



Influence of Low-Grade Bentonite Modification on Mechanical, Thermal and Electrical Properties of PVC/Clay Nanocomposites for Electrical Applications

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THE main aim of this research is to investigate the suitability of using a low-grade bentonite in poly vinyl chloride (PVC)/clay nanocomposites for electrical applications. Bentonite was modified using Benzalkonium Chloride (BAC) as cationic surfactant, then both raw and modified bentonite (RB and MB) were introduced as fillers in mixture with PVC resin, plasticizer and stabilizer to produce PVC insulation compound for cables manufacturing. X-ray diffraction (XRD) and X-ray fluorescence (XRF) analysis were carried out to investigate the mineralogical and chemical composition of bentonite sample. Fourier transform infrared spectroscopy (FT-IR), scanning electron microscope (SEM) and contact angle (CA) tests were performed on PVC insulation compound to investigate the interaction and compatibility between bentonite and PVC. Further investigations were established to characterize mechanical, thermal, and electrical properties of PVC compounds. The bentonite sample results show that bentonite is of low-grade bentonite. PVC/ clay insulation compounds results show that compatibility between PVC and bentonite increases in case of using modified bentonite (MB), therefore, the hydrophobicity of resulted PVC compound increased. Moreover, PVC/ MB nanocomposites show better mechanical properties (such as tensile strength and elongation at break) than PVC/ raw bentonite (RB) nanocomposites; the tensile strength values have increased from 21.1, 20, 19.1, and 18.2 N/mm² for 2.5, 5, 7.5, and 10 phr of RB, respectively, for PVC/RB nanocomposite samples to 22.4, 21.3, 20.5, and 20 N/mm² for the corresponding PVC/MB nanocomposites. On contrast, PVC/ RB nanocomposites give significantly better thermal properties (thermal stability) and electrical properties; the volume resistivity were decreased from 1.071012 for PVC/RB nanocomposites 10 phr of RB for to $5.86 \times 10^{10} \Omega\text{-cm}$ for the corresponding PVC/MB nanocomposite.

Keywords: Benzalkonium, Low-grade bentonite, insulation, nanocomposites, PVC, volume resistivity.

Introduction

Bentonite is composed of an octahedral layer of aluminum silicate that is incorporated between two tetrahedral layers of silicates (Konta, 1995). The Ion-deficiency of the bentonite is high relative to other clay minerals, and thus bentonite is characterized by properties such as Thixotropy, ion-exchange capacity, and adsorption (Grim, 1962), and it can be used in several industries

and applications (Seidov & Alizade, 1970). Moreover, it can be used in oil, gas, and water drilling operations. Furthermore, it is used also in refractory, pharmaceutical, foundry, and plastics industries (Murray, 2007) (Abdel-Motelib, *et al.*, 2011).

Bentonite is a hydrophilic material that is poorly compatible with hydrophobic polymer materials. Therefore, bentonite is modified with

proper surfactants to increase its hydrophobicity, and consequently; increase its compatibility with polymer materials. So modified bentonite is used properly as a filler in variety of polymer industries such as polystyrene (PS), polyethylene (PE), and polypropylene (PP) (Ean, *et al.*, 2003; Alekseeva, *et al.*, 2009; Alekseeva, *et al.*, 2012). In another hand. Wang, *et al.*, 2001 made successful trial to prepare and characterize PVC/ modified montmorillonite nanocomposites using melt compounding method. Many researches have followed that to improve the resulting properties of PVC/ montmorillonite nanocomposites using melting compound method (Matuana, 2009), in situ polymerization method (Wang, *et al.*, 2019) and solution blending method (Wang & Wilkie, 2002; Arunvisut, *et al.*, 2007; Madaleno, *et al.*, 2010) have studied the effect of nanosized organoclay as a filler in plastics industries. Motawie, *et al.*, 2014 have studied the effect of nano-size organo clay on the physical and chemical properties of PVC compound.

In this research, low-grade Egyptian bentonite from El-Fayium was modified using quaternary ammonium chloride surfactant – Benzalkonium chloride- as cationic surfactant, then mixed with PVC resin and proper additives by melt compounding method to produce PVC/ MB nanocomposites. Therefore, this research will focus on characterization of PVC/MB nanocomposites for electrical cable applications.

Geologic setting

The bentonite sample used in this research was collected from the claystone quarries located in Kom-Oshim area, El-Fayoum governorate, Egypt. The bentonite deposits belonged to Qasr El-Sagha Formation of the Upper Eocene age (Elewa, *et al.*, 1998). The studied area is situated between latitude 31° 20" and 35° 12" north and longitude 50° 10" and 59° 00" east (Fig. 1). (Abd El-Aziz, 2002) studied the stratigraphy of El-Fayoum province (Table 1). Qasr El-Sagha Formation is divided into two main members; the Temple member at the base and the Abu Lifa member at the top (Gringrgerich, 1992; Abayazeed, 2012). Swedan, (1992) subdivided Qasr El Sagha formation into five units from top to base as follows:

1. Sandy limestone (1.5 m), at the top.
2. Loose sands (19.0 m).
3. Clay, calcareous sandstone and limestone intercalations (28.0 m)
4. Interbedded purple clay with fine sand interbeds (19.0 m).
5. Gypsiferous sandy clay with fossiliferous calcareous sandstone (91.0 m), at the base.

The total thickness of the lowest two units equal about 110 m representing the bulk of the claystone-siltstone interbeds. Some of these strata were exploited at Gebel Qasr El-Sagha as bentonitic clays or around Kom Oshim village as bentonite (Kandil, 1989; El-Mahllawy, *et al.*, 2013).



Fig. 1. location of bentonite deposits in Kom Oshim in El-Fayoum, Egypt

TABLE 1. The Stratigraphic sequences -with thickness- of Kom-Oshim in El-Fayium area.

Age		Sequence	Thickness	
Miocene		Khashab Formation	>100 m	
Oligocene	Late	Widan El-Faras Basalt	0-10 m	
	Early	Widan El-Faras Basalt	1-10 m	
		Gebal Qatrani Formation	340 m	
Eocene	Late	Qasr El Sagha Formation	Abu Lifa Member	71 m
			Temple Member	123 m
		Berkat Qarun Formation	50 m	
	Middle	Gehanam Formation	70 m	
Wadi Rayan Formation		130 m		

METHODOLOGY

Sample Treatment

Crushing: A representative sample of bentonite was pulverized in the Egyptian mineral recourses authority (EMRA). 2.5 kilograms of bentonite sample were crushed to very fine grain size using the attritor mill Union process. The resulted product was analyzed using XRD and XRF analyses.

