly determined by the blend morphology [1, 2].

Another convenient possibility to produce materials with improved or new properties is to add functional fillers into polymeric matrices. The interest in such composites is very high and a lot of studies were made using different kinds of fillers. The incorporation of multiwalled carbon nanotubes (MWCNTs) into polymer materials can favourably influence different properties, like electrical conductivity, mechanical strength, thermal expansion and thermal conductivity, scratch and wear behaviour, oxidation stability and flame retardancy [3-12].

Combining polymer blending with the addition of nanofillers like MWCNTs is a very suitable way to tailor the properties of the materials, especially when electrical conductivity of the insulating blend matrix is desired. When using blends with co-continuous morphologies, a lower filler concentration compared to a composite with a one-

phase-structure is required to achieve electrical percolation, if the electrical conductive filler percolates and localizes selectively in one of the phases. This concept of double percolation was first introduced by Sumita et al. [13] using immiscible polymer blends with carbon black. Later the concept was adapted to other conductive fillers, e. g. also towards nanotubes [14-22]. The selective localization behaviour of nanotubes in polymer blends in general is most commonly explained using the concept of the wetting coefficient [20-28]. The kinetic aspect of the filler localization was also discussed in different systems [29].

The literature describes only few examples where parts of added nonfunctionalized or functionalized MWCNTs were localized at the interface of immiscible blends [26, 30]. Similar to the blend system used in this study, Gödel et al. [20] described double percolation in co-continuous poly(styrene-co-acrylonitrile) (SAN)/ polycarbonate (PC) blends with Baytubes C150HP. The selective localization of the CNTs in the PC phase occurred independently of the polymer phase in which the CNTs were first incorporated and was explained as thermodynamically induced.

There is evidence that reactive groups such as maleic anhydride (MA) can develop strong interactions or reactions with the nanotubes surface. Therefore, in order to improve dispersion of nanotubes and adhesion to the polymer matrix, the use of reactive compatibilizers or modified polymer matrices containing e.g. maleic anhydride (MA) groups is discussed as a suitable way. E.g., the improved properties of PP/MWCNT composites using grafted polypropylene (PP-g-MA) were explained by a strong hydrogen bonding between hydroxyl groups of the MWCNTs and maleic anhydride groups of PP-g-MA [31, 32]. Wang et al. show that the grafting of MWCNTs with styrene-maleic anhydride copolymers improved the compatibility between MWCNTs and PVC [33]. Bose et al. [17, 18] investigated the behavior of MWCNTs in a PA6/ABS blend with a reactive

compatibilizer based on a styrene maleic anhydride copolymer premixed with nanotubes. The authors reported that the nanotubes were located within the interphase consisting of the compatibilizer.

In this paper, the influence of the addition of the reactive component (N-phenylmaleimide styrene maleic anhydride) on the localization of amino-functionalized MWCNTs and the electrical resistivity was investigated in a co-continuous SAN/PC (40 wt%/60 wt%) blend system. The nanotube localization in the SAN-RC/PC blend systems was studied at different ratios of RC and two different MWCNT contents.

Amino-functionalized MWCNTs were used that enable reactions between the maleic anhydride groups of the reactive component (RC) and the amino groups on the tube surface. Thus, a fixation of the nanotubes in the SAN phase could be achieved. Miscibility of the RC with the SAN phase of the blend system was verified by the consistency of the glass transition temperature T_g of different SAN/RC blends with the Couchman Equation [34, 35].

2. Materials and methods

2.1. Materials

Polycarbonate Makrolon[®] 2600 (Bayer MaterialScience AG, Leverkusen, Germany) and poly(styrene-co-acrylonitrile) Luran[®] 358N (BASF AG, Ludwigshafen, Germany) and short amino-functionalized multiwalled carbon nanotubes Nanocyl 3152 (Nanocyl[®] S.A., Sambreville, Belgium) with a purity of 95 % were used. According to the supplier, the MWCNTs have an average diameter of 9.5 nm and an average length less than 1 μm . As reactive component (RC), N-phenylmaleimide styrene maleic anhydride Denka IP (DENKI KAGAKU KOGYO KABUSHIKI KAISHA, Tokyo, Japan) was applied. This reactive component containing maleic anhydride groups was found to be miscible with the SAN by differential scanning calorimetry [35].

2.2. Preparation

All materials were dried under vacuum at 80°C for 12 h. The composites and blend systems of SAN, PC, carbon nanotubes (CNTs), and the reactive component were melt mixed in a 15 cm³ microcompounder (DSM Xplore, Geleen, The Netherlands) operated at 260°C melt temperature 100 rpm and a mixing time of 5 min.

To produce composites, in a first set different concentrations of MWCNTs (0.5 - 5 wt%) were incorporated into the polymer blend components (PC, SAN and SAN with RC).

For the blends, PC and SAN were blended in a second set the proportion 60/40 wt% to get blends with a co-continuous morphology. In the composites and blends with RC, the SAN fraction was partially replaced by 20 wt% RC. The MWCNTs were incorporated in the polymer blends in different ways with or without the reactive component. On the one hand, the MWCNTs were pre-compounded in PC, SAN or SAN-RC and in a second step these pre-compounds were melt mixed with the second polymer to prepare the blend. On the other hand, all components were melt compounded in one step. All MWCNTs filled blends of the second set contained 0.5 wt% MWCNTs.

