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EFFECT OF NITRATE ACID TREATED DOLOMITE ON THE TENSILE PROPERTIES OF ULTRA-HIGH MOLECULAR WEIGHT POLYETHYLENE (UHMWPE) COMPOSITES

Ultra-High Molecular Weight Polyethylene (UHMWPE) polymers have been used in biomedical applications due to its biocompatibility, durability, toughness and high wear resistance. To enhance the mechanical properties, various types of minerals are commonly utilized as fillers in UHMWPE. One of the minerals is dolomite, which has been recognized as a valuable mineral with versatile applications, particularly in the field of biomedical applications. This paper presents the tensile properties of UHMWPE composites that filled with dolomite and treated-dolomite at various filler loading (i.e., 1-5 wt.%). Nitric acid and diammonium phosphate were used to treat the dolomite. From the results, the peaks of the FTIR spectrum displays carbonate (CO_3^{-2}), phosphate (PO_4^{-3}) and hydroxyl (OH^-) groups in the ct-dolomite powder sample while the XRD pattern reveals that using dolomite treated with 1M nitric acid resulted in the presence of calcium hydroxide phosphate ($Ca_{10}(PO_4)_5(OH)$) and MgO. For tensile strength, UHMWPE/ct-dolomite composites show better tensile strength than the pure UHMWPE composites. Treated improve the dolomite filler and resulted in significantly better matrix-filler interfacial interactions and improve the properties.

Keyword: UHMWPE; chemical treatment; dolomite; polymer composites; biomedical

1. Introduction

Polymer-based composites have garnered significant interest across various industries, including construction, automobile, electronics, packaging and biomedical applications. Due to their direct contact with the human body, polymers utilized in biomedical applications must exhibit biocompatibility and non-toxicity. Additionally, they should meet specific essential requirements, such as comfort and protection of human tissues [1,2]. UHMWPE polymers have been found to be beneficial in biomedical applications due to its biocompatibility, durability, toughness and high wear resistance. As a result, it's often employed in joint arthroplasty, artificial hip and knee implants as a bearing material [3,4]. The characteristics of polymers are frequently altered by the addition of fillers.

Various types of minerals are typically utilized as filler dispersions in polymers to enhance their mechanical properties. Among these minerals, dolomite has been identified as a valuable natural resource with a wide range of applications, particularly in the field of biomedical applications [5]. It was commonly used in industry due to mineralogical properties and has a high hardness, making it a good filler for low-hardness polymer compounds [6]. Dolomite ($CaMg(CO_3)_2$) is utilized as a filler in various applications due to its chemical composition, which is abundant in calcium carbonate and magnesium. When subjected to a temperature of 1000°C, dolomite can undergo a transformation into calcium oxide. This calcium oxide can be effectively used as a precursor for the production of calcium phosphate, specifically $Ca_{10}(PO_4)_6(OH)_2$ [7,8].

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The wet method can be employed to synthesize $Ca_{10}(PO_4)_6(OH)_2$ using various techniques, including chemical, hydrothermal, and hydrolysis methods. In this approach, an aqueous solution is utilized as a crucial component [9]. The chemical method offers several advantages in the synthesis of $Ca_{10}(PO_4)_6(OH)_2$, including the production of highly chemically reactive powder with a large surface area, cost-effectiveness, fine particle size, and the use of low processing temperatures. However, there are also drawbacks associated with the chemical method, such as the potential formation of nonstoichiometric powders and insufficient formation of $Ca_{10}(PO_4)_6(OH)_2$.

Typically, the chemical method involves several steps. Initially, calcium and phosphate reagents are mixed in accordance with the molar ratio required for $Ca_{10}(PO_4)_6(OH)_2$ formation. The pH of the solution is then adjusted to an alkaline level, and the temperature is maintained within the range of room temperature to the boiling point of water. The solution is stirred for a period of time to facilitate aging. This results in the precipitation of $Ca_{10}(PO_4)_6(OH)_2$, which is subsequently washed, filtered, dried, and subjected to calcination at temperatures between 900°C and 1200°C. These steps are necessary to prepare calcium phosphate with well-crystallized structures and ultrafine particle sizes [10]. Finally, the precipitation of $Ca_{10}(PO_4)_6(OH)_2$ is crushed into powder form. HA crystal formation can be induced through the precipitation process using a range of calcium precursors (such as $Ca(NO_3)_2$, $CaCl_2$, $Ca(OH)_2$, and $CaCO_3$) and phosphorus precursors (including $(NH_4)_2HPO_4$, K_2HPO_4, NaH_2PO_4, and H_3PO_4). The control over the characteristics of the resulting product is achievable by adjusting parameters like the sources of phosphate and calcium, the Ca/P ratio, temperature, pH, precipitation and aging duration, and the method of drying [11,12].