Modification of bentonite by Surface treatment method

Surface-modified bentonite was prepared in this research according to (Yun-Hwei, 2001; Mousavi, et al., 2006; Khalil, 2013). Preparation of MB was divided into two processes; the washing of bentonite sample from salts, and the addition of benzalkonium chloride (alkyl dimethyl benzyl ammonium chloride) as a surfactant to produce the hydrophobically MB. About 25 g of bentonite powder was stirred in 500 ml of distilled water using magnetic stirrer at 50 for 30 minutes. This step was done to wash the bentonite from accompanied salts.

The resulted mixture was filtered in filter papers and washed several times with distilled water. The resulted sample was inserted with 500 ml distilled water in addition to 25 ml of 0.5 mole Solution of BAC as quaternary amine surfactant. The mixture was stirred at 45 for 4 hours, the resulted mixture left at room temperature for 24 hours. The mixture was filtered by filter paper and washed several times to get rid of excess BAC. The resulted sample was dried at 105 in conventional oven for about 24 hours. The dried sample was pulverized by the attritor mill Union process to produce

surface-treated bentonite.

Characterization of bentonite

X-ray Fluorescence Analysis: XRF analysis was established for bentonite sample in XRF lab in EMRA, to determine the chemical composition of the bentonite sample.

X-ray Diffraction Analysis: The mineralogical composition of bentonite was analyzed by X-Ray Diffraction Analysis by P- analytical X-Ray Diffractometer equipment model X pert Pro with Mono-Chromator; Cu-radiation ($\lambda=1.542\text{\AA}$) at 50 K. V.,40 M.A, and Scanning Speed 0.02 O/ sec were used. The diffraction charts and relative intensities are obtained and compared with ICDD files.

Fourier transformed infrared (FT-IR) Spectroscopy: Spectra of PVC-free of bentonite composites, PVC/bentonite nanocomposites, and PVC/MB nanocomposites samples were recorded with wave number from 400 to 4000 nm^{-1} using FT-IR Spectrometer, model: JASCO, with resolution of 4 cm^{-1} at room temperature, and scan speed of 2 mm/Sec.

Scanning Electron Microscope SEM: morphologies of polymer composites were imaged using scanning electron microscope (SEM), model: Nova.

Water angle contact: Contact angles were determined using Theta optical tensiometer, Model: Attension. A droplet of filtered deionized distilled water was placed on the surface of PVC/ bentonite, and PVC/MB nanocomposite samples at room temperature. After 1 minute, the contact angles (right contact angle θ_r , and left contact

angle θ_j) were measured.

Preparation of PVC Composites

A standard PVC composite sample was prepared firstly without a filler as PVC natural insulation compound according to both IEC (2004) 60502-1 and BS (2005) 50363-3 standards for insulating PVC compounds. The sample was prepared by heating of PVC Resin in 100 per hundred resin (phr), Di-octyl Phthalate (DOP) as plasticizer in 50 phr and Ca/Zn-based stabilizer in 3 phr. Egyptian raw bentonite (RB) and MB were added as a filler in each of 2.5, 5, 7.5, and 10 phr (Table 2).

The test sample was mixed in Benchtop Lab Mixer (make: Lab-Tech) at 2000 rotation per minute (rpm) till the complete formation of a dry blend of PVC insulation compound. The dry blends were mixed in a double roll mill machine at 135 to form homogenous long sheets. A sample of the resulted long sheets was subjected to heat in compression press machine (make: CEAST) at 195 for 5 minutes to prepare test sheets of PVC composite with 12 cm length, 12 cm width, and 0.1 cm thickness.

Characterization techniques of PVC/bentonite nanocomposites

Characterization of Mechanical properties

Tensile strength and Elongation at break test is a significant test, which indicates the mechanical properties of the plastics. PVC/bentonite nanocomposite test samples were prepared according to ASTM (2019) D 638: standard methods for Tensile and Elongation of plastics. The test was performed using a computerized universal tensile machine (model: CEAST). Tensile strength results were estimated at Newton per millimeter square (N/mm^2), and elongation at break results was estimated as percentage value (%).

Density test is another significant mechanical test. The density of PVC/bentonite nanocomposites samples was estimated in gram per cubic centimeters (g/cm^3), and the test was performed according to the ASTM (2019) D792 standard method for density of plastics using AG balance meter (make: Mettler Toledo). Sheeted samples with dimensions of $1 \times 1 \times 0.1$ cm were used as test specimens at a temperature of 20–25°C.

Characterization of Thermal properties A thermal stability test was carried out according

to the IEC (1985) 811–Part 3–2: International standard method for Thermal Stability test. About 0.05 ± 0.002 gram was inserted into a small glass tube (inner diameter equals 4.0 ± 0.4 mm). A pH paper with a pH range of 1 to 10 was placed on the top of the glass tube as an indicator of the effervescence of colorless chloride atoms of PVC. The glass tube was inserted into a thermal stability Meter (model no. 100 –make GP) at 200 ± 0.5 °C. The thermal stability of the sample was estimated by calculating the duration time since inserting the glass tube to the instrument until the appearance of the faint blue color using a suitable time meter.

Characterization of Electrical properties: The volume resistivity test was carried out according to the ASTM (2019) D257 standard method for the insulation resistance of materials, to evaluate the electrical properties of PVC insulation compounds. The sample sheets were immersed in water for 12 hours at a temperature of 20 ± 5 °C, then the sample sheet was dried then inserted between the electrodes of high resistance meter (model no. 4339 B – make: Agilent).

Results and Discussion

Characterization of bentonite samples

X-ray Diffraction Analysis

XRD results in Figure 2 show that the sample is composed mainly from bentonite, with significant amounts of Quartz and kaolinite, which indicate that the sample can be considered as a low-grade bentonite.

X-ray Fluorescence Analysis

XRF results in Table 3 show that the sample of bentonite is composed from SiO_2 with 50.12% and Al_2O_3 with 21.19% as the main constituents of bentonite and kaolinite. The proportion of CaO in the sample is significantly more than Na_2O , which indicate that bentonite sample is calcic bentonite.

Characterization of PVC composites samples

Fourier transformed infrared (FT-IR) Spectroscopy

Fourier transformed infrared spectroscopy (FT-IR) of PVC composite-free from filler, PVC/RB nanocomposite and PVC/MB nanocomposite samples are illustrated in Figure 3 to investigate their chemical structure (Yue, *et al.*, 2019).

The infrared spectrum of PVC composite-free from filler in Figure 3 shows the presence of vibration C-CL at 607 nm^{-1} as an evidence of the presence of PVC. Sharp strong peak at 3640 nm^{-1}

TABLE 2. The Formulations of PVC/RB nanocomposite samples and PVC/ MB nanocomposite samples in Part per Hundred resins (phr).

