

# Melt Rheological Properties of Polypropylene/Clay Nanocomposites Prepared from Masterbatch: Effect of Nanoclay Loadings and Reprocessing

*by* Dewi Selvia Fardhyanti

---

**Submission date:** 17-Sep-2020 12:50PM (UTC+0700)

**Submission ID:** 1389253166

**File name:** Chafidz\_2019\_IOP\_Conf.\_Ser.\_3A\_Mater.\_Sci.\_Eng.\_543\_012036.pdf (933.99K)

**Word count:** 3702

**Character count:** 19919

PAPER • OPEN ACCESS

## Melt Rheological Properties of Polypropylene/Clay Nanocomposites Prepared from Masterbatch: Effect of Nanoclay Loadings and Reprocessing

Recent citations

- [The use of nanoadditives within recycled polymers for food packaging: Properties, recyclability, and safety](#) 4  
Carol López de Dicastillo *et al*

To cite this article: A. Chafidz *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **543** 012036

View the [article online](#) for updates and enhancements.

# Melt Rheological Properties of Polypropylene/Clay Nanocomposites Prepared from Masterbatch: Effect of Nanoclay Loadings and Reprocessing

A. Chafidz<sup>1</sup>, S. Ma'mun<sup>1,\*</sup>, D. S. Fardhyanti<sup>2</sup>, I. Kustiningsih<sup>3</sup>, A. Hidayat<sup>1</sup>

<sup>1</sup>Chemical Engineering Department, Universitas Islam Indonesia, Yogyakarta 55584, Indonesia

<sup>2</sup>Chemical Engineering Department, Universitas Negeri Semarang, Semarang 50229, Indonesia

<sup>3</sup>Chemical Engineering Department, Universitas Sultan Ageng Tirtayasa, Cilegon 42435, Indonesia

E-mail: [sholeh.mamun@uii.ac.id](mailto:sholeh.mamun@uii.ac.id)

**Abstract.** In the present work, polypropylene (PP) and nanoclay in the form of masterbatch were melt compounded using a co-rotating twin screw extruder to fabricate polypropylene (PP)/clay nanocomposites. PP/clay nanocomposites samples with four different nanoclay loadings (i.e. 0, 5, 10, and 15 wt%) were prepared. Additionally, to study the effect of reprocessing on the properties of the nanocomposites, the melt compounding process was carried twice/ recycle (i.e. 1<sup>st</sup> cycle and 2<sup>nd</sup> cycle). The surface morphological of the nanocomposites and their melt rheological behavior were investigated using a Scanning Electron Microscopy (SEM) and an oscillatory rheometer, respectively. The SEM micrographs showed that the nanoclay was well distributed in the polypropylene matrix for both 1<sup>st</sup> and 2<sup>nd</sup> cycles. While, the dispersion state of the nanoclay (either intercalated or exfoliated) could not be observed due to the limitation of the apparatus. Additionally, the melt rheological analysis results showed that the complex viscosity,  $|\mu^*|$  of all nanocomposites samples (for both 1<sup>st</sup> and 2<sup>nd</sup> cycles) were higher than the neat PP and the  $|\mu^*|$  also increased with the increase of nanoclay loadings. However, the 2<sup>nd</sup> cycle showed a slightly higher improvement of  $|\mu^*|$  compared to the 1<sup>st</sup> cycle, and the improvement of  $|\mu^*|$  was more prominent at lower angular frequencies (e.g. 0.1, 1, 10 rad/s) than at higher ones (e.g. 100, 500 rad/s).

