FLEXIBLE DIELECTRIC NANOCOMPOSITES USING NANOCELLULOSE AND RECYCLED ALUM SLUDGE

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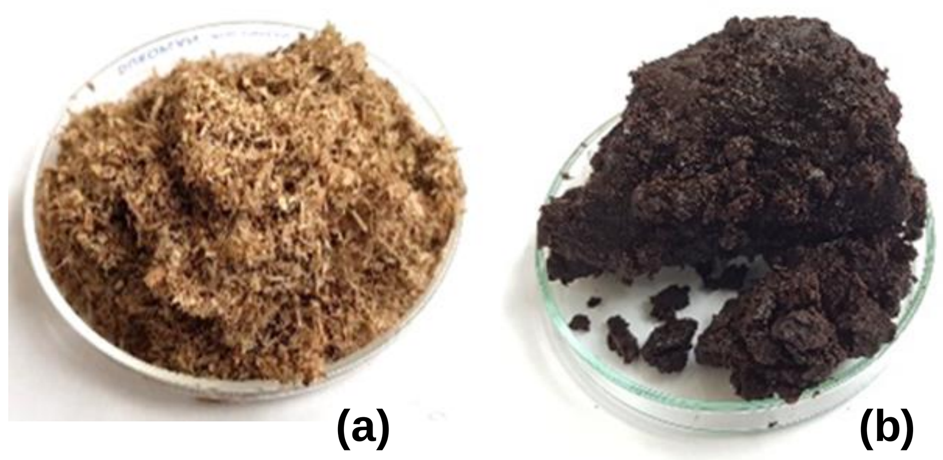
Backgrounds

A flexible nanocomposite was prepared including nanocellulose, recycled aluminium sludge and a bioelastomer acetoxy-polysiloxane (PDMS). The key components of the composite were prepared using wastes (**Figure 1**) which would otherwise be disposed to landfills. This work was to apply circular economy concept to utilise wastes and turn them into high value products. This can not only provide income stream to the industry but also reduce their cost of waste treatment and mitigate the adverse impacts to the planet. The composites exhibit reasonable mechanical and dielectric properties and are suitable as flexible dielectrics.



a) Water hyacinth was collected in a local water in Malaysia. It is a pest plant and very adaptable to the environment; it can invasively grow in a rapid pace to destroy the surrounding environment
b) Alum sludge was obtained from a local water treatment plant of Scottish Water (Rosebery Water Treatment Works)

Figure 1 (a) dried and ground water hyacinth material; **(b)** dewatered alum sludge sample collected from a treatment plant of Scottish Water in Midlothian, Scotland.

Processing methods

The processing of nanocomposites is categorised into three parts: the processing of cellulose nanofibrils (CNF), the heat treatment and refinement of alum sludge and the forming of CNF/alum sludge composites in PDMS matrix.

