Materials Today: Proceedings xxx (xxxx) xxx

Contents lists available at ScienceDirect

Materials Today: Proceedings

journal homepage: www.elsevier.com/locate/matpr

Surface roughness of ternary blends: Polypropylene/chitosan/sisal fiber membranes

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ARTICLE INFO

Article history:
Received 7 March 2020
Received in revised form 24 March 2020
Accepted 25 June 2020
Available online xxxx

Keywords:
Composite membranes
SEM
Surface roughness
Power spectral density
Morphological structure
WXSM software

ABSTRACT

The rough morphological structure of ternary blend composite membranes was studied. The surface roughness of the composites were analysed. Recurrent topographies and the reliance of length-scale on rough surfaces were established in the analysis done by scanning probe electron microscopy. The membranes with increasing amount of sisal fibre exhibited higher roughness surface.

1. Introduction

Based on the outstanding properties; like mechanical strength, high stiffness and light weight, fiber reinforced polymer composites account for a significant category of advanced materials used for structural applications [1]. Membrane surface roughness has been extensively studied for the characterization of membrane surfaces; this is accredited to its influence on the properties of membrane (fouling and wetting) [2]. However, a surface does not have a single roughness value, rather the magnitude of measured roughness is dependent on the length scales of measurement.

The equipment used for analysing surface roughness of fiber reinforced polymer composites is a scanning probe microscopy like AFM. The surfaces of images obtained from AFM are very important in characterizing fiber reinforced polymer composites [3]. The types of roughness assessment usually utilized in characterizing materials are root mean square (RMS) roughness, mean roughness and peak to peak value [4]. Surface roughness of materials are made of an immeasurable integer of the rate of recurrence; from the atomic to macroscopic length scales. The depth of a peak for any detected point on a surface could be taken to be an arbitrary variable [5] and the theory of fractal could possess a prospective properties in the morphological analysis of the surface. A self-similar fractal has been assumed for roughness configuration on surfaces [6]. Some investigations have revealed a related to islands on earth and pores, in porous media for cumulative distribution of size of contact spots on engineering surfaces. It hence, represent the fractal scaling law [7]. In addition, a study has shown that fractal roughness of membrane surfaces has the capacity to reinforce the interfacial interactivities amid foulants and membranes [8]. The study investigated the influence of sisal fiber on the surface roughness of polypropylene/chitosan/sisal fibre membranes.

2. Preparation of blends

Chitosan of high purity and of medium molecular weight was acquired from Sigma Aldrich, South Africa. Polypropylene was obtained from KR Polymer, Kryasan, Johannesburg, South Africa. It is a pre-consumer waste. The sisal fibre was obtained from the CSIR, Port Elizabeth, South Africa. The blends of polypropylene/

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https://doi.org/10.1016/j.matpr.2020.06.513
2214-7853/

Table 1
Preparation ratio of blends.

SAMPLES
50 g Polypropylene
46 g Polypropylene + 4 g Sisal fibre
46 g Polypropylene + 4 g Chitosan
43 g Polypropylene + 5 g Sisal fibre + 2 g Chitosan
43 g Polypropylene + 2 g Sisal fibre + 5 g Chitosan

chitosan/sisal at various ratios (see Table 1) were prepared in a counter-rotating mixer (Haake Rheomixer) for distributive mixing. The composites were mixed at 190 °C for 10 min at a speed of 60 rmp. The moulds of the blends were crushed and further grounded to powder. The powder was used to prepare the composite membranes using compression mould.

2.1. Scanning electron microscopy (SEM)

The morphology of the blended composite membranes was examined with the aid of field emission scanning electron microscopy (JEOL model, Japan). The characterization was done with a fast-tracking voltage of 15 kV, operating with a low beam mode for the purpose of preventing the samples from getting damaged. The samples prepared were fixed on a double-sided carbon tape. Iridium (≈5 nm thick) was used to coat the surfaces of the samples in order to make them conductive.