Limited research has been conducted on the synthesis of $Ca_{10}(PO_4)_6(OH)_2$ using calcium oxide (CaO) and nitric acid (HNO₃). Some studies have focused on the conversion process of calcium oxide into $Ca_{10}(PO_4)_6(OH)_2$ [13,14]. In their research, Jamarun et al. [15] investigated the synthesis of $Ca_{10}(PO_4)_6(OH)_2$ through a chemical reaction involving nitric acid. Nitric acid plays a crucial role in transforming calcium oxide (CaO) into calcium nitrate hydrate $(Ca(NO_3)_2 \cdot 4H_2O)$. Subsequently, the resulting calcium nitrate hydrate readily reacts with a solution of $(NH_4)_2HPO_4$, facilitating the conversion into hydroxyapatite. HNO_3 is utilized as an inhibitor to hinder the formation of calcium phosphate by effectively chelating with calcium ions. Additionally, the presence of HNO₃ slows down or even prevents the nucleation of $Ca_{10}(PO_4)_6(OH)_2$ crystals due to the inhibitory properties of the compound [16]. Using a chemical method, Luo et al. [17] synthesized $Ca_{10}(PO_4)_6(OH)_2$ by employing $Ca(NO_3)_2 \cdot 4H_2O$ as the calcium source and $(NH_4)_2HPO_4$ as the phosphate source. The resulting crystals of $Ca_{10}(PO_4)_6(OH)_2$ exhibited a complete formation and displayed a smooth surface. This finding was corroborated by Pham [18], who observed that the chemically treated $Ca_{10}(PO_4)_6(OH)_2$ powders exhibited a single-phase crystal structure with cylindrical shapes measuring less than 100 nm in size. Furthermore, the Ca/P ratio in these samples corresponded to the ratio found in natural bones. Cur-

rently, it is believed that the chemical method involving calcined dolomite and $(NH_4)_2HPO_4$ may influence the growth mechanism of calcium phosphate.

This paper presents a chemical approach to produce hydroxyapatite, utilizing nitric acid as an inhibitor, dolomite as a calcium source, and diammonium hydrogen phosphate as a phosphate source. The paper includes the characterization of the powder, covering phase composition and FTIR analysis. Additionally, the study investigates the effect of chemically treated dolomite-filled ultra-high molecular weight polyethylene (UHMWPE) composites to determine their mechanical properties.

2. Experimental

Materials and methods

In this study, the matrix used was Ultra-High Molecular Weight Polyethylene (UHMWPE) with a melt index of 4.0 and a density of 0.903 g/cm^3. Dolomite was used as the filler material, purchased from Perlis Dolomite Industries Sdn. Bhd. in Perlis, Malaysia.

Methodology

Preparation of treated dolomite using nitric acid

Initially, 5.6 g of dolomite was mixed with 100 ml of 1 M nitric acid (HNO_3). The resulting filtrate was then combined with a 100 ml 0.6 M solution of diammonium hydrogen phosphate $[(NH_4)_2HPO_4]$, with stirring at 90°C and at pH 11 for 1 hour. To adjust the pH, 20 ml of ammonium hydroxide (NH_4OH) was added. Subsequently, the solution was left undisturbed for 24 hours, resulting in the formation of a precipitate. The precipitate was left to stabilize overnight. Next, the resulting precipitate was filtered and subjected to drying at 110°C to remove any remaining solvents. After drying, the precipitate was ground into a powder and then calcined at 1000°C for 2 hours. The same procedures were repeated for 2 M and 3 M of HNO_3.

Preparation of UHMWPE/dolomite and UHMWPE/ct-dolomite composites

Ct-dolomite and UHMWPE were blended together using a stainless-steel ball with a powder-to-ball ratio of 10:1 and a revolution speed of 270 rpm. After the ball milling process, the mixed sample was preheated to 190°C for 3 minutes and then hot-pressed for 10 minutes under a compression pressure of 20 MPa. The resulting composite sheet was subsequently cut into appropriate shapes for further testing. The same procedure was repeated for the mixing of dolomite and UHMWPE. The formulation of the UHMWPE/dolomite and UHMWPE/ct-dolomite composites used in this study is presented in TABLE 1.