In addition, in a third set RC was added in a second step to SAN/PC/MWCNT blends by varying the RC amount (20 wt%, 2 wt%, 0.2 wt% of the SAN replaced by RC). For this, SAN/PC blends were prepared in the ratios of 20/60, 38/60, and 39.8/60 wt%.

For additional investigations, in set 4 also 5 wt% MWCNT loading was used in blends containing 2 wt% and 20 wt% RC. These blends were afterwards diluted with SAN and PC to a concentration of 0.5 wt% MWCNTs.

2.3. Electrical measurements

The electrical volume resistivity was measured on compression moulded samples (diameter 60 mm, thickness 0.5 mm) which were prepared by pressing extruded strand

pieces using a Weber PW 40 EH hot press (Paul-Otto Weber GmbH, Remshalden, Germany) at 260°C, 100 kN for 1 min and subsequent cooling. A Keithley electrometer Model E 6517A equipped with an 8009 Resistivity Test Fixture was used to measure highly resistive samples. For samples with resistivities $< 10^7$ Ohm cm, strips (approx. $20 \times 3 \times 0.5 \text{ mm}^3$) cut from the pressed plates were measured in a four point test fixture combined with Keithley Multimeter Model 2000.

2.4. Morphological characterization

The morphology of the blend systems was characterized on extruded strands using a Leo VP 435 scanning electron microscope (Leo Elektronenmikroskopie, Oberkochen, Germany). For the MWCNTs filled blends an Ultra Plus scanning electron microscope (Carl Zeiss SMT AG, Oberkochen, Germany) having higher resolution was used. After cutting, the strands were etched and coated with platinum. The PC phase of the blends was selectively hydrolysed with a solution of NaOH (30 wt%) at a constant temperature of 105°C and different etching times depending on the blend ratio as described by Dong et al. [36].

Transmission electron microscopy (TEM) investigations were performed on ultra-thin sections of 80 nm thickness cut at room temperature from the extruded strands by applying a TEM LIBRA 200 MC (Carl Zeiss SMT AG, Oberkochen, Germany) at an acceleration voltage of 200 kV. Energy-filtered TEM (EF-TEM) and electron energy-loss spectroscopy (EELS) were used to assign the phases of the blends.

3. Results and discussion

3.1. Morphology of blends without nanotubes

As it is desired to achieve electrical conductivity at low nanotube loadings, it was the aim to use blends having double percolated structures with percolated nanotubes in one of the co-continuous blend phases. In a previous study [35], by varying the blend composition of

SAN/PC blends co-continuous morphologies were obtained >50 wt% and <75 wt% PC and are well developed at 60 wt% PC. The SAN/PC blend produced in this study at 60 wt% PC was characterized concerning the phase morphology as shown on a scanning electron micrograph (Figure 1 A). Due to the etching procedure the three-dimensional continuous SAN phase (remaining grey areas) is visible in the SEM image and the missing PC phase appears black. The blend reveals a well developed co-continuous blend structure.

Furthermore, the influence of increasing amounts of the reactive component (RC) was studied for SAN-RC/PC (40 /60) blends (Figure 1 B-D). At increased RC contents the micrographs show a slightly finer co-continuous morphology, while the phase continuity was unaffected by the reactive component.

3.2. Electrical properties of composites with MWCNTs

The electrical volume resistivity of SAN, PC and SAN-RC (50/50) composites at different MWCNT concentrations and of SAN/PC (40/60) and SAN-RC/PC (20-20/60) composites with 0.5 wt% -MWCNTs are illustrated in Figures 2 and 3. The electrical percolation threshold of the PC composites as well as that of the SAN composites was found at 0.5 wt% (Figure 2) whereas the resistivity values for PC were generally slightly lower than those of SAN.

Figure 2 shows significantly lower electrical percolation thresholds for the composites with amino-functionalized MWCNTs as compared to values found by Gödel et al. [20] for Baytubes C150HP. There, the percolation threshold in SAN occurred at a filler content of 2 wt% and in PC at a filler content of 1 wt%.

Differing from the electrical percolation behavior of the SAN composites, the electrical volume resistivity of the SAN-RC/MWCNT composites only slightly decreases with the MWCNT content (Figure 3): (from 10^{17} Ohm cm for the SAN-RC to 10^{10} Ohm cm for the composite containing 5 wt% MWCNTs). It can be assumed that an encapsulation of the

amino-functionalized MWCNTs is caused either by the chemical reaction or by strong interactions between the amino groups and the maleic anhydride groups of the reactive component which results in disturbing electrical contacts of the nanotubes and percolation between them. Bhattacharyya et al. [37-40] found similar effects when discussing the influence of nanotube encapsulation on the composite resistivity. They incorporated singlewalled carbon nanotubes (SWCNT) encapsulated by maleic anhydride groups into PA12 [38, 40] and PA6 [37, 39] in which a reaction between maleic anhydride groups on the nanotubes surface and amine groups of the polyamides was proven. This encapsulation hindered the electron transfer between the separated carbon nanotubes and so across composites.