2.2. 3D surface topography from SEM

During the study of surfaces using stereomicroscopy, the ostensible separation amid two points, observed from diverse angles is unswervingly associated to the discrepancy via given information in the 3-dimension (3D) [9]. Hence, in order to acquire information of the 3D from a stereo pair of SEM images, the roughness of composite membranes was studied with WXSM 5.0 software. WXSM 5.0 software is a freeware scanning probe microscopy software [10]. The roughness is reliant on the size of the scan; it is hence, essential that roughness of images under examination should be analysed with the same scan regions for the comparative analysis, [11]. Here, the images obtained from SEM with the same magnification were used. Nanotechnology Research Tool was utilized to achieved the value of the RMS on the rough surfaces [10]. The RMS of the roughness differs with the interval range (see Eq. (1)) [10]:

$$RMS = \sqrt{\frac{\sum_{ij} (a_{ij} - \langle a \rangle)^2}{N}} \tag{1}$$

where a_{ij} represent the value of the height for a certain point on the image (nm), a represents the mean height of the whole pixels in the image (nm) and N represents the whole number of pixels in the image. Eq. (1) is an in-built equation in WXSM 5.0 software and was used to calculate the surface roughness.

3. Result and discussion

3.1. Scanning electron microscopy

The morphological surface of polypropylene/chitosan/sisal fibre composite membranes is shown in Fig. 1. The composite membranes show a fibrous network structure due to the net prevalence of the solid–solid mixing during the blending process; which result to roughness of the composite surfaces. The membranes with increasing amount of sisal fibre (46 g PP/ 4 g sisal fibre and 43 g PP/ 5 g sisal fibre/ 2 g chitosan) appeared to be rougher than the remaining three composite membranes; this suggests an excellent separation performance. The micrograph of these rougher surfaces shows a complex interconnected network of fibres (Fig. 1b and d),