## 1. Introduction

Nanotechnology has become a new trend of research in the world, which could solve problems of the world (e.g. energy, water, food, etc.), and thus affect the economies and societies of the world over the next decades. One of nanotechnology application is polymer nanocomposite (PNC). It is a relatively new class of composites materials that consist of nano-size materials incorporated in polymer matrix [1]. The PNCs have been widely investigated and developed for many applications in the last two decades [2, 3]. It was due to their improved mechanical (e.g. tensile modulus and strength), thermal stability, reduced gas permeability and flammability, etc. as compared to their conventional composites materials [4]. Among the various nanomaterials used for the preparation of nanocomposites, two of the widely investigated nanomaterials are carbon nanotubes (CNTs) and nanoclay or layered silicates, which are one- and two- dimensional nanomaterials, and therefore have a large aspect ratio [5]. The focus of the current work is the nanoclay materials, which has been found to be effective reinforcing nanomaterials due to their availability, economic competitiveness, high aspect ratio, low density, lamellar structure, high specific surface area, etc [6, 7]. Among various types of clay, montmorillonite

(MMT) type of clay has been extensively used in the fabrication of clay based polymer nanocomposites. The aspect ratio of the MMT clay approximately one nm thick and hundreds nm long [2].

Polypropylene (PP) is one of most important and widely used thermoplastic polymers for the production of versatile products in many applications, e.g. automotive, electronics, packaging, etc. It is due to its good mechanical properties, low density and cost, good processability and recyclability [4]. Therefore, fabrication of PP/clay nanocomposites has become an interesting topic of research. The work on these nanocomposites was first started at Toyota Research Laboratory, and until now, the studies about these nanocomposites have been carried out by many researchers [2]. In general, there are three methods to fabricate polymer nanocomposites, which are in-situ polymerization, solution intercalation, and melt compounding/blending [3, 4, 8]. The later one is the most favored and used method to fabricate polymer nanocomposites. It is because this method is simple, use no-solvent, and thus low cost and environmentally friendly. Moreover, this method is very compatible and suitable with existing industrial processes, such as extrusion and injection molding, and thus make the nanocomposites easy to be commercialized [3, 4].

Recently, the use of masterbatch has become an attractive alternative method to produce polymer nanocomposites via melt compounding compared with the use of bulk nanomaterials. Because, this method is a dust free, thus it has low health and safety risks compared to the use of bulk nanomaterials, as well as easy to handle. Additionally, the use of this method could eliminate the dispersion and formulation difficulties [5, 8]. Nevertheless, the number of literatures that studied the use of nanoclay based masterbatch to produce PP/clay nanocomposites were still limited, and thus it becomes an interesting topic of research. In the current work, PP/clay nanocomposites has been fabricated via melt compounding method using a commercial nanoclay based masterbatch. The prepared nanocomposites were characterized for their morphological and rheological properties. The objectives of this work was to effect of nanoclay loadings and reprocessing on the morphological and rheological properties of the prepared nanocomposites.

## 2. Experimental

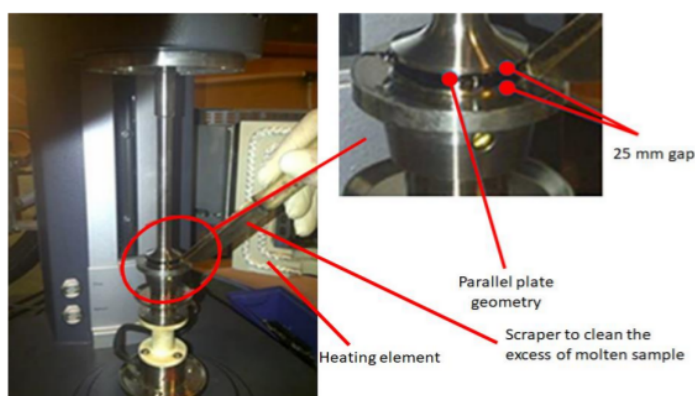
### 2.1. Materials and nanocomposites fabrication