3.3. Electrical properties of MWCNTs filled blends

The electrical resistivities of PC, SAN and SAN-RC with MWCNTs is compared to the electrical resistivity values of SAN/PC and SAN-RC/PC (20-20/60) blends containing 0.5 wt% MWCNTs. Interestingly, the electrical resistivity values of the blends strongly depend on the absence or presence of the reactive component. The MWCNTs filled SAN/PC blends without the RC showed resistivity values between 10^3 Ohm cm and 10^2 Ohm cm, which are comparable to the resistivity of a PC composite containing 0.83 wt% MWCNTs (Figure 2) and the resistivity of a SAN composite containing 1.25 wt% MWCNTs. These concentrations correlate with the hypothetical filler concentrations assuming that 0.5 wt% MWCNTs are either selectively localized in the PC or SAN blend phase of the blends (Figure 2). These results indicate a highly selective localization of the MWCNTs in the PC or SAN phase of the blends.

Similar resistivity values are obtained when the MWCNT filled blends are fabricated in one step or by precompounding MWCNTs in PC or SAN and subsequent blending with the respective neat polymer. Thus, the electrical resistivities of all MWCNTs filled SAN/PC

blends without RC are independent of the MWCNT incorporation sequence. The same effect was reported by Gödel et al. [20] for SAN/PC blends filled with unfunctionalized Baytubes[®] C150HP.

When SAN-RC is used as blend phase, the electrical resistivity of the blends with 0.5 wt% is 10^{16} Ohm cm. Thus, the blends are insulating (Figure 3). This was similarly observed for all SAN-RC/PC blends filled with amino-functionalized MWCNTs independently from the mixing sequence. The electrical properties of all SAN-RC/PC blends with 0.5 wt% MWCNTs are comparable to the SAN-RC/MWCNT-composite containing 1.25 wt% MWCNTs which represents the hypothetical filler concentration assuming that all MWCNTs are localized in SAN-RC. Assuming that all filler was in PC would lead to a theoretical expectation of resistivity values in the range of 10^3 Ohm cm and 10^2 Ohm cm. Therefore, the selective localization of the MWCNTs in the SAN-RC phase can be concluded from the electrical measurements.

3.4. Localization of the nanotubes

In order to prove the previous conclusion from electrical volume resistivity measurements, scanning electron microscopy (SEM) and transmission electron microscopy (TEM) were used to detect the localization of the functionalized MWCNTs (0.5 wt%). The SEM image of the selectively etched MWCNTs filled SAN/PC blend without RC (Figure 4 A) illustrate some isolated MWCNTs laying on the surface of the SAN phase remaining after the etching process. Interestingly, in the SAN phase no inclusions of MWCNTs could be observed. This indicates that the MWCNTs were embedded in PC, but eluted during the hydrolysis process of the PC and remained inside the holes of the former PC phase. In contrast, the micrograph of the MWCNTs filled SAN-RC/PC blend (Figure 4 B) shows the MWCNTs within the SAN phase. They appear as white dots and were cut perpendicular to their length axis during the preparation of cut surfaces. In contrast to the SAN/PC blend

without RC, no nanotubes were found on the surface of SAN. Again, the localization was independent of the MWCNT incorporation sequence, even if the nanotubes were first mixed into PC. Therefore, the results indicate, corresponding to the results of electrical resistivity measurements, the selective localization of functionalized MWCNTs in the SAN-RC phase.

TEM images of microtomed MWCNTs filled blends unequivocally prove the MWCNT localization already observed by SEM. Assuming the PC phase having a smooth appearance and SAN appearing as ruffled phase in the TEM images, the nanotubes are localized in the PC phase in the SAN/PC blend (Figure 5 A) and in the SAN-RC phase in the SAN-RC/PC (20-20/60) blend (Figure 5 B). To prove the CNT localization and this phase assignment, EF-TEM and EELS detectors were used. Figure 6 A shows the SAN-RC/PC (20-20/60) blend with selective localization of CNTs in the bright phase. In the nitrogen map of the EF-TEM this phase is nitrogen-rich and can be clearly attributed to SAN. This verifies that in the SAN-RC/PC (20-20/60) the CNTs are localized in the SAN-RC phase. Figure 6 B shows the SAN/PC blend without RC. There the CNTs localize in the dark phase. The oxygen map clearly indicates that this phase is oxygen-rich and thus can be assigned to the PC phase.

The results clearly indicate that the MWCNT localization is determined by the addition of the reactive component but not by the way of MWCNT incorporation. If the blend is prepared without RC the MWCNTs are always selectively localized within the PC phase. The addition of RC inverts the localization behavior of MWCNTs and co-continuous morphologies with MWCNTs selectively localized in the SAN-RC phase are obtained. Accordingly, co-continuous blends could be fabricated with either selectively filled PC or SAN phase and the localization can be tuned by adding the reactive component. The CNT localization in the PC phase of SAN/PC blends was attributed by Göldel et al. [20] to the

better wetting of the nanotubes by PC as compared to SAN. The observed migration of the MWCNTs from the prefilled PC phase into the SAN-RC phase can be explained either by interfacial tension effects or by a chemical reaction/strong interaction between the amino groups of the functionalized MWCNTs and the maleic anhydride groups of the reactive component.

