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ELECTROSPUN NANOFIBRES FROM CELLULOSE

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INTRODUCTION

Cellulose has become one of the sustainable materials that suits to a broad type of applications due to its biodegradable attributes (Cucolo et al. 2001). It is the most abundant renewable material with 75 billion tonnes production per year around the globe (Youseef et al. 2010). The story of cellulose began in the year of 1838 when a French alchemist, Anselme Payen successfully extracted the cellulose from green plants (Sullivan 1997). Figure 1 shows the illustration of cellulose in plant cell and Figure 2 shows the chemical structure of the cellulose.

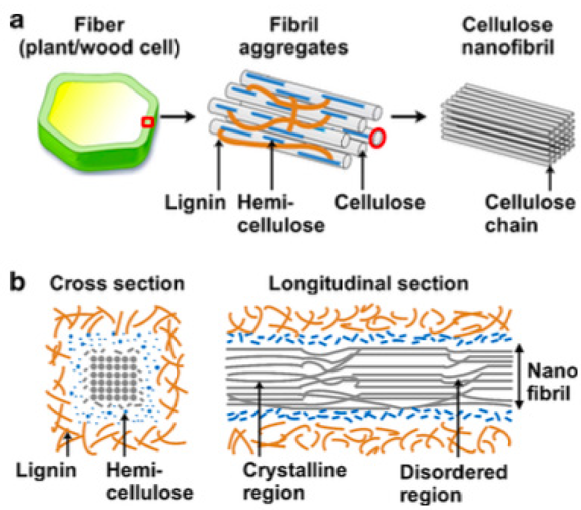


Figure 1 (a) cellulose in plant cell, (b) cross section of cellulose structure (Seddiqi et al. 2021)

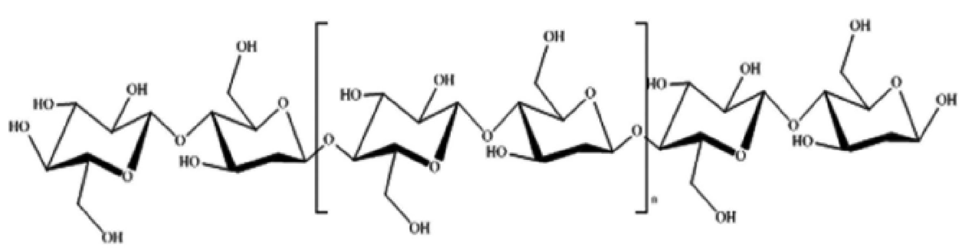


Figure 2 Chemical structure of cellulose (Wan Fathilah and Othaman 2019)

The long linear chains of cellulose allows the hydroxyl groups (-OH) on each anhydroglucose unit to interconnect with hydroxyl groups on adjacent chains by hydrogen bonding and van der Waals forces (Raghavan et al. 2015). This phenomenon accounts for the good mechanical properties of cellulose and makes it a prominent reinforcement agent.

ELECTROSPUN NANOFIBRES

Nanomaterials are materials possessing at least one external dimension that can be measured below 100 nm. Nanomaterials can be divided into four classes. 0D (nanoparticles), 1D (nanofibres), 2D (nanosheets) and 3D, a combination of each class (Tiwari et al. 2012). Nanofibres is one of the prominent materials among the group of nanomaterials. One of the most highlighted features of nanofibres is their high surface area-to-volume ratio and high porosity (Kenry 2017). Nanofibres also can be produced from either natural polymer or synthetic polymer (Behrens et al. 2014) using electrospinning process. Electrospinning process is the state of the art for producing nanofibres due to its feasible process (Feng et al. 2013). Figure 3 shows a common setup for electrospinning that consists of a voltage supply, syringe pump, nozzle, and a collector.

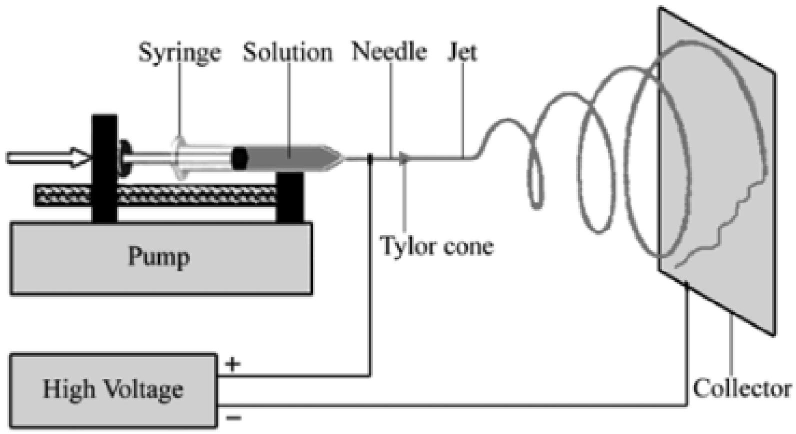


Figure 3 Common electrospinning setup (Ziabari et al. 2008)