PP/clay nanocomposites were fabricated by melt compounding nanoclay masterbatch pellets (concentration of 50 wt% of nanoclay) with polypropylene (PP) pellets. The masterbatch (product name: NanoMax) was obtained from Nanacor, USA. Whereas, the PP (product name: PP570, MFI 8 g/10 min) was obtained from SABIC, Saudi Arabia. Based on the information provided by the supplier, the nanoclay material is organophilic montmorillonite (MMT) or organoclay, which has been modified with dimethyl-dihydrogenated tallow ammonium. The polymer carrier is PP, which has also been compatibilized with maleic anhydride (MA). The melt compounding process was done in a co-rotating twin screw extruder (TSE). Details about the extruder, preparation step, and processing conditions have been explained in our previous work [4]. The melt compounding process was carried out twice. The first melt compounding process was called 1<sup>st</sup> cycle, and the pellets obtained from the 1<sup>st</sup> cycle was then recycled/reprocessed again using the same procedure to get the 2<sup>nd</sup> cycle nanocomposites pellets. The nanocomposites obtained from the 1<sup>st</sup> cycle were referred to as NC-0-I, NC-5-I, NC-10-I, and NC-15-I for nanoclay loadings of 0, 5, 10, and 15 wt%, respectively. Whereas, the nanocomposites obtained from the 2<sup>nd</sup> cycle were referred to as NC-0-II, NC-5-II, NC-10-II, and NC-15-II. Afterward, all the nanocomposites pellets (i.e. 1<sup>st</sup> and 2<sup>nd</sup> cycle) from the extruder were molded into a set of ASTM standard samples for testing by using an injection molding machine. Details of the injection molding machine and processing conditions have been mentioned in our previous work [4].

### 2.2. Sample characterization

Morphological characterization is carried out by utilizing a Scanning Electron Microscopy (SEM). The SEM used in this work is a JEOL JSM-6360A, Japan. Molded bar samples were cryogenically-fractured

prior to SEM examination. To examine using SEM, first the fractured samples were finely coated with a gold. The coating can minimize the overcharging and overheating of the samples, and also can improve the signal as well as the surface resolution. All the samples were analyzed by the SEM at voltage of 15 kV. Additionally, an oscillatory rheometer instrument model AR G2 (TA Instruments, USA) was used to investigate the effect of nanoclay loadings and reprocessing on the melt rheological characteristic of PP/clay nanocomposites. All the rheological analyses were done using frequency sweep procedure with parallel plates fixture (dia. 25 mm and gap 2 mm). The following test conditions were used: constant temperature of 260°C; oscillation stress of 500 Pa; angular frequency range of 0.1 - 628.3 rad/s. The samples used for this test were disk-like sample from the injection molding machine. Prior to the test, the sample was conditioned first at constant temperature of 260°C until the samples were completely melted. Afterward, the excess of the molten nanocomposites samples around the parallel plates was cleaned to ensure the validity of the analysis. One of the data generated and studied in the current work was complex viscosity  $|\mu^*|$  vs angular frequency ( $\omega$ ). Figure 1 shows a photograph of an oscillatory rheometer with a parallel plates geometry. As seen in the figure, the excess of the molten nanocomposites samples is cleaned prior to the melt rheological test.



**Figure 1.** Photo of an oscillatory rheometer with a parallel plate fixture. (During cleaning proses of the excess molten sample prior to the frequency sweep test