3.5. Investigations of the tunability of MWCNT localization

To gain a deeper understanding of the mechanism of the localization change, the effect of the content of RC on the CNT localization was studied. 20 wt% RC were added in a second mixing step to a previously prepared SAN/PC blend (20/60) with 0.5 wt% MWCNTs which before addition were selectively localized within PC (Figure 7 A). Interestingly, this addition inverted the carbon nanotube localization and all MWCNTs were subsequently located within the SAN-RC phase, thus illustrating the efficiency of the RC as a “tuning additive” (Figure 7 B).

Two different mechanisms appear suitable to explain the observed phenomenon. If the addition of the RC to SAN would significantly change the surface energy and thus the CNT-wetting of the obtained miscible SAN-RC phase, the transfer of MWCNTs from one phase to the other could be attributed to the same interfacial effects that were proposed to transfer CNTs from a SAN-CNT precompound into PC [20]. If the inverted localization behavior would occur due to covalent coupling or strong interactions, the maleic anhydride group of the RC has to be available exactly at the moment an individual CNT approaches the blend interface and at the position of the amino group of the CNT. Due to the high number of shear induced collisions of any volume element with the blend interface during mixing, a certain number of contacts between the CNTs and the blend interface can be assumed. The probability for successful chemical coupling or interactions would then be

declining for decreasing concentrations of the maleic anhydride groups within the SAN phase.

In order to clarify the effect of the RC on the localization change, varying amounts of RC were added to SAN/PC blends with a selectively MWCNT loaded PC phase.

It is found that the MWCNTs moved from the PC to the SAN-RC phase after the addition of 2 wt% RC in the second mixing step (Figure 8 A). However, when introducing only 0.2 wt% RC no localization change was observed (Figure 8 B).

As obviously the ratio between available amino groups on the CNTs and anhydride groups of RC plays an important role, in set 4 the MWCNT concentration was increased to 5 wt% in SAN/PC blends containing 2 wt% and 20 wt% RC. As described above for a MWCNT concentration of 0.5 wt% (Figure 8 A), an amount of 2 wt% RC is enough to invert the localization behavior of CNTs. If the MWCNT migration would be caused by changes in the surface energy or polarity of SAN by the addition of the RC phase, the localization behavior should be independent of the CNT concentration in the blend. Nevertheless, the TEM image (Figure 9 A) shows that 5 wt% amino-functionalized MWCNTs can be found in both blend phases for a RC concentration of 2 wt%, which is obviously not sufficient to localize the MWCNTs selectively in the SAN-RC phase of the blend. When increasing the RC content to 20% RC, also 5 wt% MWCNTs can be exclusively localized in the SAN-RC phase.

Based on those results, a ratio between RC concentration and amount of MWCNT-NH₂ (RC: MWCNT) can be estimated which is needed to achieve complete localization within the SAN-RC phase. The critical ratio, at which completely selective localization of MWCNTs in the SAN-RC phase occurs, thus can be expected between 0.4:1 < RC:MWCNTs < 4:1. In conclusion, the assumed chemical reaction or strong interactions of the RC and the amino-functionalized MWCNTs seem to be the driving force for the

MWCNT migration rather than changes in interfacial energy relationships between SAN-RC and PC.

Interestingly, when diluting a blend of SAN-RC/PC (38-2/60) having 5 wt% MWCNTs localized in both phases (Figure 9 A) using additional PC and SAN to get a blend with 0.5 wt% MWCNTs and 0.2 wt% RC, the nanotubes stay in the SAN-RC and PC phases (Figure 9 B). In contrast, when preparing that blend composition directly (Figure 8 B), MWCNT localization in PC was found. This observation can be interpreted as an indication for the occurrence of the coupling reaction and the importance of availability of maleic anhydride groups at the blend interface in the moment of mixing induced contact of nanotube and blend interface. The probability of random encounters between the CNTs that are initially located within the PC phase and the maleic anhydride groups is statistically decreasing for decreasing RC concentrations. Thus, irreversible coupling between amino-functionalized MWCNTs and RC like a covalent bonding or an irreversible adsorption of RC on the surface of MWCNTs caused by strong interactions can be concluded as reason for the localization change of the nanotubes.

Another argument for the occurrence of chemical reactions or strong interactions between MWCNTs and RC is the finding that the electrical resistivity of SAN-RC composite does not show a typical percolation behavior and remains above 10^{10} Ohm cm even up to MWCNT contents of 5 wt% (see Fig. 3). This can be attributed to an encapsulation of the MWCNTs by the RC thus hindering the electron transfer between the separated MWCNTs [37-40].

However, a direct proof of the reaction in the composites via FTIR investigations was not possible as the amount of functional groups on the surface of the MWCNTs is too low for quantification and the reaction product is a maleimide already contained in the RC.

4. Summary and conclusions

The investigations showed that the addition of a reactive component containing maleic anhydride groups changes the localization of amino-functionalized MWCNTs and the electrical properties of co-continuous SAN/PC blends. In SAN/PC blends without the reactive component the MWCNTs are localized in the PC phase independently of the mixing sequence due to interfacial tension effects [20]. However, the modification of SAN using the miscible RC changed its properties in such a way, that MWCNTs (0.5 wt%) localized in the SAN-RC phase.