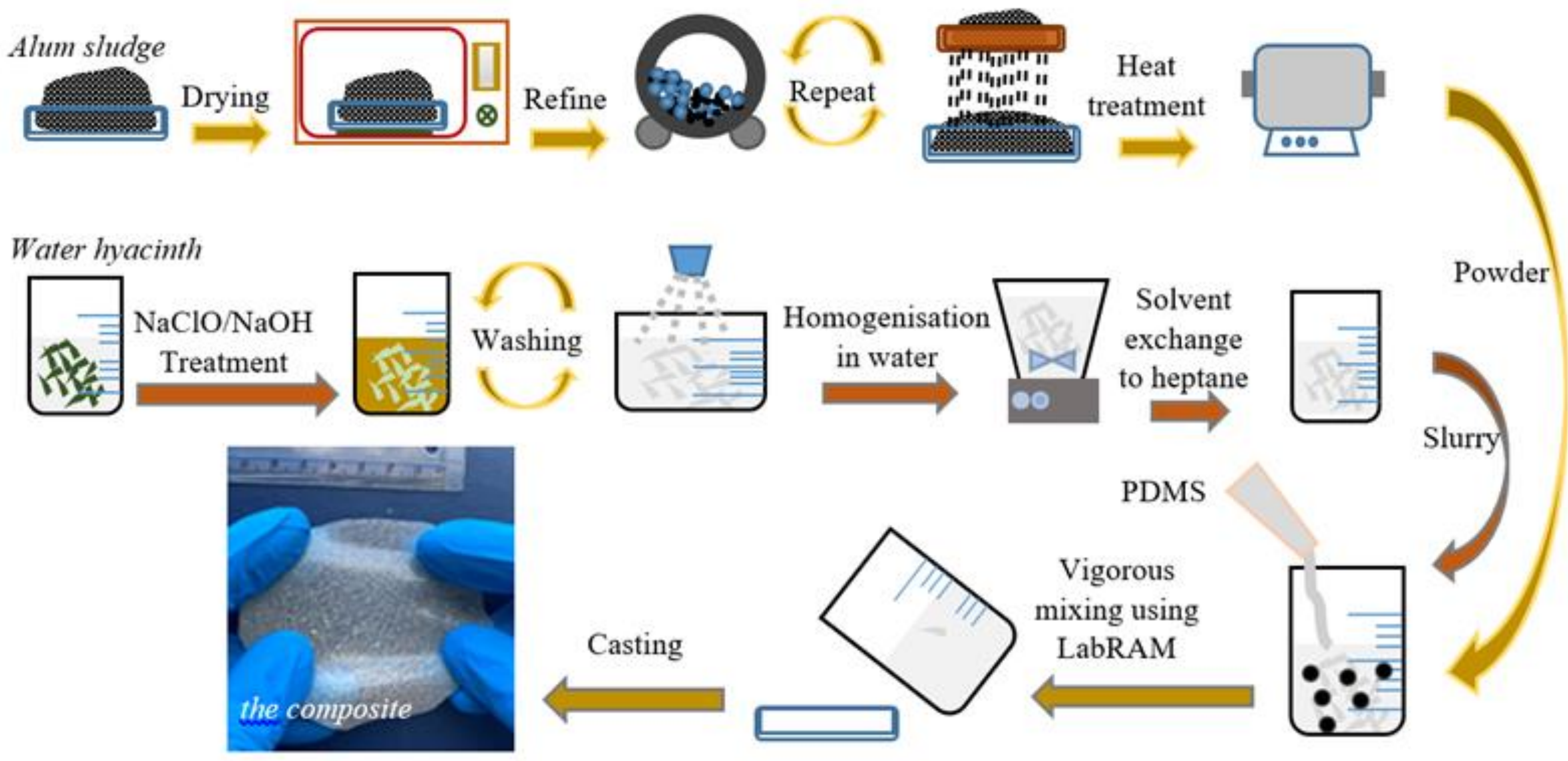


Figure 2 Schematic presentation of processing methods for alum sludge heat treatment, cellulose nanofibrils extraction and composite forming.

Results

No major difference on morphology for the sludge samples without and