TABLE 1

Description of composite samples

Sample	Description
Pure UHMWPE	Pure UHMWPE with no addition of filler
UHMWPE/d-1	UHMWPE filled with 1 wt.% of dolomite
UHMWPE/d-3	UHMWPE filled with 3 wt.% of dolomite
UHMWPE/d-5	UHMWPE filled with 5 wt.% of dolomite
UHMWPE/ct-D1	UHMWPE filled with 1 wt.% of ct-dolomite
UHMWPE/ct-D1	UHMWPE filled with 3 wt.% of ct-dolomite
UHMWPE/ct-D5	UHMWPE filled with 5 wt.% of ct-dolomite

Phase analysis

Treated-dolomite powders were characterized by X-ray diffraction (XRD), Bruker D2 Phaser, Cu$K\alpha$) in the $2\theta = 10°-90°$. The obtained data were analysed by using a PANalytical X'Pert HighScore Plus software for phase analysis.

Fourier Transform Infrared (FTIR) analysis

The treated-dolomite in powder form was determined by using a Perkin Elmer Spectrum in the range of 400-4000 cm^{-1}.

Tensile test

The samples of the composite sheets were cut into dumbbell-shaped specimens using a dumb bell cutter machine to the dimensions required in ASTM D638. The Universal Testing Machine Instron 5569 was used to determine the tensile properties of pure UHMWPE, UHMWPE/ct-dolomite and UHMWPE/dolomite composites. The tensile load was applied at a 50 mm/min cross-head speed. At the end of each test, the results of three replicates of each sample such as average values of tensile strength, elongation at break, and Young's modulus have been recorded for comparison between samples.

Scanning Electron Microscope (SEM)

The morphology of tensile fracture surface of pure UHMWPE, UHMWPE/ct-D3 and UHMWPE/ct-D5 were examined through SEM. A thin layer of platinum was applied to coat the sample in order to enhance the quality of the captured images. This was to avoid electrostatic charging during characterization.

Hardness test

The hardness was used to determine the ability of a material to resist penetration. 3 samples of UHMWPE, UHMWPE/ct-dolomite and UHMWPE/dolomite composites with different ratios have been prep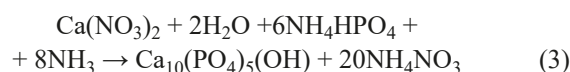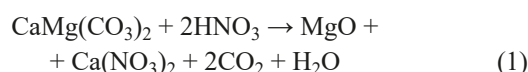ared. Shore hardness tester (Syntek) was used to measure the hardness of the sample. Durometer type D was used as an indenter to all samples. The sample hardness was measured based on the ASTM D2240. The shore D hardness values have shown the results of the different mixing ratio.

3. Results and discussion

X-Ray Diffraction (XRD) analysis

The XRD pattern depicted in Fig. 1 illustrates the influence of different concentrations of nitric acid (ranging from 1 M to 3 M) on dolomite. Analyzing the XRD pattern revealed that using dolomite treated with 1 M nitric acid resulted in the presence of calcium hydroxide phosphate ($Ca_{10}(PO_4)_5(OH)$) and a phase containing MgO. This MgO phase exhibited a chemical composition similar to hydroxyapatite (HA). The XRD pattern of the treated dolomite with 1 M nitric acid displayed intense peaks corresponding to $Ca_{10}(PO_4)_5(OH)$, indicating successful synthesis of hydroxyapatite with magnesium incorporation through the chemical treatment method using pure dolomite.

The presence of MgO can be attributed to the chemical reaction between dolomite ($CaMg(CO_3)_2$) and nitric acid (HNO_3). Additionally, the precipitation and filtration processes led to the formation of calcium phosphate. The precipitate contained several compounds, including magnesium oxide (MgO), hydroxyapatite ($Ca_{10}(PO_4)_5(OH)$), calcium hydroxide ($Ca(OH)_2$), and calcium oxide (CaO). The formation of these compounds occurred due to the acidic conditions during the precipitation process. This phase formation can be described by chemical reactions, specifically Equations (1)-(3), and (4). Upon breaking the bonds in $Ca(NO_3)_2$, compounds such as CaO, NO_2, and O_2 gas are produced. The reaction between CaO and H_2O generates $Ca(OH)_2$. As for the CaO compounds, they are unstable and readily react with atmospheric moisture (H_2O) in the air.