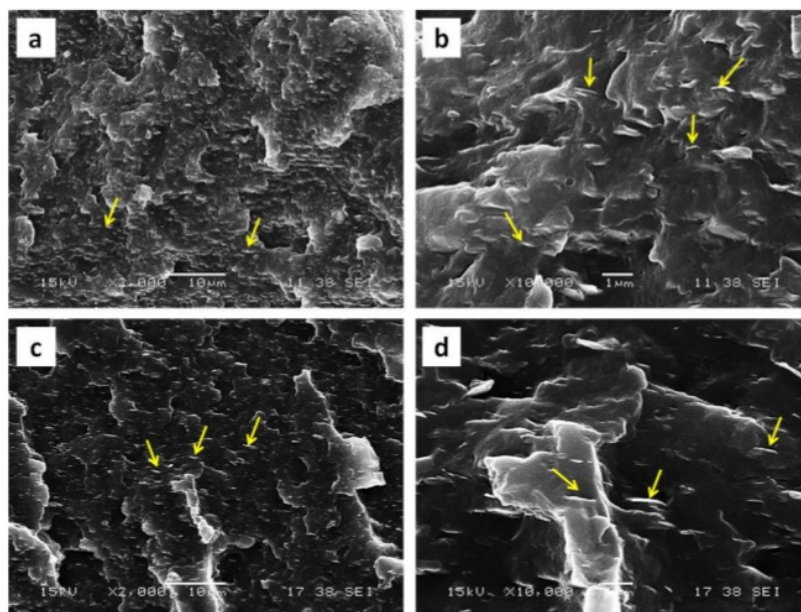
### 3. Results and discussion

The surface morphology of the PP/clay nanocomposites samples for both 1<sup>st</sup> and 2<sup>nd</sup> cycle are shown by scanning electron microscopy (SEM) images depicted in Figures 2a-b and Figures 2c-d, respectively. The distribution of nanoclay platelets in the PP matrix could be analyzed by observing the SEM images. The SEM images shown in Figure 2 were only for nanocomposites samples with nanoclay loading of 5 wt%, i.e. NC-5-I (1<sup>st</sup> cycle) and NC-5-II (2<sup>nd</sup> cycle). In general, the nanoclay platelets were showed by the white needle-like in the dark area of PP matrix (as shown by the arrows). This has been confirmed by an EDX analysis of the SEM, which has been reported in our previous work [9]. As seen in Figure 2a (SEM magnification of 2,000X), the nanoclay platelets of the 1<sup>st</sup> cycle were fairly well distributed in the PP matrix. This distribution of nanoclay platelets were looked more clear at higher SEM magnification, i.e. 10,000X (see Figure 2b).

Whereas, for the nanocomposites 2<sup>n</sup> cycle, the distribution of nanoclay platelets in the PP matrix were quite better than that of the 1<sup>st</sup> cycle, which can be observed in Figures 2c and 2d. This results could be attributed to the fact that during the recycle or melt compounding of PP/clay nanocomposites (1<sup>st</sup> cycle), the nanoclay platelets that already distributed in the PP matrix were redistributed again by the shear stress induced by the twin screw extruder, and thus became much better distributed than the 1<sup>st</sup> cycle. Nevertheless, the dispersion state of the nanoclay (either intercalated or exfoliated) could not be

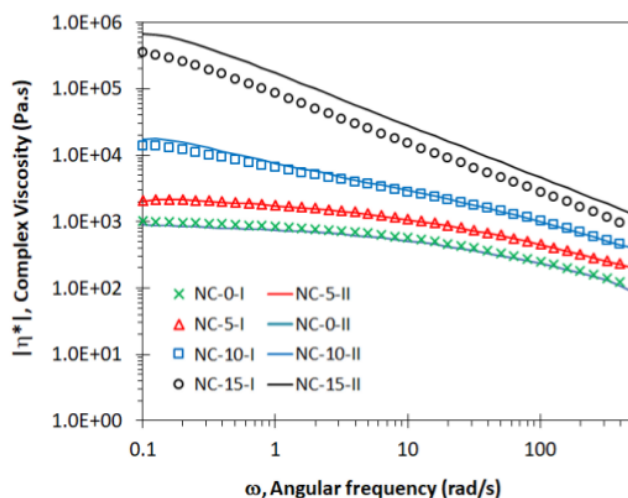


observed in these SEM images. To further study the dispersion state of the nanoclay, better microscopy technique such as Transmission Electron Microscopy (TEM) or Atomic Force Microscopy (AFM) are needed. Additionally, for the rest of the nanocomposites samples, i.e. NC-0, NC-10, and NC-15 for both 1<sup>st</sup> and 2<sup>nd</sup> cycle also showed the similar trend, but they were not presented in this paper.