Material	PVC Resin (k-67)	Filler		DOP Plasticizer	Stabilizer (Ca/Zn based stabilizer)
		RB	MB		
PVC - free from fillers	100	-	-	50	3
PVC /2.5 RB ^a	100	2.5	-	50	3
PVC /5 RB	100	5	-	50	3
PVC /7.5 RB	100	7.5	-	50	3
PVC /10 RB	100	10	-	50	3
PVC /2.5 MB ^b	100	-	2.5	50	3
PVC /5 MB	100	-	5	50	3
PVC /7.5 MB	100	-	7.5	50	3
PVC /10 MB	100	-	10	50	3
^a Raw Bentonite					
^b Modified Bentonite					

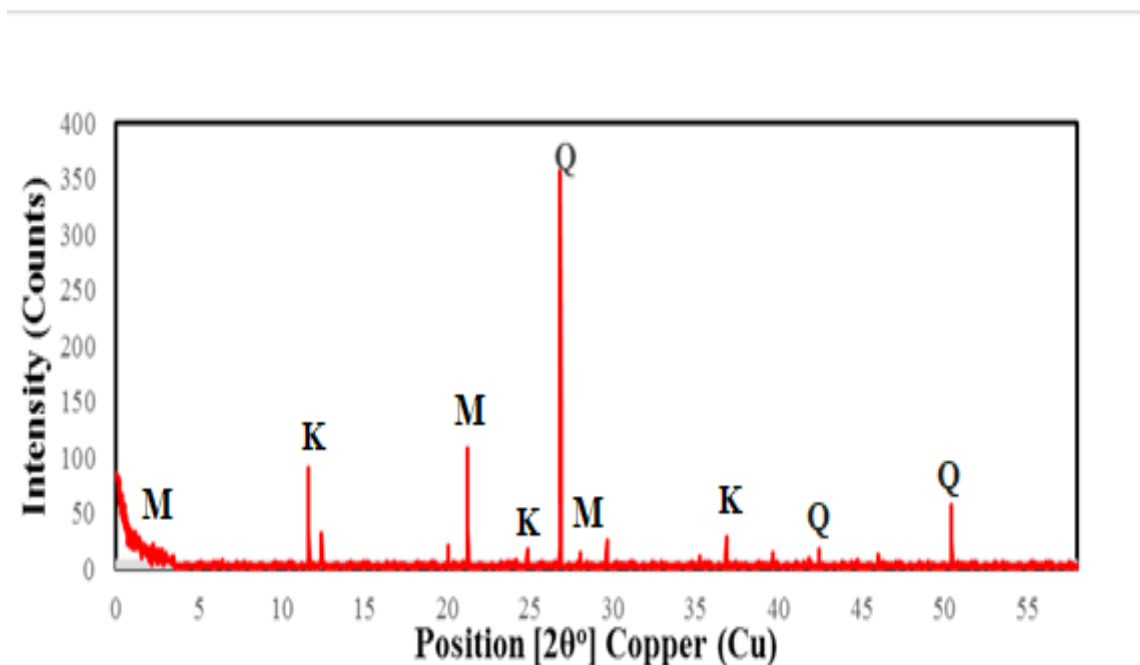


Fig.2. XRD chart of raw bentonite samples: M is Montmorillonite (PDF 00-013-0135), K is kaolinite (PDF 01-089-6538) and Q is quartz (PDF 01-078-2315).

TABLE 3. The X-ray fluorescence chemical analysis results (in wt. %) of the Egyptian raw bentonite.

Item	Egyptian Raw Bentonite
SiO ₂	50.12
TiO ₂	1.23
Al ₂ O ₃	21.19
Fe ₂ O ₃	7.49
MnO	0.1
MgO	2
CaO	4.45
Na ₂ O	1.35
K ₂ O	1.59
P ₂ O ₅	0.22
Cl	0.24
SO ₃	2.04
LOI	7.51
Total	99.53

indicates CaO of stabilizer. The vibration 1752 nm⁻¹ belongs to vinyl group (Elena *et al.*, 2020).

The infrared spectrum of PVC/RB nanocomposite in Figure 3 show the presence of stretching vibration spectrum of Al-OH at 3625 nm⁻¹, as evidence for the presence of raw bentonite. On the other hand, the infrared spectrum at Figure 3 shows the presence of both asymmetrical stretching vibration at 2957 nm⁻¹ and vibration spectrum at 2867 nm⁻¹. These two peaks indicate the presence of BAC, which indicate the interaction between bentonite and BACe as cationic surfactant.

Scanning Electron Microscope SEM

SEM micrograph in Figure 4-a shows significant dense irregular distribution of bentonite aggregates in the surface of sheet sample of PVC/RB nanocomposite. In the other hand, PVC/MB nanocomposite micrograph in Figure 4-b show remarkable low amount of bentonite aggregates at the surface. The dense distribution of raw bentonite in Figure 4-a can be revealed as a result of the incompatibility between PVC and bentonite particles (Abdel-Gawad, *et al.*, 2020), but in the case of PVC/MB nanocomposite, the bentonite