$$CaMg(CO_3)_2 + 2HNO_3 \rightarrow MgO + \\ + Ca(NO_3)_2 + 2CO_2 + H_2O \tag{1}$$

$$Ca(NO_3)_2 \rightarrow CaO + NO_2 + O_2 \tag{2}$$

$$Ca(NO_3)_2 + 2H_2O + 6NH_4HPO_4 + \\ + 8NH_3 \rightarrow Ca_{10}(PO_4)_5(OH) + 20NH_4NO_3 \tag{3}$$

$$CaO + H_2O \rightarrow Ca(OH)_2 \tag{4}$$

Hydroxyapatite, possessing a mineral phase resembling that of human bone, is an exceptional biomaterial. Jamarun et al. [15] suggest that the addition of calcium oxide enhances the quality of hydroxyapatite. Therefore, there is strong encouragement for the utilization of hydroxyapatite filled with magnesium oxide, as it offers numerous advantages for body implants and extends the lifespan of the implants. Additionally, the incorporation of magnesium into hydroxyapatite slows down mineral degradation, fosters bone growth, and enhances metabolic activity. This combination of hydroxyapatite and magnesium exhibits potential as a bone substitute material with improved mechanical strength

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[19,20]. This is corroborated by the research of Bystrov et al. [20], who observed that the presence of magnesium in hydroxyapatite (HA) affects how it interacts with living bone tissue when used as a filler for bone defects or as a coating for implants.
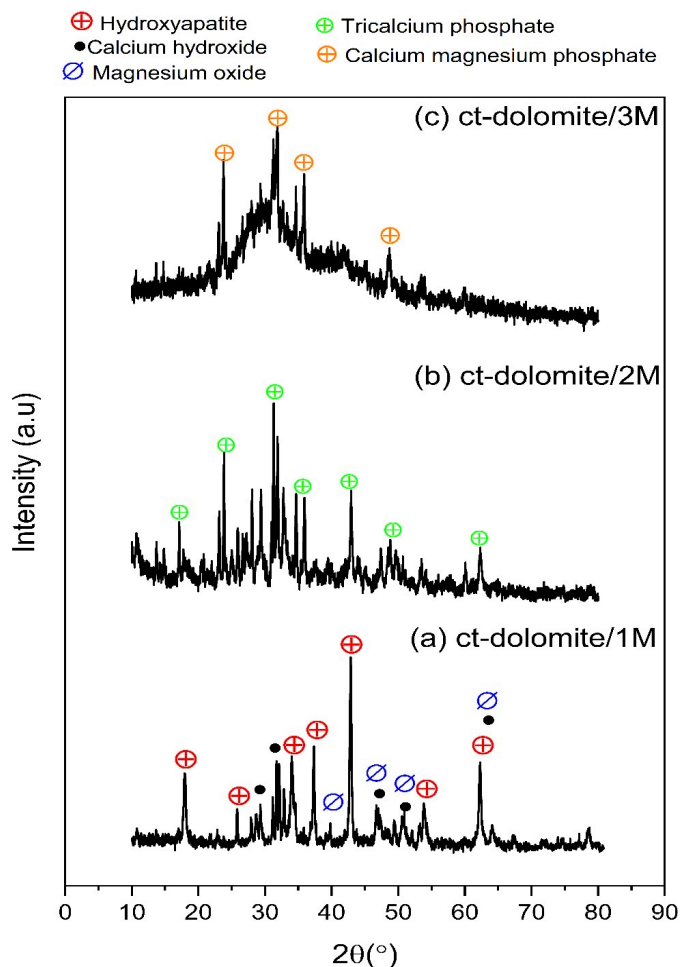
the presence of hydroxyapatite. The absorption bands for these functional groups were observed at approximately 565, 616, 880, 1033, and 1071 cm^{-1}. Lastly, the presence of MgO was indicated by moderate peaks at 443 cm^{-1} [22].
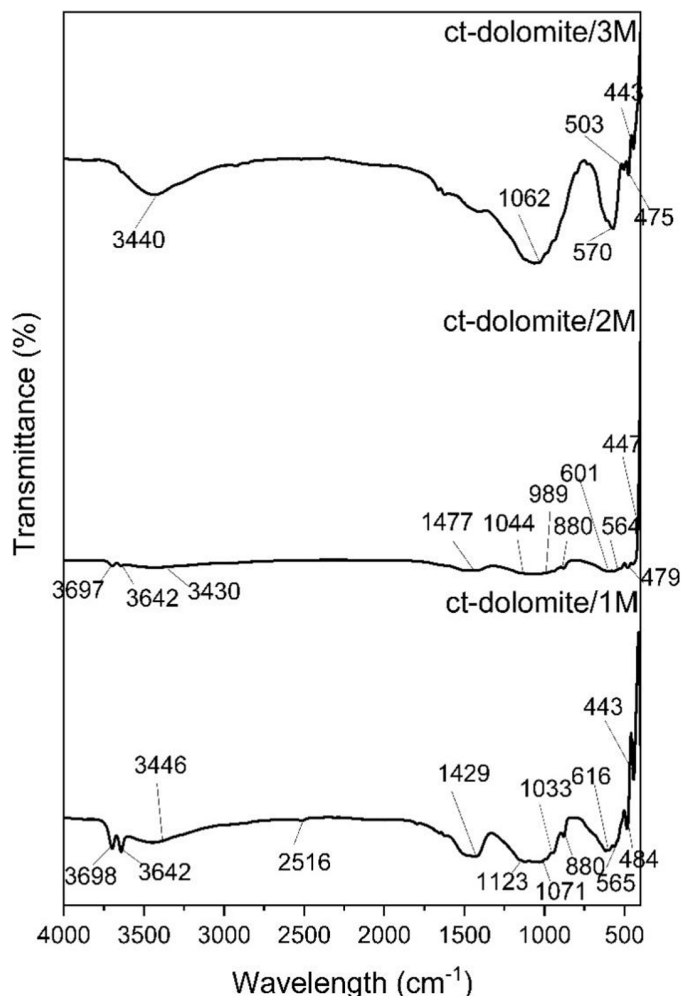