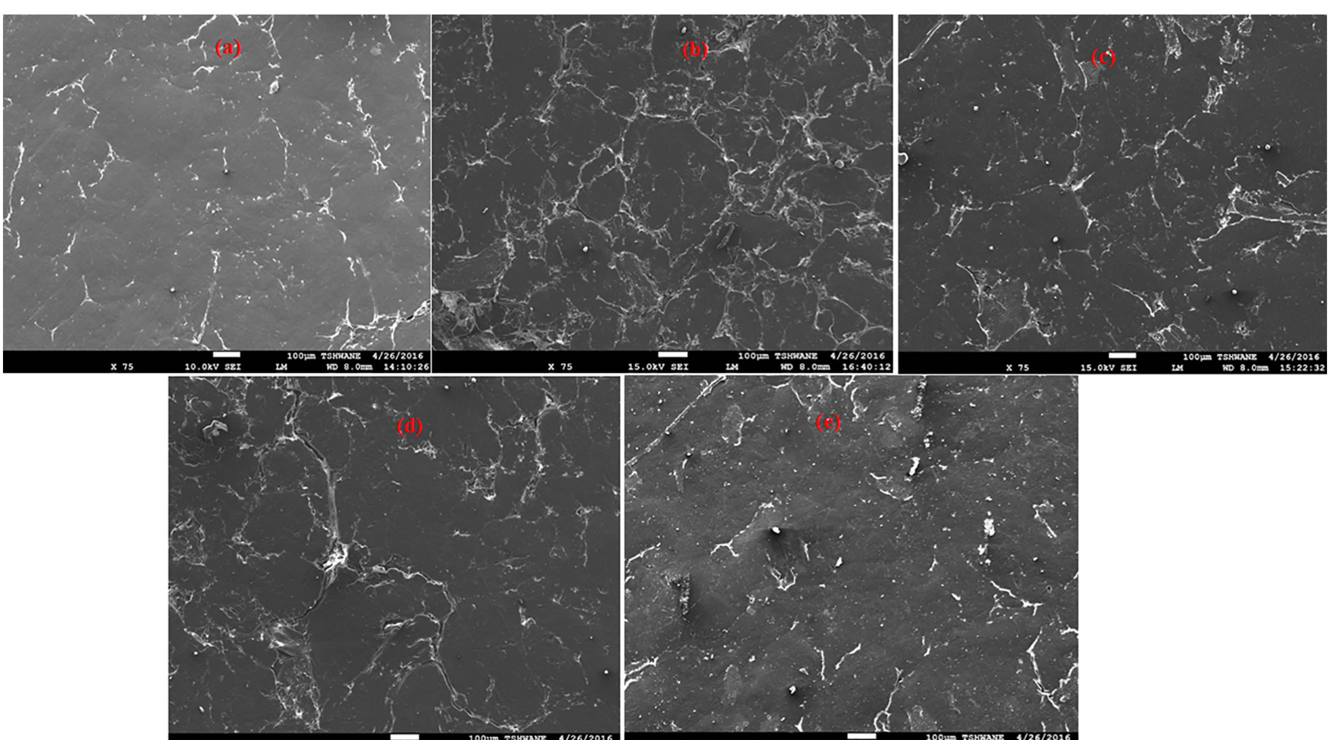

Fig. 1. Morphology of polypropylene/chitosan/sisal surfaces of: (a) 50 g, (b) 46 g PP/ 4 g sisal fibre, (c) 46 g PP/ 4 g chitosan, (d) 43 g PP/ 5 g sisal fibre/ 2 g chitosan, (e) 43 g PP/ 5 g chitosan/ 2 g sisal fibre at a voltage of 15 kV.

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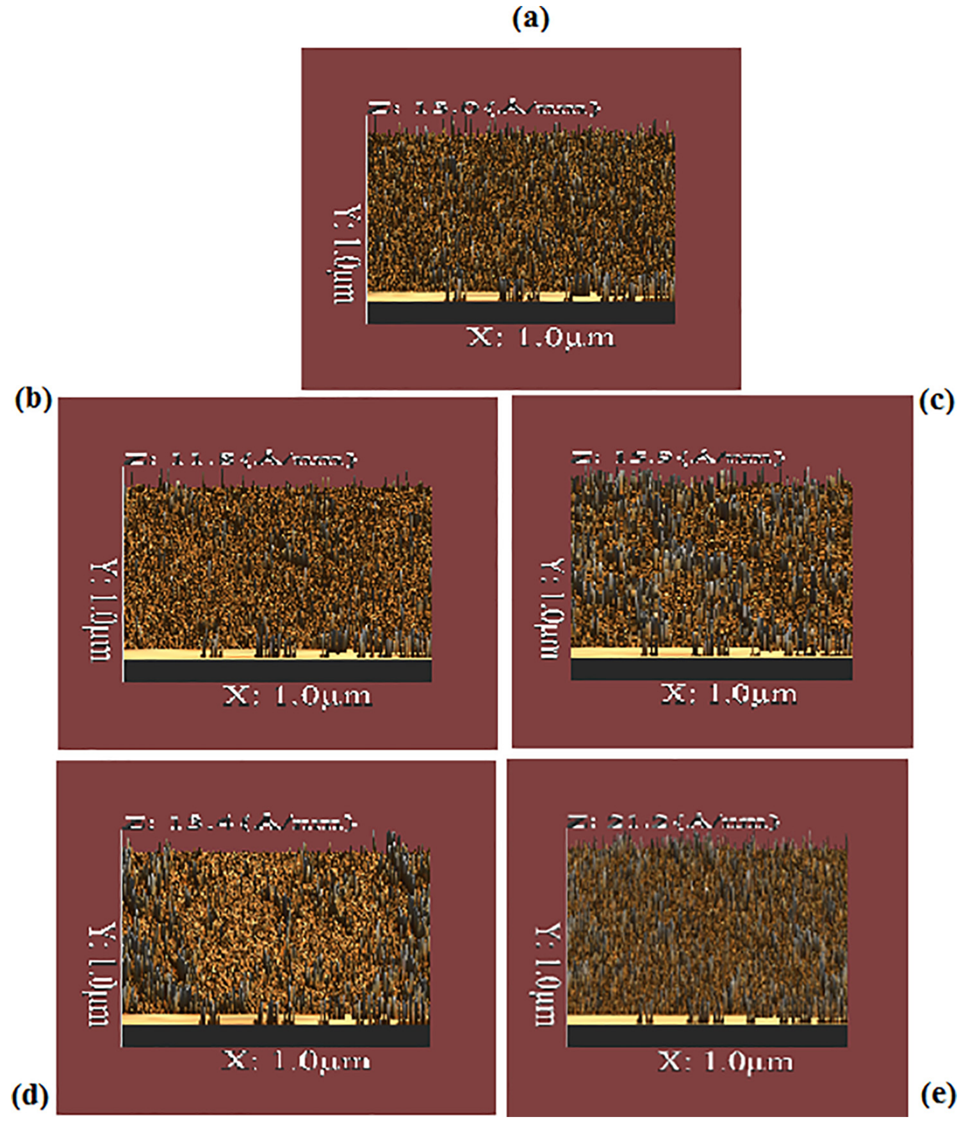