In order to clarify the mechanism responsible for the observed localization change of CNTs different ratios between the reactive component and CNTs were employed. The investigations revealed that

- a certain critical ratio is required to achieve selective localization in the SAN-RC phase
- the CNT localization behavior is dependent on the mixing sequence at low ratios of the reactive component and CNTs indicating a chemical coupling or strong interactions between CNTs and RC as reason for the localization behavior
- MWCNTs once experienced the RC during the mixing procedure stay in SAN-RC phase

Based on that, not only the mechanism of nanotube localization was revealed; it is also possible to tune the localization behavior of CNTs in different concentrations by adapting the amount of the reactive component.

In further works, the effects of non-functionalized nanotubes on the localization in the presence of RC will be studied, as well as the behavior of SWCNTs.

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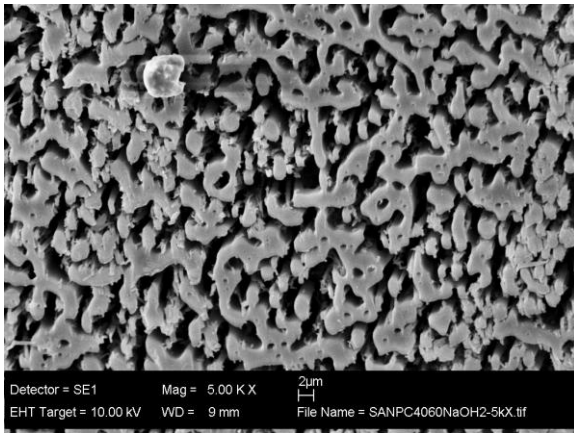
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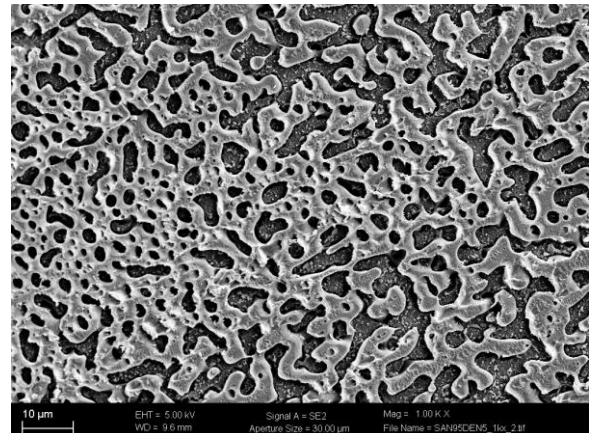
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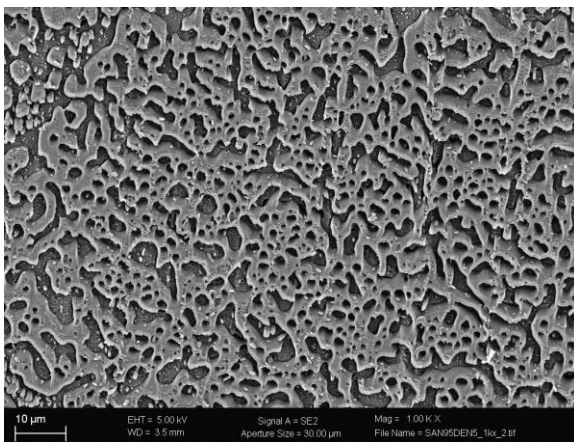
Figures:



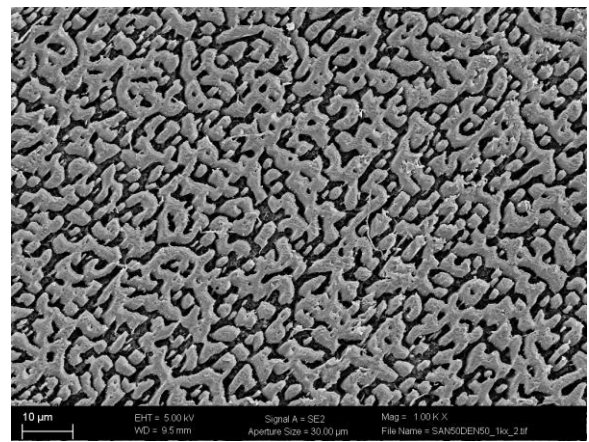
A: SAN/PC (40/60)



B: SAN-RC/PC (39.8-0.2/60)



C: SAN-RC/PC (38-2/60)



D: SAN-RC/PC (20-20/60)

Figure 1: SEM images of the morphology of SAN/PC (40/60) blends with different amounts of the reactive component (PC etched using NaOH, remaining SAN phase is seen).

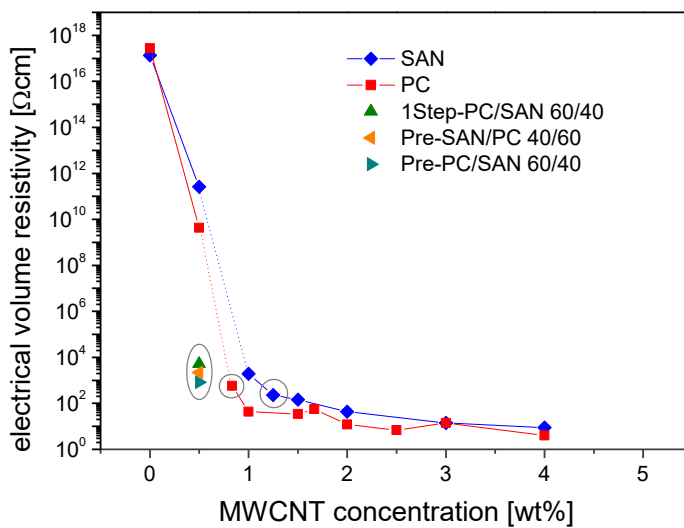


Figure 2: Electrical volume resistivity of the SAN and PC composites at different MWCNT concentrations and of SAN/PC blends filled with 0.5 wt% MWCNTs obtained by different mixing sequences.