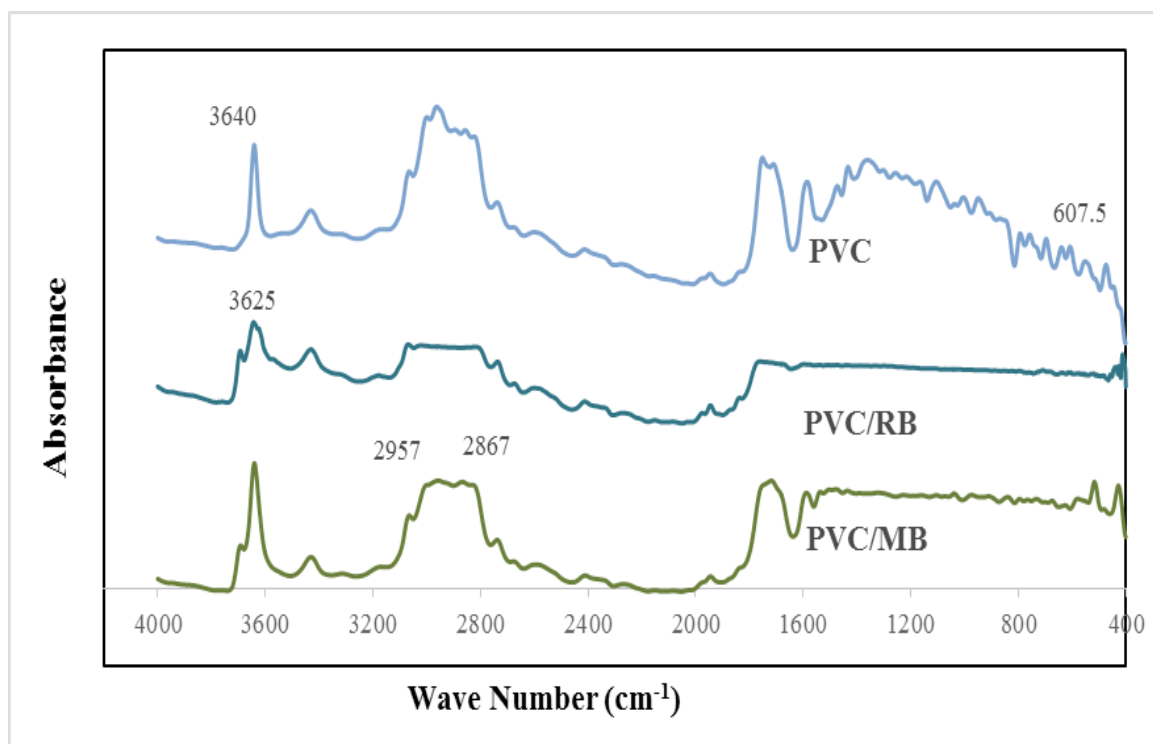


Fig.3. FT-IR charts for PVC-free from bentonite composite (PVC), PVC/RB nanocomposite (PVC/RB) and PVC/MB nanocomposite (PVC/MB).

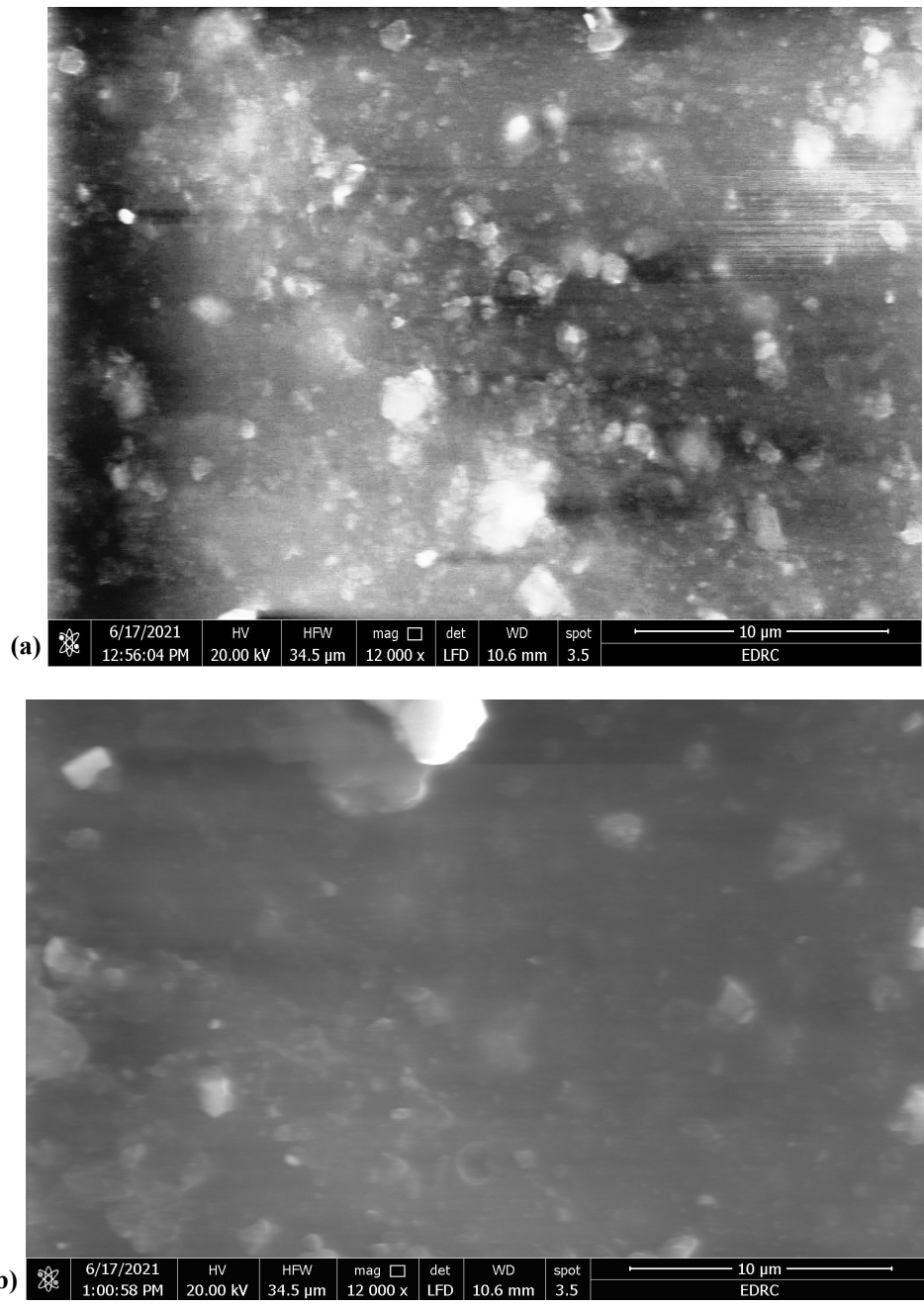


Fig. 4. Scanning electron microscope (SEM) micrographs for: a- PVC/RB nanocomposite, b- PVC/MB nanocomposite.

aggregates seem to be incorporated with PVC due to the increase of compatibility between them.

Water angle contact

The contact angle of PVC/MB at figure 5-b shows significant increase of both right contact angle CA_r and left contact angle CA_l with values 109.89° and 108.41° respectively, than the corresponding CA_r and CA_l of PVC/RB with values 101.88° and 102.56° respectively (Figure

5-b). The relative increase of contact angle of PVC/MB Nano composites after bentonite modification indicates increase of hydrophobicity of PVC composites (Shah, *et al.*, 2020). These could be revealed as result of increase of hydrophobicity of bentonite after its modification with BAC as cationic surfactant; nonetheless, these ensure the increase of compatibility between surface-modified bentonite and hydrophobic PVC resins,