Fig 2. Surface roughness of: (a) 50 g [PP] (b) 46 g [PP] + 4 g SF, (c) 46 g [PP] + 4 g [C], (d) 43 g [PP] + 5 g [SF] + 2 g [C] (e) 43 g [PP] + 2 g [SF] + 5 g [C].

which will thus, offers a compounding pathway that can improve a separation processes.

3.2. Surface roughness

Fig. 2 shows the surface roughness of polypropylene/chitosan/sisal fibre composite membranes. The surface roughness of the composites increase as the amount of sisal fibre added to the composite increases (see Fig. 2b and d); this confirms the SEM characterization obtained in Fig. 1. From, Fig. 2a, the roughness of PP membrane seems to be moderately smooth and dense, however, the roughness the composites is more obvious at this scale and the structure as it depicts inter-winning fibrous network with many pores. The roughness surface of the composites increases with increasing amount of sisal fiber (Fig. 2e, b and d respectively). Studies have shown that membranes with moderately smooth and dense possess a relatively high fouling on it as a result of its dense nature [12]. The roughness histogram and numerical data in Fig. 3 were utilized to completely delineate the membranes surface roughness. Fig. 3b and d show that the membranes with increasing amount of sisal fiber, correspondingly have their RMS roughness increased (see Table 2). Table 2 and Fig. 3 show that the surface roughness of PP membranes was lower (0.8256) in comparison to the surface roughness of the composites. The surface roughness with higher amount of sisal fiber (43 g PP + 5 g SF + 2 g C) was the highest (1.6426); hence, the higher the amount of sisal fiber added to the composite, the higher the roughness. The active layer of Fig. 2b and d consists of cross-linked net-works, such as: fibrous structure with existence of tiny peaks and vales which were the reason for higher roughness. The roughness of a surface is very significant in assessing how effective a membrane would be [13]. This is because it can impact the trans-membrane transport and fouling potential. The roughness of a surface could relate with the characteristics of other materials, like pore size distribution [14–17]. A high roughness will lead to great adhesive strength of membranes and high great efficiency in the separation process [18,19]. It can therefore, be said that the membranes with increasing amount of sisal fiber would perform better in separation process. Increasing sisal content results in increasing RMS value as represented with (*) is shown in Table 2, with sample having the highest numbers of (*), containing the highest sisal content.