**Figure 2.** SEM micrographs of a) NC-5-I (2,000X); b) NC-5-I (10,000X); c) NC-5-II (2,000X); and d) NC-5-II (10,000X)

Additionally, the melt rheological analysis of the PP/clay nanocomposites for both 1<sup>st</sup> and 2<sup>nd</sup> cycle samples were also carried out using an oscillatory rheometer instrument. The melt rheological analysis results were presented as the plot of complex viscosity,  $|\eta^*|$  vs angular frequency ( $\omega$ ), as shown in Figure 3. As seen in the figure, the nanocomposites 1<sup>st</sup> cycle and 2<sup>nd</sup> cycle have similar trends. As seen in the figure, the complex viscosity of the nanocomposites for both cycles increased with increasing nanoclay loadings at all angular frequencies. This indicates that the incorporation of nanoclay in the PP matrix has enhanced the complex viscosity of the nanocomposites [10]. This improvement of the  $|\eta^*|$  was likely due to the interaction of nanoclay platelets with the PP matrix that restricted the mobility of the molten PP chains. The higher the nanoclay loadings, the more hindered mobility of the molecular PP chains, and the higher the  $|\eta^*|$  values. Additionally, it was also in accordance with the literature's reports, which mentioned that the distribution and dispersion of nano-materials in the polymer matrix could affect the melt rheological behavior of the nanocomposites [5, 11]. The better the distribution and dispersion of the nano-materials, the better the interaction between the nano-materials and the polymer matrix. Therefore, the  $|\eta^*|$  of the 2<sup>nd</sup> cycle (indicated by solid lines) was slightly higher than that of the 1<sup>st</sup> cycle (indicated by symbols). It was likely due to the better distribution of the nanoclay in the PP matrix compared to the 1<sup>st</sup> cycle.



10

**Figure 3.** The plot of complex viscosity  $|\eta^*|$  vs angular frequency ( $\omega$ ) for PP/clay nanocomposites at different nanoclay loadings for 1<sup>st</sup> cycle (symbols) and 2<sup>nd</sup> cycle (lines)

Furthermore, to observe effect of nanoclay loadings and reprocessing on the melt rheological characteristics of the nanocomposites, several representative complex viscosities of PP/clay nanocomposites (1<sup>st</sup> cycle and 2<sup>nd</sup> cycle) are listed in Table 1 and also plotted in Figure 4. As seen in the table and figure, the  $|\eta^*|$  of both nanocomposites (1<sup>st</sup> and 2<sup>nd</sup> cycle) were all higher than the neat PP, and increased with the increasing nanoclay loadings. Additionally, as mentioned in the previous paragraph, the nanocomposites 2<sup>nd</sup> cycle showed a slightly higher improvement of  $|\eta^*|$  compared to the 1<sup>st</sup> cycle. Additionally, as seen in Table 1 and Figure 4, the improvement of  $|\eta^*|$  was more prominent at lower angular frequencies (e.g. 0.1, 1, 10 rad/s) than at higher ones (e.g. 100, 500 rad/s). For example, at angular frequency of 0.1 rad/s, for the PP/clay nanocomposites 1<sup>st</sup> cycle, the increases of complex viscosity compared to the neat PP (i.e. NC-0-I) were about 101.38%; 1255.77%; and 34,423.23% for NC-5-I; NC-10-I; and NC-15-I, respectively. Whereas, at angular frequency of 500 rad/s, for the PP/clay nanocomposites 1<sup>st</sup> cycle, the increases of complex viscosity compared to the neat PP (i.e. NC-0-I) were about 97.34%; 292.49%; and 626.59% for NC-5-I; NC-10-I; and NC-15-I, respectively.

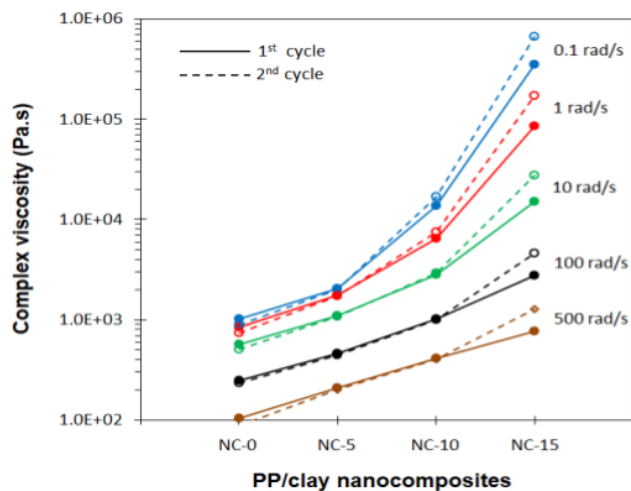
**Table 1.** Representative complex viscosity of PP/clay nanocomposites (1<sup>st</sup> cycle and 2<sup>nd</sup> cycle)

