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Synthesis and characterization of cellulose nanocrystal derived from paper as nanofiller for polymer insulation materials

Nurul Shafiqah Amirah Badi [a,*], Mohamad Zul Hilmey Makmud [a,*], Chin Se Mun [a], Zuhair Jamain [a], Jahimin Asik [b], Khairatun Najwa Mohd Amin [c]

[a] Future Material & Sustainable Energy (FuSE) Research Group, Faculty of Science and Natural Resources, Universiti Malaysia Sabah, 88400 Kota Kinabalu, Sabah, Malaysia
[b] Industrial Chemistry Programme, Faculty of Science and Natural Resources, Universiti Malaysia Sabah, 88400 Kota Kinabalu, Sabah, Malaysia
[c] Faculty of Chemical and Process Engineering Technology, College of Engineering Technology, Universiti Malaysia Pahang, Gambang, Kuantan 26300, Pahang, Malaysia

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ABSTRACT

The synthesis and characterization of cellulose nanocrystal by utilizing filter paper as the source of material deserves to be an advanced approach. Nanocellulose has received enormous attention due to its unique properties. Being the most abundant organic polymer on earth, nanocellulose is the most suitable candidate for alternative replacement of petroleum-based products. The cellulose was extracted from filter paper by chemical processes involved alkali treatment, bleaching treatment, and acid hydrolysis. Cellulose nanocrystal has been characterized by scanning electron microscopy (SEM), Fourier transform infrared (FTIR) spectroscopy, X-ray diffraction (XRD) and Electrical Impedance Spectroscopy (EIS). The dielectric permittivity of the prepared CNC have been investigated in the different temperatures. The nanofiller CNC exhibits a higher real permittivity value at elevated temperatures (60 °C) in the low-frequency region. At high-frequency region, the real permittivity is independent on temperature. In brief, the studies point to the application potential of CNC for future insulation materials.

1. Introduction

Environmental problems are now a major concern for both humans and other living things. Many synthetic goods and materials have been developed over time to meet human requirements. These synthetic materials could have a negative impact on the environment and our life. To overcome these threats and due to the depletion of non-renewable resources, there is a growing interest in renewable resources and bio-based materials for the use as raw materials in the creation of value-added products. Nanocellulose derived from lignocellulosic materials is one of the sustainable materials which is abundantly available. It has gain significant attention in both research and industrial areas due to its appealing characteristics, including excellent mechanical properties, high surface area, rich hydroxyl groups for modification, and natural properties with 100 % environmental friendliness [1]. The properties of nanocellulose make it an interesting material for many applications such as paper and paperboard production, electronic devices, optical, sensor, insulation applications [2]. In recent years, the interest in advanced materials such as nanotechnology has been growing. The use of nanotechnology in insulation materials is a new way to develop high performance dielectric materials.

Cellulose nanocrystals (CNCs), stressed as one of the promising biodegradable materials in the nanotechnology industry, is normally extracted from wood pulp or agricultural residues and produced by the acid hydrolysis method, which is utilised to eliminate the disordered region of cellulose [3,4]. CNCs consist of rod-like shapes with a diameter of up to 100 nm and length of a few hundred nanometers [5]. They have impressive properties, being non-toxic, biodegradable, renewable, unique morphology, high crystallinity, and low thermal expansion [6]. The benefit of nano-sized filler is the high aspect ratio, resulting in high surface area, which can potentially change the property to enhance the insulation system [7].

Different types of composite and polymeric materials can be used as insulators in electrical systems. The behaviour of material permittivity can be a crucial factor and available polarizable aromatic rings like bromine and iodine can contribute to improving its dielectric constant [8]. According to findings by Müller et al. 2017 [9], the main criteria for electrical equipment as insulating to possess higher dielectric strength

* Corresponding authors.
E-mail addresses: pikaschafiqah@gmail.com (N.S. Amirah Badi), mzhilmey@ums.edu.my (M. Zul Hilmey Makmud).

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