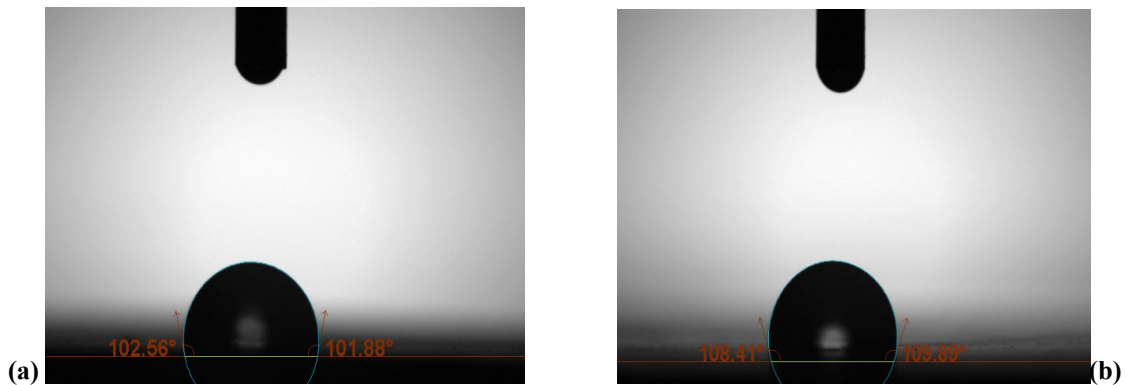


Fig. 5. Contact angle graph for: a- PVC/RB nanocomposite, b- PVC/MB nanocomposite.

as deduced by SEM results.

Characterization of Mechanical properties

The tensile strength, elongation at break and density of PVC/bentonite nanocomposites have been obtained, the results are shown in Table 4 and Figure 6

Tensile strength test results (Table 4 and Figure 6-a) show that the tensile strength value for the standard free filler-PVC composite sample equals to 23.1 Newton per square millimeter (N/mm^2). This value decreased gradually with increasing raw bentonite and surface-modified bentonite fillers. The PVC/RB nanocomposite samples have tensile strength values of 21.1, 20, 19.1, and 18.2 N/mm^2 for 2.5, 5, 7.5, and 10 phr of RB, respectively, these values are acceptable according to British standard (BS 50363-3(2005)), which stated that the minimum acceptable value of tensile strength for insulating PVC compounds is 12.5 N/mm^2 , the corresponding PVC/MB nanocomposites have values of 22.4, 21.3, 20.5, and 20 N/mm^2 , respectively (Figure 6-a), which indicates that the surface modification of Egyptian raw bentonite with BAC as surfactant, caused evident improvements in the mechanical properties of PVC nano composites.

Meanwhile, the elongation at break value for the standard free filler-PVC composite sample equals to 708%. This value decreased gradually with increasing RB and surface-modified bentonite fillers. The PVC/RB nanocomposite samples have elongation at break values of 581, 536, 473, and 441 % for 2.5, 5, 7.5, and 10 phr of RB. The PVC/MB composites have significant higher quality results of elongation at break values with 632, 578, 532 and 496 % for 2.5, 5, 7.5, and 10 phr MB respectively (as shown in Table 4 and Figure

6-b), which ensures the relative enhancement in the mechanical properties of PVC/bentonite nano composites, these values are acceptable according to British standard (BS 50363-3(2005)), which stated that the minimum acceptable value of elongation at break for insulating PVC compounds is 150%.

On the other hand, Density results of PVC/ RB and PVC/MB composites (Table 4 and Figure 6-c) show similar values after adding 2.5, 5, 7.5, and 10 phr of filler in PVC composites.

Characterization of Thermal properties

The results of the thermal stability test (Table 4 and Figure 7) indicate a general increase in the thermal stability of PVC/RB composites with increasing the RB content. The thermal stability was increased gradually from 34 minutes in the PVC standard sample (without filler) to 37, 38, 41, and, 43 minutes in case of adding 2.5, 5, 7.5, and 10 phr of RB, respectively. These results give an indication of the heat stabilizing effect of raw bentonite on PVC composites, which could be revealed because of the reasonable content of metal oxides in the raw bentonite. Metal oxides of calcium, iron and titanium enhance the thermal stability of PVC composites (Titow 1984; Wikes et al. 2005). On contrast, the thermal stability results of PVC/MB nanocomposites (Table 4 and Figure 7) show a gradual decrease in the thermal stability values from 34 minutes for standard PVC composite sample to 30, 28, 25, and, 23 minutes in case of adding 2.5, 5, 7.5, and 10 phr of RB respectively. The gradual decrease of the thermal stability of PVC composites with increase the amount of surface-treated bentonite can be as attributed to the presence of BAC as quaternary amine surfactant (Pagacz & Pielichowski, 2009), which has relatively low thermal stability

than PVC, and degraded quickly with using temperature (200).

Characterization of Electrical properties

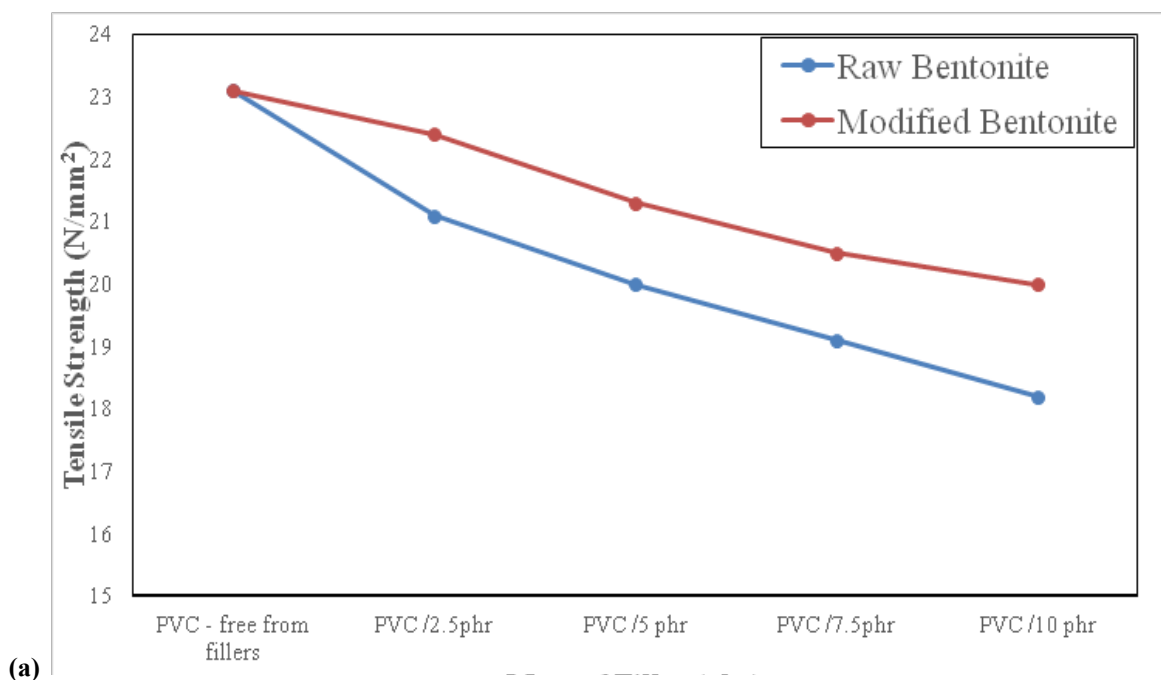
Volume resistivity data (Table 4 and Figure 8) show a moderate enhancement in PVC/RB results with the gradual addition of RB content, from $3.21 \times \Omega\text{-cm}$ for standard PVC composite sample, until valued $1.07 \times \Omega\text{-cm}$ for 10 PVC/RB nanocomposite. This gradual increase in volume