Ang. Freq. (rad/s)	PP/clay nanocomposites - 1 <sup>st</sup> cycle				PP/clay nanocomposites - 2 <sup>nd</sup> cycle			
	NC-0-I	NC-5-I	NC-10-I	NC-15-I	NC-0-II	NC-5-II	NC-10-II	NC-15-II
0.1	1022.5	2059.1	13862.7	353000.0	895.5	2007.8	17045.0	666000.0
1	846.7	1778.0	6499.7	85060.5	746.2	1739.1	7547.2	172000.0
10	567.4	1101.4	2811.3	15000.8	512.3	1071.2	2936.4	27733.3
100	250.5	458.3	1027.5	2787.0	232.5	448.1	1001.4	4585.4
500	105.3	207.8	413.3	765.1	87.5	202.5	408.8	1270.7

The similar results also found for the PP/clay nanocomposites 2<sup>nd</sup> cycle. For example, at angular frequency of 0.1 rad/s, the increases of complex viscosity compared to the neat PP (i.e. NC-0-II) were about 124.21%; 1803.41%; and 74,271.86% for NC-5-II; NC-10-II; and NC-15-II, respectively. Whereas, at angular frequency of 500 rad/s, for the PP/clay nanocomposites 2<sup>nd</sup> cycle, the increases of complex viscosity compared to the neat PP (i.e. NC-0-II) were about 131.43%; 367.2%; and 1352.23% for NC-5-II; NC-10-II; and NC-15-II, respectively. As seen from the results, at low angular frequencies,

the presence of nanoclay platelets on the melt rheological properties of the nanocomposites was more prominent. The interaction between the matrix and the nanoclay resulted in considerable improvement of complex viscosity of the nanocomposites. Whereas, at higher angular frequencies, the nanoclay layers have oriented due to the shear induced by the rheometer apparatus, thus the effect of interaction between the matrix and the nanoclay on the complex viscosity of the nanocomposites was much lower.

Additionally, as seen in Figure 4, the  $|\eta^*|$  of the 2<sup>nd</sup> cycle (indicated by dashed lines) was higher than that of the 1<sup>st</sup> cycle (indicated by solid lines). The differences of  $|\eta^*|$  were more prominent at higher nanoclay loading (e.g. 15 wt%) than at neat PP (i.e. 0 wt%) and at lower nanoclay loadings (e.g. 5, 10 wt%). Whereas, the effect of angular frequencies on the differences of  $|\eta^*|$  between 1<sup>st</sup> and 2<sup>nd</sup> cycles for all nanoclay loadings was not significant. As seen in Table 1 and Figure 4, the differences of  $|\eta^*|$  between 1<sup>st</sup> and 2<sup>nd</sup> cycles at 15 wt% of nanoclay load (i.e. NC-15-I vs NC-15-II) were about 313,000; 86,939; 12,732; 1798; and 505 Pa.s for angular frequencies of 0.1; 1; 10; 100; and 500 rad/s, respectively.



**Figure 4.** The plot of representative complex viscosity  $|\eta^*|$  at several angular frequencies ( $\omega$ ) for PP/clay nanocomposites at different nanoclay loadings for 1<sup>st</sup> cycle (solid lines) and 2<sup>nd</sup> cycle (dashed lines)