Fig. 1. XRD pattern of treated-dolomite with various concentration of nitric acid: (a) 1 M; (b) 2 M; and (c) 3 M

Fig. 2. FTIR spectra of treated-dolomite with various concentration of nitric acid: (a) 1 M; (b) 2 M; and (c) 3 M

FTIR analysis

FTIR analysis was carried out on the treated dolomite samples to investigate the chemical bonding in the synthesized hydroxyapatite. The resulting spectra are presented in Fig. 2. The graph clearly shows that the treated 1 M dolomite exhibited the essential hydroxyapatite functional groups, which are crucial for this study. These findings provide further support to the XRD results, which also identified diffraction peaks characteristic of hydroxyapatite in the powder. The FTIR spectrum confirms the presence of carbonate (CO_3^{2-}), phosphate (PO_4^{3-}), and hydroxyl (OH^-) groups, thereby confirming the successful synthesis of hydroxyapatite (HA) [21].

In Fig. 2, the absorption band observed around 3446-3699 cm^{-1} indicates the presence of the hydroxyl (OH) functional group. Additionally, the FTIR spectra displayed characteristic absorption bands in the range of 560-1050 cm^{-1}, which are attributed to the PO_4^{3-} absorption, further confirming

Tensile properties

Tensile test was conducted to determine the tensile strength, elongation at break and Young's modulus of the materials. TABLE 2 summarizes the tensile properties of the pure UHMWPE, UHMWPE/ct-D1, UHMWPE/ct-D3, UHMWPE/ct-D5, UHMWPE/d-1, UHMWPE/d-3 and UHMWPE/d-5 composites. Fig. 3 illustrate the effect of ct-dolomite and dolomite filler loading on the tensile strength and elongation at break of the pure UHMWPE, UHMWPE/ct-D1, UHMWPE/ct-D3, UHMWPE/ct-D5, UHMWPE/d-1, UHMWPE/d-3 and UHMWPE/d-5 composites. The tensile strength values of UHMWPE composites increase with the addition of both ct-dolomite and dolomite. The tensile strength of pure UHMWPE is 23.181 MPa, and when treated with ct-dolomite, the tensile strength improves to 23.513 MPa (UHMWPE/ct-D1), 23.769 MPa (UHMWPE/ct-D3), and 32.120 MPa (UHMWPE/ct-D5). Similarly, when

treated with dolomite, the tensile strength further increases to 33.509 MPa (UHMWPE/d-1), 37.659 MPa (UHMWPE/d-3), and 39.297 MPa (UHMWPE/d-5). The incorporation of both ct-dolomite and dolomite enhances the tensile strength of UH-MWPE composites, with higher improvements observed with dolomite compared to ct-dolomite.

to pure UHMWPE, as ct-dolomite contains calcium phosphate and magnesium, which directly enhance the mechanical properties of UHMWPE composites. However, UHMWPE with a 5 wt.% dolomite filler demonstrated a higher tensile strength of 39.297 MPa compared to UHMWPE/ct-D5. This can be attributed to the rock-like characteristics of dolomite, indicating its high strength and hardness [6].