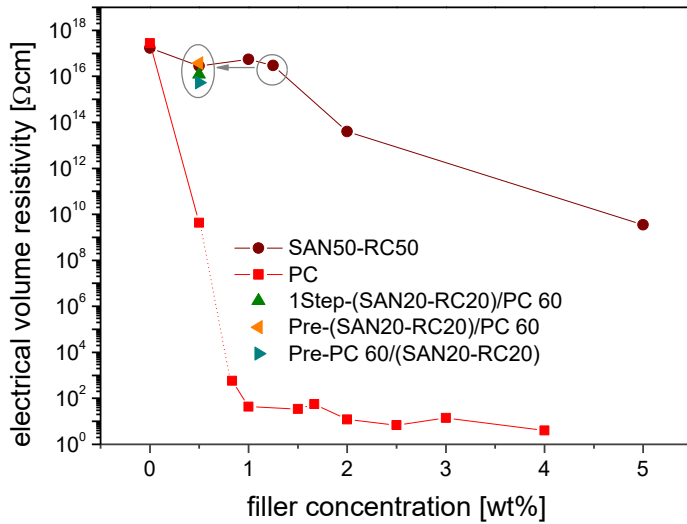


Figure 3: Electrical volume resistivity of the SAN-RC (50-50) and PC composites at different MWCNT concentrations and of SAN-RC/PC (20-20/60) blends filled with 0.5 wt% MWCNTs obtained by different mixing sequences.

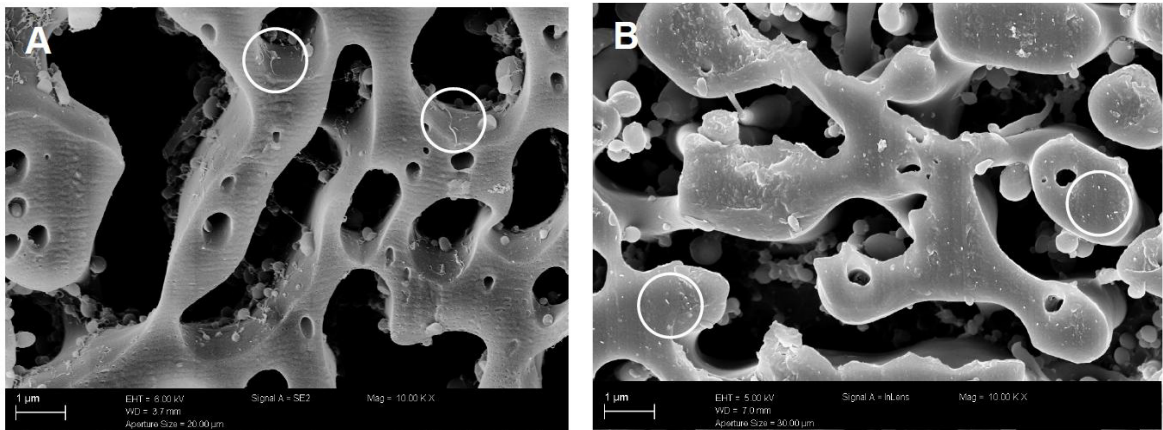


Figure 4: SEM images of nanocomposite blends where the PC phase was selectively hydrolysed (SAN phase and MWCNTs are visible): (A) SAN/PC (40/60) nanocomposite blend without reactive component with MWCNTs (0.5 wt%) located on the surface of the remaining SAN phase and (B) SAN-RC/PC (20-20/60) showing well-embedded MWCNTs (0.5 wt%) in the SAN-RC phase (see circles).