#### 4. Conclusion

The effects of nanoclay loadings and reprocessing on the morphology and melt rheological properties of the PP/clay nanocomposites have been investigated. In order to study the reprocessing effect on the properties of PP-nanoclay composites, melt compounding was carried out twice/recycle (i.e. 1<sup>st</sup> cycle and 2<sup>nd</sup> cycle). Morphological study on the nanocomposites revealed that all the nanocomposites samples (both 1<sup>st</sup> cycle and 2<sup>nd</sup> cycle) showed good distribution of nanoclay platelets in PP matrix at all nanoclay loadings. In melt rheological behavior, all the nanocomposites samples for both 1<sup>st</sup> cycle and 2<sup>nd</sup> cycle exhibited higher complex viscosity than the neat PP. The complex viscosity of the nanocomposites increased with increasing nanoclay loadings at all angular frequencies. However, the improvement of  $|\eta^*|$  was more prominent at lower angular frequencies (e.g. 0.1, 1, 10 rad/s) than at higher ones (e.g. 100, 500 rad/s). For example, at angular frequency of 0.1 rad/s, for the PP/clay nanocomposites 1<sup>st</sup> cycle, the increases of complex viscosity compared to the neat PP (i.e. NC-0-I) were about 101.38%; 1255.77%; and 34,423.23% for NC-5-I; NC-10-I; and NC-15-I, respectively. Whereas, at angular frequency of 500 rad/s, for the PP/clay nanocomposites 1<sup>st</sup> cycle, the increases of complex viscosity compared to the neat PP (i.e. NC-0-I) were about 97.34%; 292.49%; and 626.59% for NC-5-



I; NC-10-I; and NC-15-I, respectively. Additionally, the 2<sup>nd</sup> cycle showed a slightly higher improvement of  $|\eta^*|$  compared to the 1<sup>st</sup> cycle. The differences of  $|\eta^*|$  were more prominent at higher nanoclay loading (e.g. 15 wt%) than at neat PP (i.e. 0 wt%) and at lower nanoclay loadings (e.g. 5, 10 wt%). Whereas, the effect of angular frequencies on the differences of  $|\eta^*|$  between 1<sup>st</sup> and 2<sup>nd</sup> cycles for all nanoclay loadings was not significant.

### References

- [1] Martínez-Colunga J G, Sánchez-Valdés S, Ramos-deValle L, Muñoz-Jiménez L, Ramírez-Vargas E, Ibarra-Alonso M C, Lozano-Ramirez T, and Lafleur P G 2014 Simultaneous polypropylene functionalization and nanoclay dispersion in PP/Clay nanocomposites using ultrasound *J. Appl. Polym. Sci.* **131** 40631-42.
- [2] Lee S, Yoo J, and Lee J W 2015 Water-assisted extrusion of polypropylene/clay nanocomposites in high shear condition *J. Ind. Eng. Chem.* **31** 317-22.
- [3] Zhang G, Wu T, Lin W, Tan Y, Chen R, Huang Z, Yin X, Qu J 2017 Preparation of polymer/clay nanocomposites via melt intercalation under continuous elongation flow *Compos Sci Technol.* **145** 157-64.
- [4] Chafidz A, Latief F H, Samad U A, Ajbar A, Al-Masry W 2016 Nanoindentation creep, nano-impact, and thermal properties of multiwall carbon nanotubes-polypropylene nanocomposites prepared via melt blending *Polym-Plas. Technol.* **55** 1373-85.
- [5] Chafidz A, Kaavessina M, Al-Zahrani S, Al-Otaibi M N 2016 Rheological and mechanical properties of polypropylene/calcium carbonate nanocomposites prepared from masterbatch, *J. Thermoplast. Compos.* **29** 593-22.
- [6] Wang M, Fan X, Thitsartarn W, He C 2015 Rheological and mechanical properties of epoxy/clay nanocomposites with enhanced tensile and fracture toughnesses *Polymer* **58** 43-52.
- [7] Adak B, Joshi M, Butola B S 2018 Polyurethane/clay nanocomposites with improved helium gas barrier and mechanical properties: Direct versus masterbatch melt mixing route *J. Appl. Polym. Sci.* **135** 46422.
- [8] Pokharel P, Lee D S 2014 High performance polyurethane nanocomposite films prepared from a masterbatch of graphene oxide in polyether polyol *Chem. Eng. J.* **253** 33-65.
- [9] Chafidz A, Kaavessina M, Al-Zahrani S, Al-Otaibi M N 2014 Polypropylene/organoclay nanocomposites prepared using a Laboratory Mixing Extruder (LME): crystallization thermal stability and dynamic mechanical properties, *J. Polym. Res.* **21** 483-95.
- [10] La-Mantia F P, Scaffaro R, Ceraulo M, Mistretta M C, Dintcheva N T, Botta 2016 A simple method to interpret the rheological behaviour of intercalated polymer nanocomposites, *Compos. Part B: Eng.* **98** 382-88.
- [11] Choi H J, Kim S G, Hyun Y H, Jhon M S 2001 Preparation and Rheological Characteristics of Solvent-Cast Poly(ethylene oxide)/Montmorillonite Nanocomposites *Macromol. Rapid Comm.* **22** 320-25.