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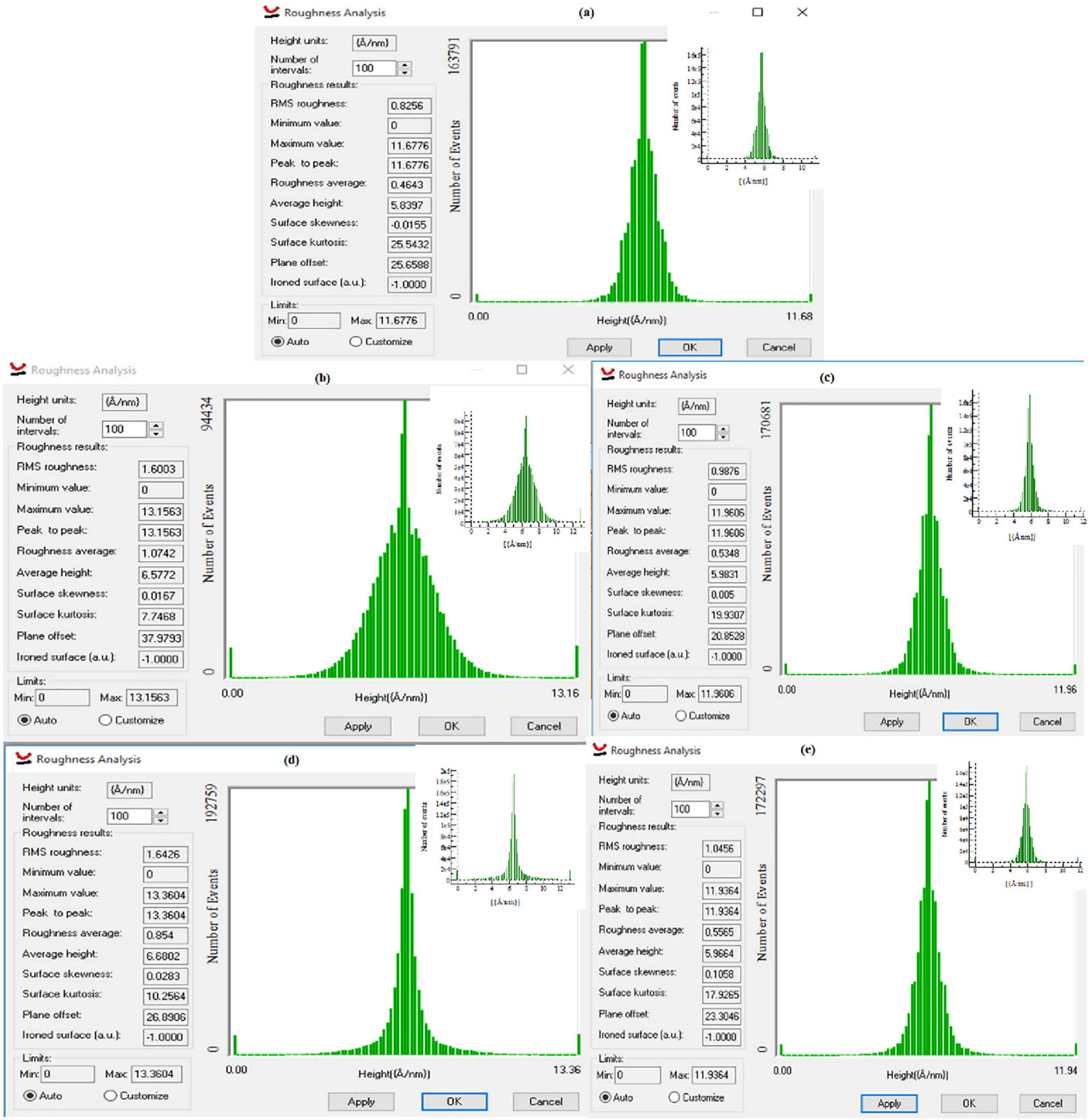

Fig. 3. Roughness parameters of: (a) 50 g [PP] (b) 46 g [PP] + 4 g SF, (c) 46 g [PP] + 4 g [C], (d) 43 g [PP] + 5 g [SF] + 2 g [C] (e) 43 g [PP] + 2 g [SF] + 5 g [C].

Table 2
The RMS values.

SAMPLES	RMS values
50 g PP	0.8256
46 g PP + 4 g SF	1.6003**
46 g PP + 4 g C	0.9876
43 g PP + 5 g SF + 2 g C	1.6426***
43 g PP + 2 g SF + 5 g C	1.0456*

PP – Polypropylene, SF – Sisal Fibre, C – Chitosan.

4. Conclusion

The roughness of a surface has substantial impact in particle adhesion. The influence of sisal fiber on the surface roughness of polypropylene/chitosan/sisal fibre membranes was investigated. The membranes with high quantity of sisal fibre showed higher roughness surfaces. The surface roughness analysis proposed that the membranes with increasing amount of sisal fiber would perform better in separation process.

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CRediT authorship contribution statement

O. Agboola: Conceptualization, Investigation. **E.R. Sadiku:** Supervision. **P. Popoola:** Supervision. **O.S.I. Fayomi:** Methodology, Investigation. **A.O. Ayeni:** Supervision. **D.T. Dick:** Investigation. **A. T. Adegbola:** Investigation. **L. Moropeng:** . **M. Ramakhokhovhu:** .

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

The authors acknowledges Covenant University for the financial support provided for the publication of this manuscript.

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