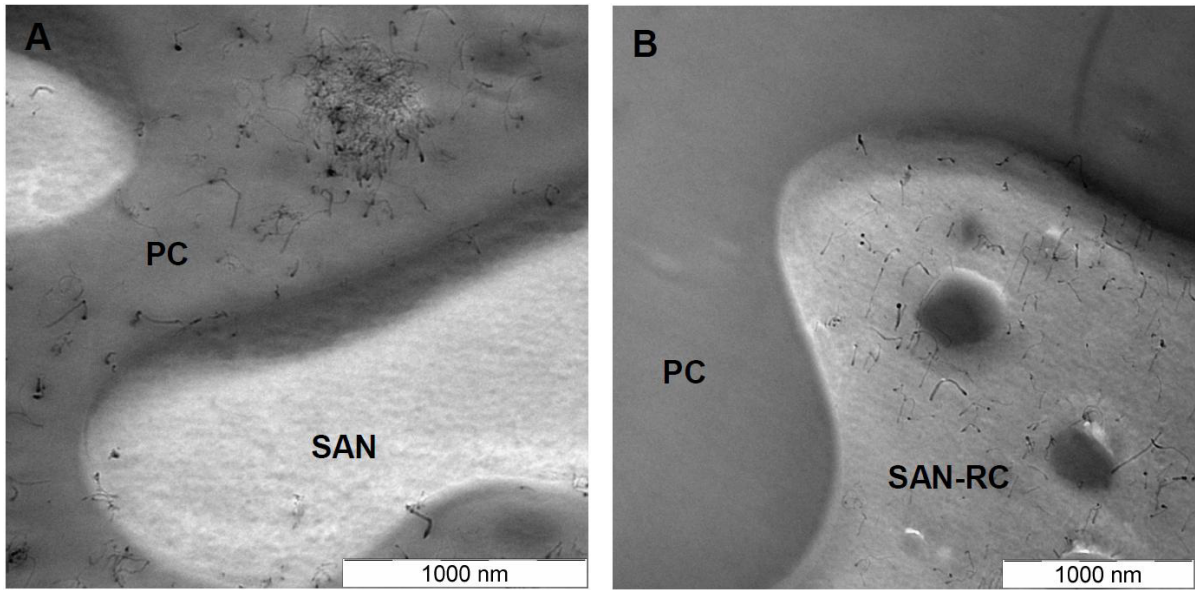


Figure 5: TEM images of nanocomposite blends as one step compound (PC phase appearing dark/smooth, SAN phase bright and ruffled area): (A) SAN/PC (40/60) nanocomposite blend illustrating MWCNTs (0.5 wt%) localized within the PC phase and (B) SAN-RC/PC (20-20/60) showing MWCNTs (0.5 wt%) in the SAN phase.

	Bright Field Image	Nitrogen map	Oxygen map
A: SAN/PC nanocomposite blend with reactive component			
B: SAN/PC nanocomposite blend without reactive component			

Figure 6: Assignment of the blend phases by EF-TEM (PC phase appears dark and smooth, SAN phase as bright and ruffled area): (A) SAN/PC (40/60) nanocomposite blend illustrating MWCNTs (0.5 wt%) localized within the PC phase and (B) SAN-RC/PC (20-20/60) showing MWCNTs (0.5 wt%) in the SAN phase. In the nitrogen maps the bright phase is nitrogen rich (SAN) and the dark phase is nitrogen poor (PC), in the oxygen maps the bright phase is oxygen rich (PC) and the dark phase is oxygen poor (SAN).

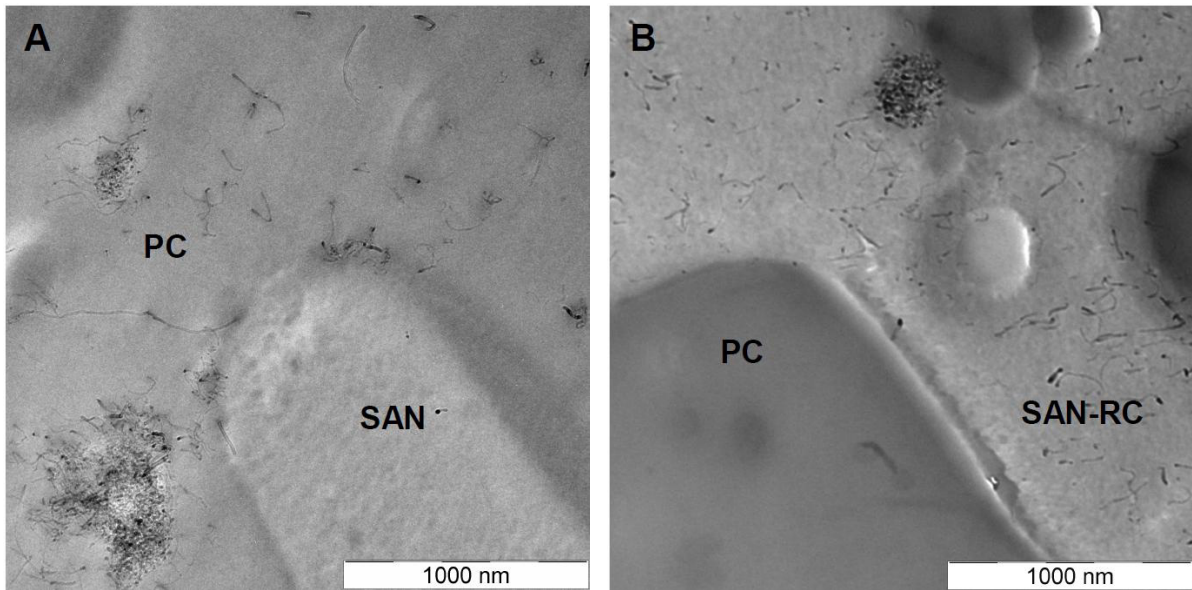


Figure 7: TEM images of set 3: (A) SAN/PC/MWCNT (20/60) nanocomposite blend illustrating MWCNTs (0.5 wt%) localized in the PC phase and (B) after adding 20 wt% of RC in a second mixing step showing MWCNTs in the SAN phase.