# Melt Rheological Properties of Polypropylene/Clay Nanocomposites Prepared from Masterbatch: Effect of Nanoclay Loadings and Reprocessing

## ORIGINALITY REPORT

8%

SIMILARITY INDEX

%

INTERNET SOURCES

%

PUBLICATIONS

%

STUDENT PAPERS

## PRIMARY SOURCES

1	<a href="http://www.scientific.net">www.scientific.net</a> Internet Source	3%
2	<a href="http://www.tandfonline.com">www.tandfonline.com</a> Internet Source	1%
3	<a href="http://zh.scientific.net">zh.scientific.net</a> Internet Source	1%
4	<a href="http://ulir.ul.ie">ulir.ul.ie</a> Internet Source	<1%
5	<a href="http://vdocuments.site">vdocuments.site</a> Internet Source	<1%
6	Roger M. Downs. "The Development of Expertise in Geography: A Cognitive-Developmental Approach to Geographic Education", <i>Annals of the Association of American Geographers</i> , 6/1991 Publication	<1%
7	Kusmono. "Compatibilizing effect of SEBS-g-MA	

on the mechanical properties of different types of OMMT filled polyamide 6/polypropylene nanocomposites", Composites Part A, 200812

Publication

<1%

8

Submitted to Universitas Islam Indonesia

Student Paper

<1%

9

[rheology.tripod.com](http://rheology.tripod.com)

Internet Source

<1%

10

M. M. Salehi, H. Nazockdast, G. R. Pircheraghi. "The Role of Organoclay on Microstructure Development and Rheological Properties of Poly(Butylene Terephthalate)/Epoxy/Organoclay Hybrid Systems", Journal of Macromolecular Science, Part B, 2011

Publication

<1%

11

[worldwidescience.org](http://worldwidescience.org)

Internet Source

<1%

12

Ryo Mogi, Minoru Inaba, Takeshi Abe, Zempachi Ogumi. "In situ atomic force microscopy observation of lithium deposition at an elevated temperature", Journal of Power Sources, 2001

Publication

<1%

13

Han Yin. "Orientation behavior of attapulgite nanoparticles in poly(acrylonitrile)/attapulgite solutions by rheological analysis", Journal of

<1%

14

A. E. Bonilla-Blancas, I. C. Romero-Ibarra, J. Vazquez-Arenas, A. Sanchez-Solis, O. Manero, J. Alvarez-Ramirez. "Molecular interactions arising in polyethylene-bentonite nanocomposites", Journal of Applied Polymer Science, 2018

Publication

<1%

---

15

Weiguo Shao, Qi Wang, Feng Wang, Yinghong Chen. "Polyamide-6/natural clay mineral nanocomposites prepared by solid-state shear milling using pan-mill equipment", Journal of Polymer Science Part B: Polymer Physics, 2006

Publication

<1%

---

16

Sinha Ray, S.. "Polymer/layered silicate nanocomposites: a review from preparation to processing", Progress in Polymer Science, 200311

Publication

<1%

---

17

Hong Yan Ji, Ying Liu, Xiu Ting Zheng, Li Min Meng, Da Ming Wu, Hong Xu. "Study on the Reflecting Properties of PET Composites with TiO<sub>2</sub>, Glass Beads and Fluorescent Brightener", Applied Mechanics and Materials, 2012

Publication

<1%

---



---

Exclude quotes Off

Exclude matches Off

Exclude bibliography Off