TABLE 2

Tensile properties of UHMWPE, UHMWPE/ct-dolomite and UHMWPE/dolomite composites. The data presented here are the average results of three specimens for each sample

Sample	Tensile strength (MPa)	Elongation at break (%)	Young's modulus (MPa)
UHMWPE	23.181	197.92	326.72
UHMWPE/ct-D1	23.513	229.86	360.3
UHMWPE/ct-D3	23.769	236.81	306.9
UHMWPE/ct-D5	32.120	337.81	187.2
UHMWPE/d-1	33.509	295.67	315.52
UHMWPE/d-3	37.659	308.00	285.28
UHMWPE/d-5	39.297	307.50	216.76

To achieve a strengthening effect, it is crucial for composite materials to exhibit a strong interfacial interaction between the filler and matrix [19,23]. The results indicate that the addition of ct-dolomite and dolomite at filler loadings ranging from 1 to 5 wt.% successfully improved the tensile strength of UHMWPE composites. This trend suggests that the strength of UHWMPE composites was influenced by the incorporation of ct-dolomite and dolomite fillers. Among the composites, UHMWPE/ct-D5 exhibited the highest tensile strength at 32.12 MPa compared

The elongation at break of UHMWPE composites also shows a significant increase when ct-dolomite and dolomite are added. The elongation at break of pure UHMWPE is 197.92%. When treated with ct-dolomite, the elongation at break improves to 229.86% (UHMWPE/ct-D1), 236.81% (UHMWPE/ct-D3), and 337.81% (UHMWPE/ct-D5). Similarly, when treated with dolomite, the elongation at break further increases to 295.67% (UHMWPE/d-1), 308.00% (UHMWPE/d-3), and 307.50% (UHMWPE/d-5). The incorporation of both ct-dolomite and dolomite results in a notable enhancement in the elongation at break of UHMWPE composites, with higher improvements observed with ct-dolomite compared to dolomite. Wypych [24] studied that elongation typically parallels tensile strength, indicating that an increase in tensile strength of a filled material generally leads to an increment in elongation [25]. Moreover, the inclusion of fillers in the matrix restricts the movement of chains within the polymer matrix, leading to an increase in deformation when the composite is subjected to an applied force [3].

From Fig. 3, it can be observed that the Young's modulus varies for different UHMWPE composites, depending on the type and concentration of the fillers (ct-dolomite and dolomite) added to the matrix. Comparing the Young's modulus values, it is evident that the pure UHMWPE exhibits a Young's modulus of 326.72 MPa.
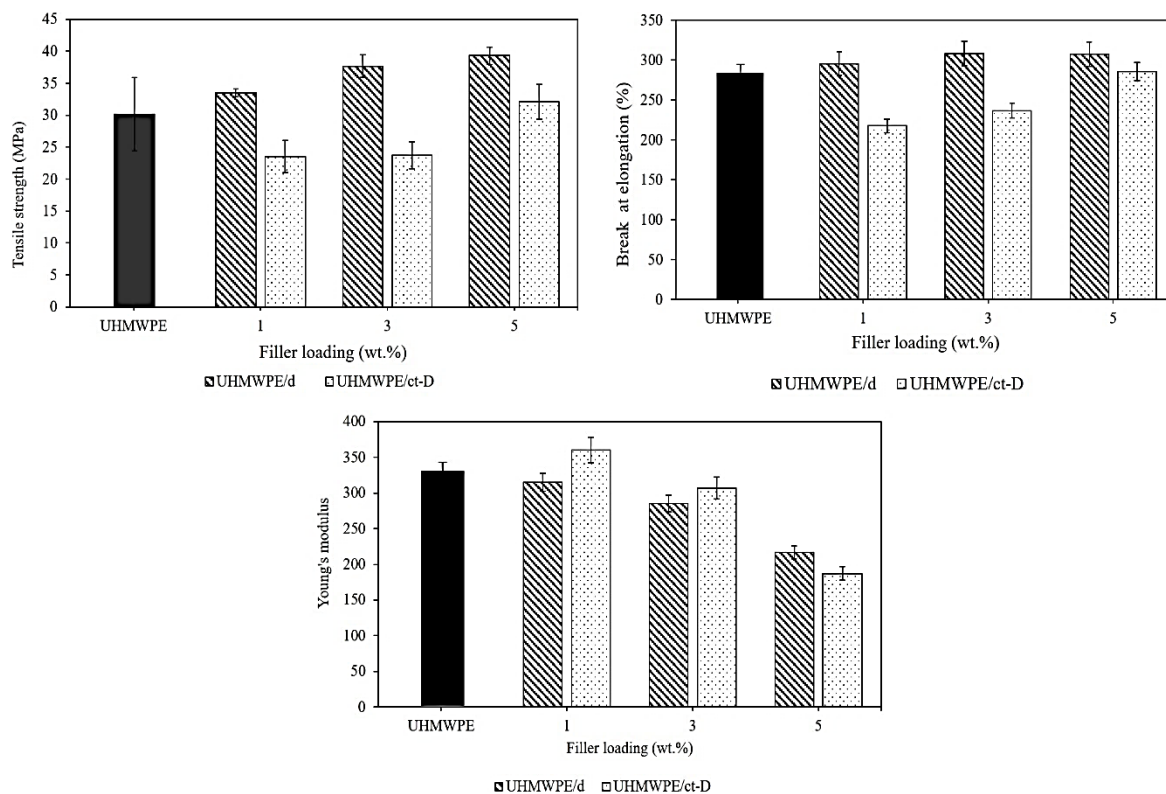