resistivity of PVC /RB nanocomposites indicates electrical resistant properties of RB material. On the contrary, the gradual addition of surface-modified bentonite as filler to PVC composites shows accompanied gradual decrease to the resulted PVC/MB nanocomposites until equal $5.86 \times \Omega\text{-cm}$ after addition 10 phr of MB. This gradual decrease in volume resistivity of PVC/ MB nanocomposites can be revealed as result

TABLE 4. Results from tensile strength, elongation at break, density, thermal stability and electrical volume resistivity tests for PVC-free from bentonite composite, PVC/ RB nanocomposites and PVC/ MB nanocomposites.

Material	Tensile Strength (N*/mm ²)	Elongation (%)	Thermal Stability (Minute)	Specific Gravity (g/cc)	Electrical Volume Resistivity (Ω.cm) At 500 volts
PVC - free from fillers	23.1	708	34	1.244	3.21E+11
PVC /2.5RB	21.1	581	37	1.259	7.39E+11
PVC /5 RB	20	536	38	1.27	8.44E+11
PVC /7.5 RB	19.1	473	41	1.285	9.57E+11
PVC /10 RB	18.2	441	43	1.294	1.07E+12
PVC /2.5 MB	22.4	632	30	1.257	1.70E+11
PVC /5 MB	21.3	578	28	1.266	1.18E+11
PVC /7.5 MB	20.5	532	25	1.282	7.92E+10
PVC /10 MB	20	496	23	1.291	5.86E+10

*Newton per square centimeter (tensile strength unit)



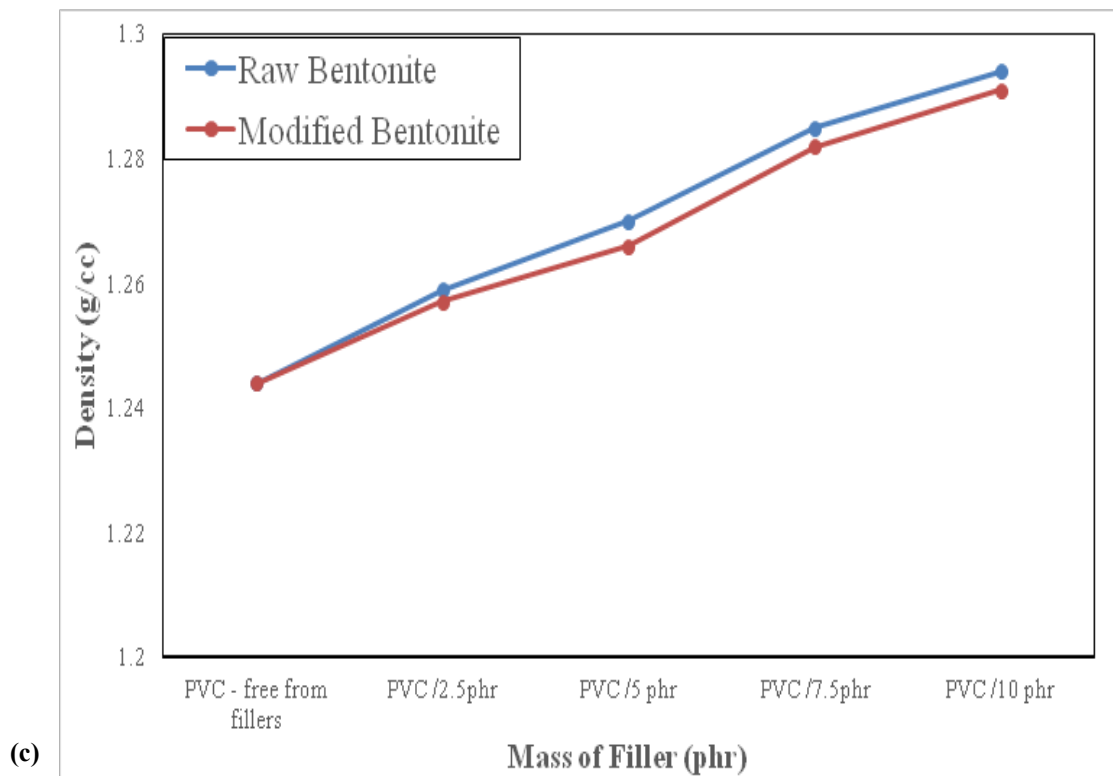
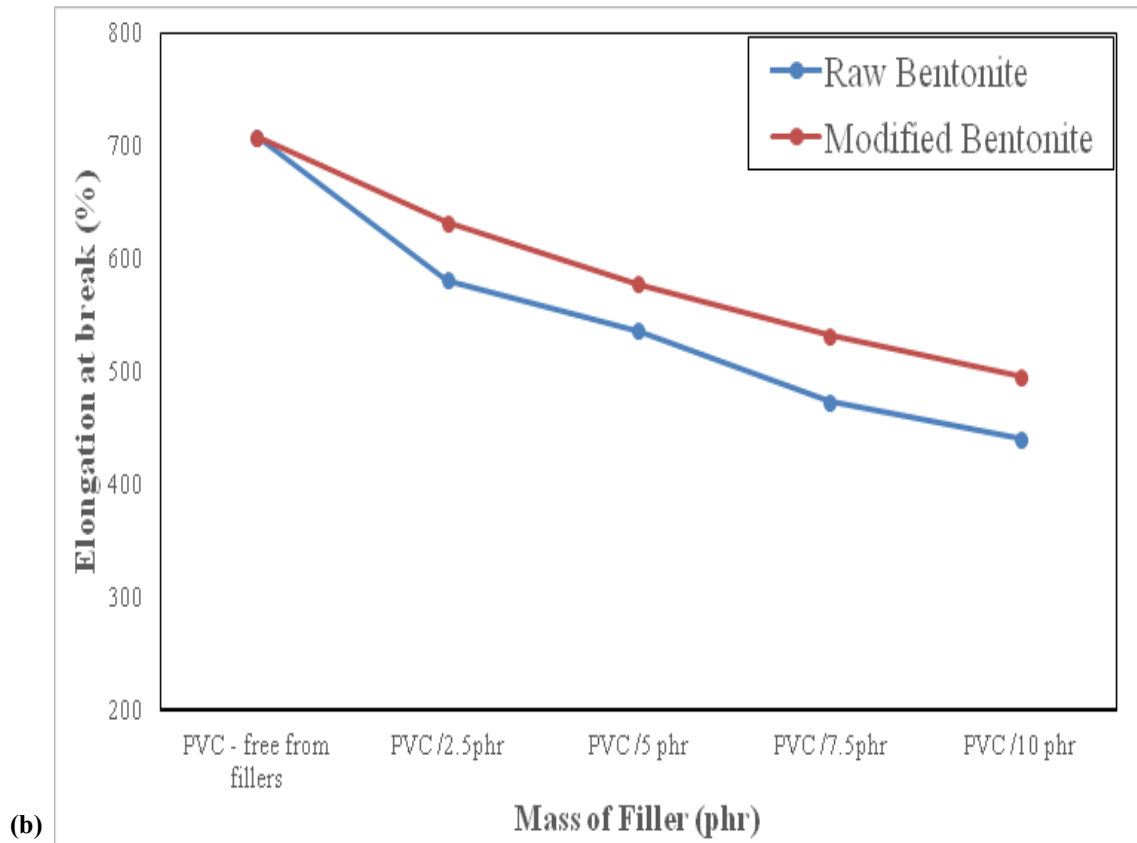