with heat treatments; although the surface of the latter appears more compact. Both samples show quartz structure and the heated one contains the structure of cubic γ-Al_2O_3.

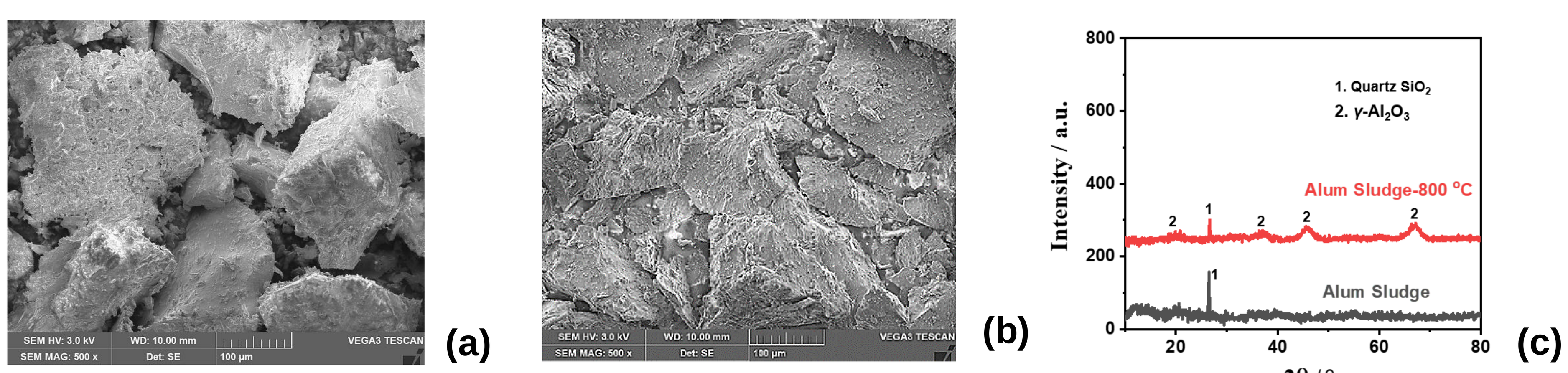
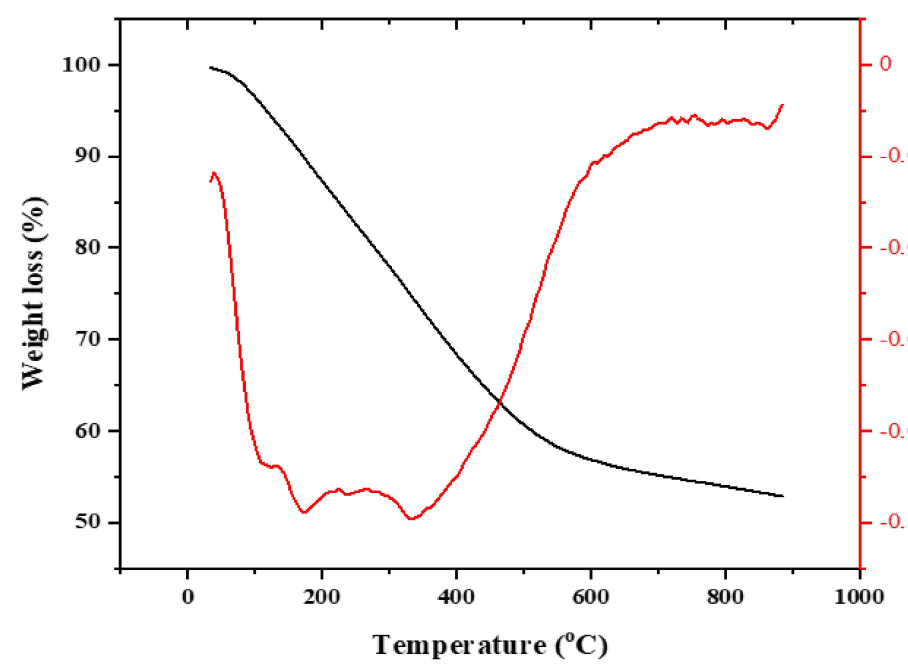