Fig. 3. The tensile properties of UHMWPE, UHMWPE/ct-dolomite and UHMWPE/dolomite

When ct-dolomite fillers are added, the Young's modulus tends to increase, resulting in higher values for the composites. For example, UHMWPE/ct-D1 has a Young's modulus of 360.3 MPa, UHMWPE/ct-D3 has 306.9 MPa, and UHMWPE/ct-D5 has 187.2 MPa. The trend shows that the Young's modulus increases initially with the addition of ct-dolomite, but as the addition of the filler increases, the Young's modulus decreases. Similarly, when dolomite fillers are incorporated into UHMWPE, the Young's modulus also shows variations. UHMWPE/d-1 has a Young's modulus of 315.52 MPa, UHMWPE/d-3 has 285.28 MPa, and UHMWPE/d-5 has 216.76 MPa. The Young's modulus appears to decrease as the concentration of dolomite increases.

The changes in Young's modulus were identified for pure UHMWPE and UHMWPE composites, as shown in Fig. 3. It was found that the Young's modulus was decreased after the addition of 1 wt.% of ct-dolomite from 315.52 MPa to 216.76 MPa. The addition of filler increases the stiffness of the composites which in turn increased the elongation at break. The stiffness of polymer matrices increased by the incorporation of rigid particulate filler as well as the interfacial contact that exists between the filler and matrix [26]. The decrease in Young's modulus demonstrated that ct-dolomite had the capability to increase the rigidity of the composites. This improvement can be attributed to the higher interfacial adhesion and better dispersion of ct-dolomite filler within the matrix, which in turn led to an enhancement in both the tensile strength and rigidity of the composite. This finding is consistent with the study conducted by Chang et al. [26], which also suggested that the presence of a rigid filler in the matrix was the primary factor responsible for the increase in composite stiffness.

Microstructural analysis

Fig. 4 shows the fractured surfaces of pure UHMWPE, UHMWPE/ct-D3 and UHMWPE/ct-D5. The tensile-fractured surface of the pure UHMWPE in Fig. 4(a) exhibits flat matrix tearing. When a tension force was exerted on the pure UHMWPE, the crack propagates along the boundary interfaces. SEM morphology of UHMWPE/ct-D5 in Fig. 4(c) shows smooth edge and better bonding between ct-dolomite filler and UHMWPE matrix compare to UHMWPE/ct-D3 in Fig. 4(b). Ct-dolomite that were added in the 5 wt.% UHMWPE/ct-dolomite composite has improved the dispersion of fillers throughout the matrix. Therefore, at 5 wt.% filler loading, better stress transfer from matrix to filler which result in increasing tensile strength. This observation is in line with the explanation given in Fig. 3, which shows that a composite with well dispersed of 5 wt.% of ct-dolomite demonstrated good tensile performances.

Hardness test

TABLE 3 shows the hardness properties of UHMWPE composites and Fig. 5 illustrates the average hardness of UHMWPE
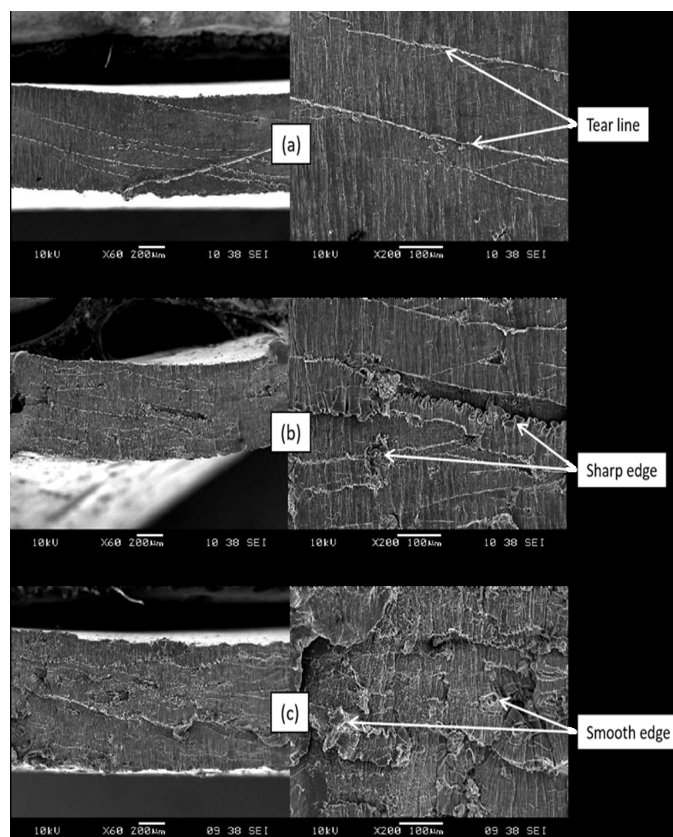