Fig. 6. Mechanical properties Graphs of results for PVC/ RB nanocomposite and PVC/ MB nanocomposite: a-Tensile strength graph, b- Elongation at break graph, and c-Density test graph.

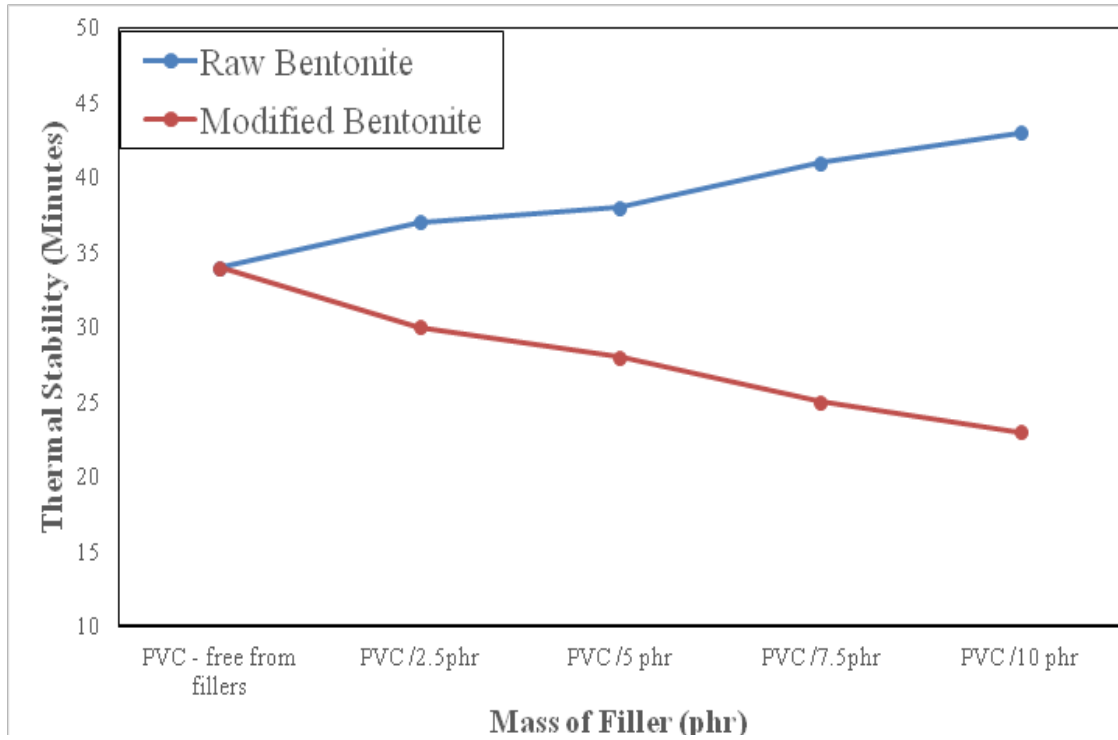


Fig. 7. Thermal stability Graph of results for PVC/ RB nanocomposite and PVC/MB nanocomposite.