Figure 3 a) FESEM images of untreated alum sludge crumb and **b)** after being heat treated at 800°C; **c)** XRD spectra for the raw and heat treated alum sludge.

The TGA/DTG thermogram (**Figure 4**) shows the thermal stability of the raw alum sludge. Approximately 46% weight has been lost when the sample was heated up to 900°C. Three steps can be seen in the weight loss profile.



I. Up to 100°C, 4% weight loss, due to the removal of remaining free water
II. 105°C and 500°C, the majority of the weight loss; due to the removal of bound water and decomposition of some organic compounds (e.g. polyaluminium chloride hydroxide sulfate and Magnafloc®)
III. Above 500°C, the plateauing curve shows insignificant weight loss

Figure 4 TGA/DTG thermograms of the raw alum sludge crumb showing three steps of major weight loss when heated up to 900°C.

The water hyacinth raw material after chemical treatment was placed in a Z-shape interaction chamber of approximately 200 µm in diameter using a microfluidiser (**Figure 5a**), where a significant amount of shear force was generated to fibrillate the material into nanofibrils, CNF (**Figure 5b**). The CNF are of approximately 20nm in diameter and their length is estimated as approximately several micrometres.

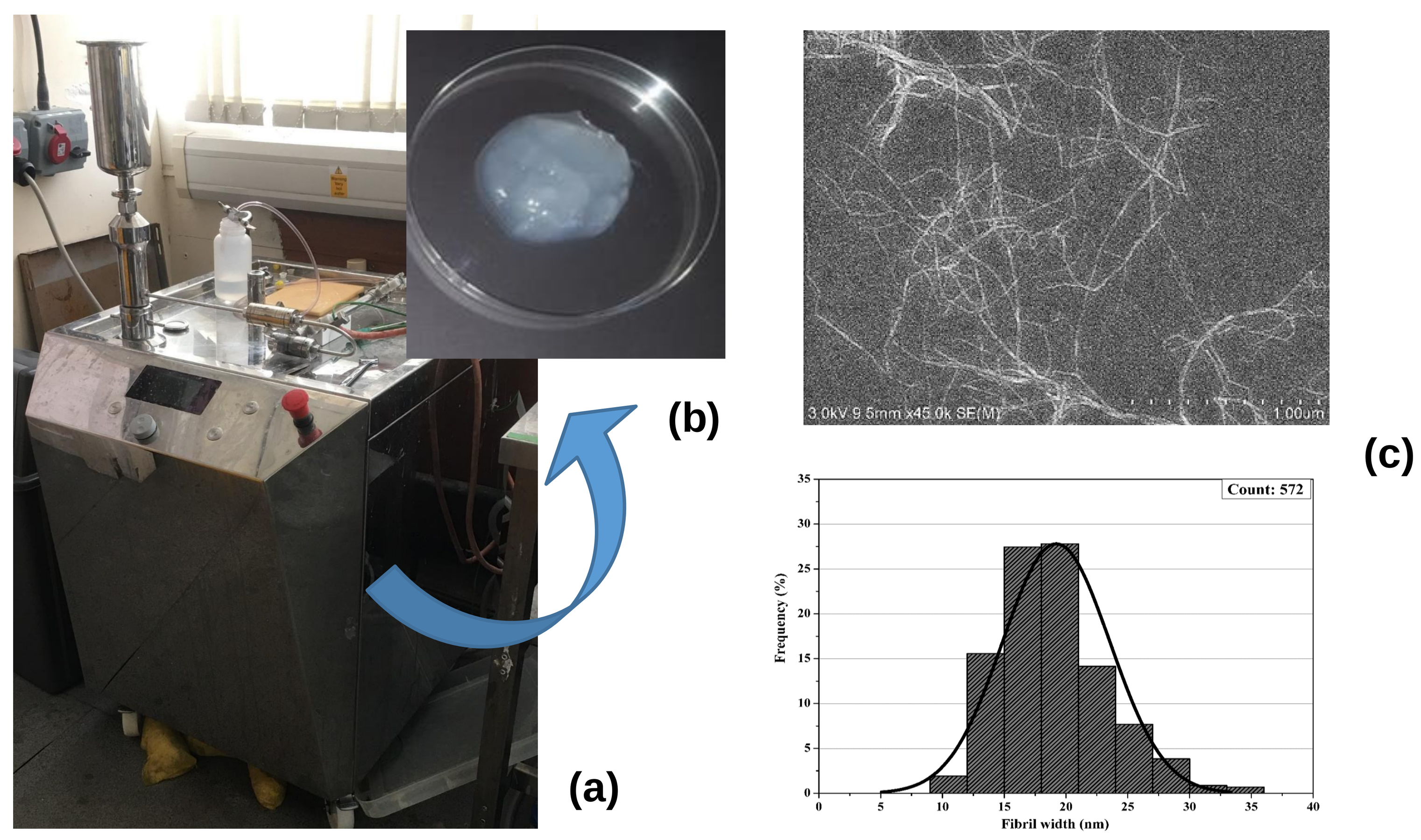


Figure 5 a) the microfluidiser with 200µm interaction chamber; **b)** the processed CNF after 1pass in the chamber; **c)** micrograph of CNF and their diameter size distribution.

The cross-sectional structure of the composite in the SEM micrograph shows an even distribution of alum sludge particles. Further investigation is needed for the lower value of tensile strength, although the composite has a 1.5% elongation at break. The composite has a dielectric permittivity of 2.77 ± 0.01 and a loss tangent of 0.0231 ± 0.005 at 1.9 GHz, indicating a promising candidate as a flexible dielectric material.

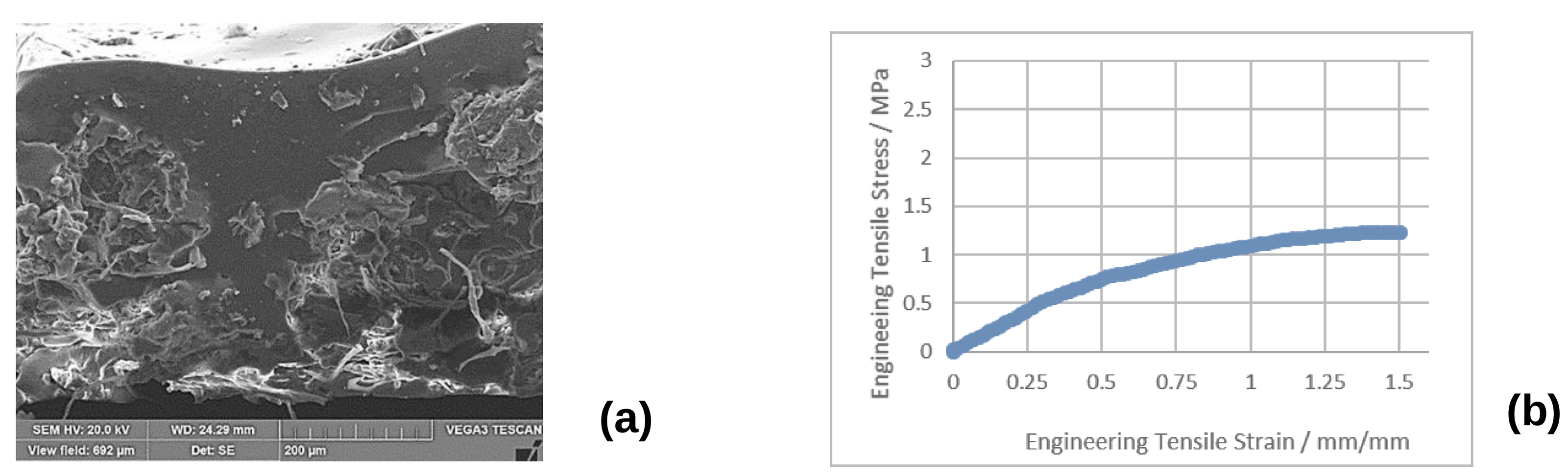


Figure 6 a) SEM micrograph of composite cross-section and **b)** its tensile test curve.

Acknowledgements

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