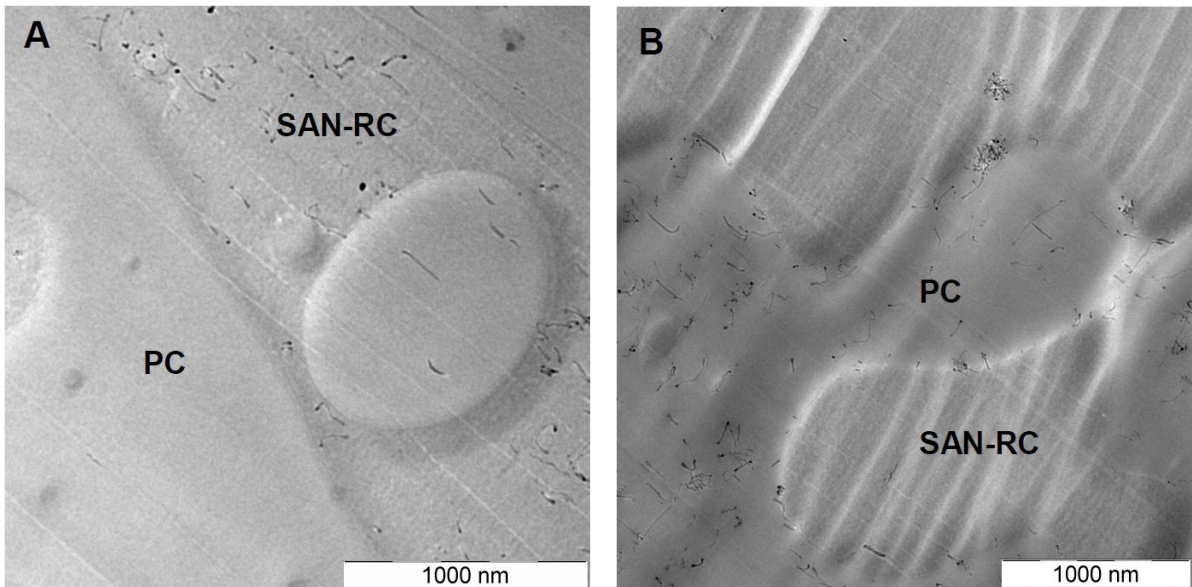


Figure 8: TEM images of set 3 (PC phase appears smooth, SAN-RC phase as ruffled): (A) SAN-RC/PC (38-2/60) blend showing MWCNTs (0.5 wt%) in the SAN-RC phase and (B) SAN-RC/PC (39.8-0.2/60) blend illustrating MWCNTs (0.5 wt%) in the PC phase.

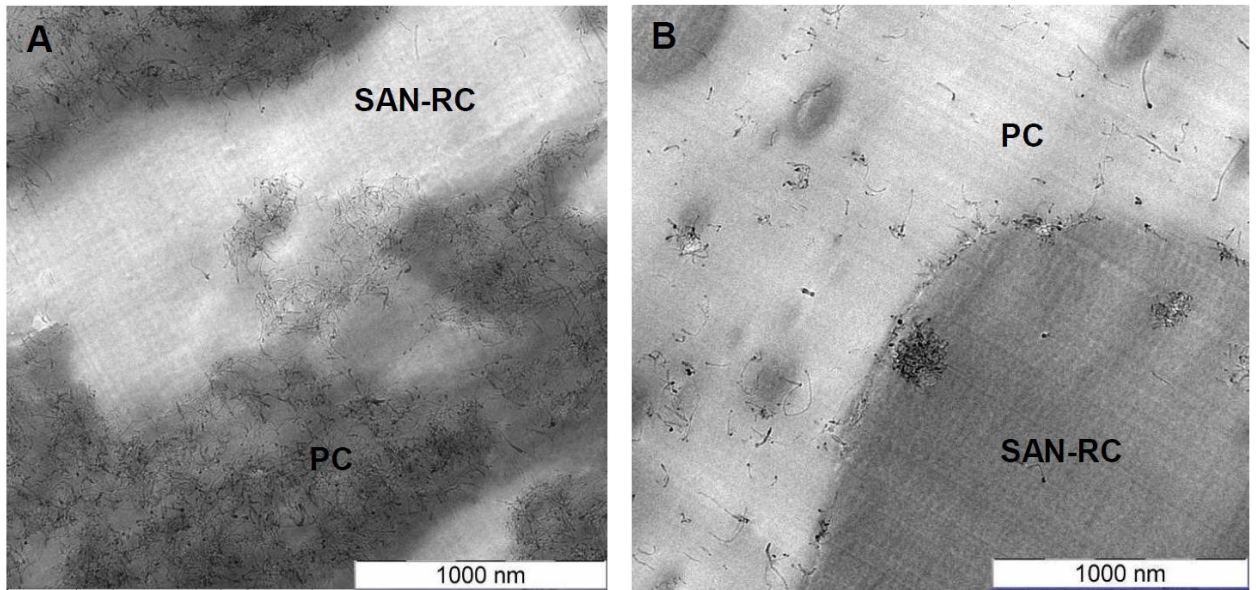


Figure 9: TEM images of set 4: (A) SAN-RC/PC (38-2/60) showing MWCNTs (5 wt%) in both phases and (B) from (A) diluted SAN-RC/PC (39.8-0.2/60) blend with 0.5 wt% MWCNTs illustrating MWCNTs still localized in both phases.