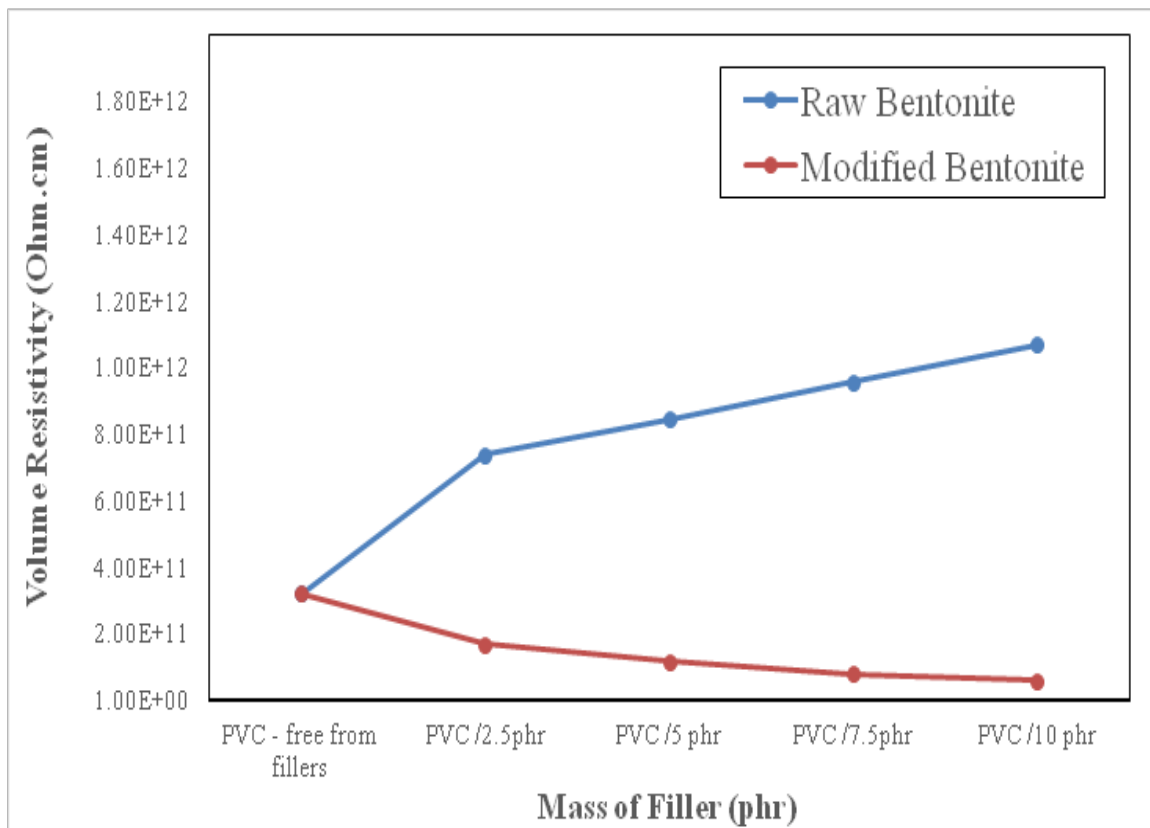


Fig. 8. Volume resistivity Graph of results for PVC/ RB nanocomposite and PVC/MB nanocomposite.

of the presence of surfactant material (Giancoli, 1995; Abdel-Gawad, *et al.*, 2020).

Conclusion

In this work, bentonite sample from komoshim in the Fayium area have been investigated as filler in PVC/clay nanocomposites. XRD and XRF analysis show that bentonite sample is of a low-grade calcium bentonite. Raw and modified bentonites were used as filler in PVC/bentonite nanocomposites by melt compounding method, the synthetic composites were designed for electrical applications. The modification of bentonite with BAC as cationic surfactant improved the hydrophobicity of bentonite, and consequently increased the compatibility between bentonite and PVC. FT-IR, SEM, and contact angle tests ensured the compatibility between PVC and MB. Supplementary evidence for increasing the compatibility between PVC and bentonite appear obviously in the enhanced tensile strength and elongation at break results as mechanical properties of PVC/MB nanocomposites.

In contrast, thermal stability of PVC/MB nanocomposites decreased gradually from 34 minutes for standard PVC composite to 21.1, 20, 19.1, and 18.2 minutes for 2.5, 5, 7.5, and 10 phr of MB, respectively, because of the thermal degradable cationic surfactant, however, thermal stability of PVC/RB nanocomposites increases gradually with increasing RB quantity, which means that raw bentonite gives some thermal stabilizing properties.

Furthermore, electrical properties of PVC composites increased after the gradual addition of RB with values 7.39×10^{11} , 8.44×10^{11} , 9.57×10^{11} , and 1.07×10^{12} $\Omega \cdot \text{cm}$ for 2.5, 5, 7.5, and 10 phr of MB, respectively, oppositely, decreased after the gradual addition of MB.

Finally, low-grade raw bentonite is relatively incompatible with PVC, decrease mechanical properties of resulted PVC/clay nanocomposites, but enhance their thermal and electrical properties. On the other hand, modified low-grade bentonite is compatible with PVC, and enhances the mechanical properties of resulted PVC/clay nanocomposites, but decrease thermal and electrical properties. Therefore, hydrophobic modified low-grade bentonite can be used as a filler with hydrophobic polymers industries such as polyethylene (PE), polypropylene (PP), polystyrene (PS) and acrylic polymers. In addition, future enhancements for modified low-

grade bentonite are recommended to improve its thermal and electrical properties.

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تأثير معالجة البنتونيت منخفض الدرجة على الخواص الميكانيكية والحرارية والكهربائية للمركبات النانوية المصنوعة من البولي فينيل كلوريد\الطفلة الطينية لاستخدامها في التطبيقات الكهربائية

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إن الهدف الرئيسي من هذا البحث هو معرفة مدى ملائمة استخدام البنتونيت منخفض الدرجة في مركبات البولي فينيل كلوريد (PVC) \ مركبات الطفلة الطينية النانوية الحجم في التطبيقات الكهربائية. ولقد تم تعديل البنتونيت باستخدام كلوريد البنزوكونيوم (BAC) كمادة خافضة للتوتر السطحي الكاتيوني، ثم تم إدخال كل من البنتونيت الخام والمعالج (MB و RB) كمواد مالئة في خليط مع راتينج PVC والملدنات والمثبت لإنتاج مركب PVC لتصنيع الكابلات العازلة. تم إجراء تحليل حيود الأشعة السينية (XRD)، وفلورة الأشعة السينية (XRF) لفحص التركيب المعدني والكيميائي لعينة البنتونيت. كما تم إجراء اختبارات طيف فورييه لتحويل الأشعة تحت الحمراء (FT-IR) ومجهر الفحص الإلكتروني (SEM) واختبارات زاوية التلامس (CA) على مركب العزل PVC للتحقق من التداخل والتوافق بين البنتونيت والـ PVC. وتم إجراء مزيد من الاختبارات لوصف الخصائص الميكانيكية والحرارية والكهربائية لمركبات PVC. ولقد أظهرت نتائج العينة أنها من البنتونيت منخفض الدرجة. كما أظهرت نتائج مركبات عزل PVC \ البنتونيت أن التوافق بين PVC والبنتونيت يزيد في حالة استخدام البنتونيت المعالج (MB)، وبالتالي، تزداد المقاومة للماء (Hydrophobicity) لمركب PVC الناتج. علاوة على ذلك، تُظهر المركبات المعالجة النانوية PVC / MB خصائص ميكانيكية أفضل (مثل قوة الشد والاستطالة) من المركبات النانوية PVC \ البنتونيت الخام (RB)؛ فلقد ارتفعت قيم قوة الشد من ٢١,١، ٢٠، ١٩,١، ١٨,٢ نيوتن\مم^٢ عند استخدام البنتونيت الخام RB بكميات ٢,٥، ٥، ٧,٥ و ١٠ phr على التوالي، والخاصة بعينات المركبات النانوية PVC / RB؛ إلى ٤,٢٢، ٣,٢١، ٥,٢٠ و ٢٠ نيوتن\مم^٢ للمركبات النانوية باستخدام البنتونيت المعالج PVC / MB المقابلة، وعلى النقيض من ذلك، تعطي المركبات النانوية PVC / RB خصائص حرارية أفضل بكثير (مثل الثبات الحراري) والخصائص الكهربائية؛ والتي أظهرت أن المقاومة الكهربائية الحجمية قد قلت من ١,٠٧ × ١٠^{١٢} Ω سم في حالة استخدام ١٠ Phr من البنتونيت الخام RB نانوي الحجم في مركبات PVC/RB، إلى ٥,٨٦ × ١٠^{١٠} Ω سم في حالة استخدام ١٠ phr من البنتونيت المعالج MB نانوي الحجم للمركب النانوي المقابل PVC / MB.