Fig. 4. SEM micrograph of UHMWPE/ct-dolomite composites

composites containing ct-dolomite and dolomite fillers. The composites exhibit higher hardness compared to pure UHMWPE. Notably, the UHMWPE/ct-D5 composites demonstrate a higher hardness value compared to UHMWPE/ct-D1 and UHMWPE/ct-D3, with an average force of 13.78 N. Tian Yang et al. [20], suggest that materials with greater surface hardness tend to have improved wear resistance. This enhancement can be attributed to the incorporation of hydroxyapatite (HA) with magnesium, which enhances the mechanical properties of the UHMWPE matrix, particularly hardness, resulting in a significant increase in resistance to indentation. Additionally, the high aspect ratio ct-dolomite fillers exhibit strong adhesion with UHMWPE, enhancing the polymer matrix's load-minimization capabilities. Yusuf et al. [27] reported that hydroxyapatite particles act as rigid points against the counterface, reducing the normal load and shear stress on the polymers and consequently increasing the hardness of UHMWPE composites

From Fig. 5, it is evident that the presence of ct-dolomite and dolomite contributes to the increased hardness of UHMWPE composites compared to pure UHMWPE. Among the composites, UHMWPE/ct-D5 exhibits the highest hardness value, measuring 31.0 (Shore D), followed by 33.0 (Shore D) for UHMWPE/d-1 composites, whereas pure UHMWPE has a hardness of 26.2 Shore D. According to Oleiwi, Gh., and Othman [28], the addition of hydroxyapatite to polymers generally leads to increased hardness and roughness. Lai, Ishak, and Ishiaku [29] state that HA plays a crucial role in polymer composites by stiffening the overall structure when added.

TABLE 3

Hardness properties of UHMWPE composites

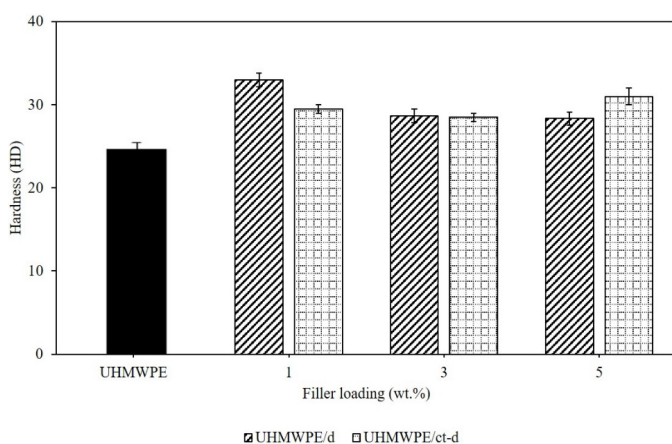| Sample	Hardness (Shore D)				Average Force (N)
	1	2	3	Average	
UHMWPE	27.5	25	26	26.2	11.64
UHMWPE/ct-D1	28	29	28.5	29.5	12.67
UHMWPE/ct-D3	29.5	30	29	28.5	13.11
UHMWPE/ct-D5	31	30	32	31	13.78
UHMWPE/d-1	33	26	26	28.3	12.59
UHMWPE/d-3	26	26	34	28.7	12.74
UHMWPE/d-5	35	37	27	33.0	14.67

Fig. 5. Average hardness of UHMWPE/dolomite and UHMWPE/ct-dolomite composites with different filler (wt.%)

4. Conclusion

In conclusion, hydroxyapatite (HA) was successfully synthesized using the chemical treatment method on dolomite without the need for calcination. Based on the XRD analysis, the HA produced with MgO was found to be associated with 1 M of HNO_3, and this finding was further confirmed by FTIR analysis. The mechanical properties of UHMWPE composites improved after the addition of the filler, showing an increment in both tensile strength and hardness compared to pure UHM-WPE. These results demonstrate that the addition of the filler has a significant impact on the mechanical properties, including hardness.

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