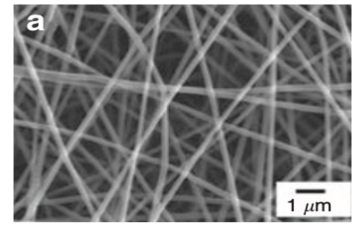
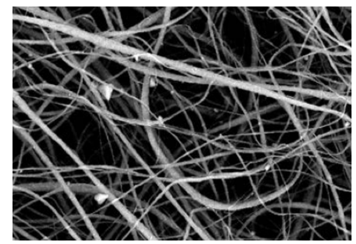
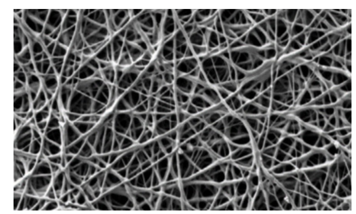
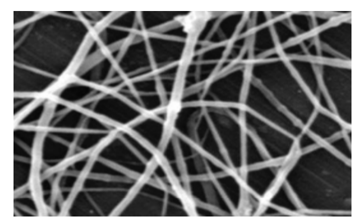
In this process, material solution is injected using syringe pump and drawn through nozzle by electrostatic forces and collected as randomly formed fibres or oriented fibres. The properties of the nanofibres are affected by parameter of the solution viscosity, voltage, humidity, distance, and flow rate (Nasreen et al. 2013). Studies on electrospun nanofibres using various synthetic and natural polymers are listed in Table 1.

However, apart from numerous advantages, nanofibres possess low mechanical properties (Yao et al. 2014) due to several factors such as high porosity, randomly oriented fibres and weak interaction between the fibres network (Huang et al. 2014). These factors limited their applicability in many fields. There are few reported methods that could improve the mechanical properties such as heating, chemical cross-linking (Li et al. 2017), and mixing with reinforcement agent (Tarus et al. 2020) such as cellulose. High abundance with good mechanical properties, cellulose is a prominent reinforcement material in improving the mechanical properties of nanofibres.

ELECTROSPINNING OF CELLULOSE

In order for cellulose to become feasible material for electrospinning process, cellulose must be converted into solution. However, the presence of strong intramolecular and intermolecular hydrogen bond and its rigid structure, almost no conventional solvent can dissolve cellulose (Raghavan et al. 2015). In the last decade, there are tremendous attempt to find an efficient and eco-friendly solvent to dissolve cellulose. At least, there are three types of solvents that seem prominent to dissolve cellulose which are NMMO (N-methylmorpholine-N-oxide) in Lyocell process (Mortimer 1996), sodium hydroxide-water solution in Celsol technology (Chen et al. 2007) and imidazole-based ionic liquid (Wang et al. 2012).

Table 1 List of publications on electrospun nanofibres produced from various polymers

Matrix	Solvent	Parameter	Diameter of the fibre (nm)	SEM Image	Reference
Polyvinyl alcohol (PVA)	Distilled water	-Diameter of needle: 0.6 mm -Voltage: 10kV -Distance between needle and collector: 15 cm	~190		(Park et al. 2010)
Polyvinylidene fluoride (PVDF)	N, N-dimethylformamide/ acetone	-Voltage: 20kV -Feed rate: 1.0 ml/hr -Distance between needle and collector: 15 cm	~394		(Mohd Salleh et al. 2020)
Chitosan/PVA	Acetic acid/Distilled water	-Voltage:14kV -Feed rate: 0.4 ml/hr -Distance between needle and collector: 10 cm	~59		(Habiba et al. 2017)
Polyethylene oxide (PEO)	Distilled water	-Voltage: 25kV -Distance between needle and collector: 20 cm	~113		(Filip and Peer 2019)

Among these, ionic liquid attracted many researchers to explore the feasibility as a safe solvent for cellulose due to its low melting temperature, high thermal stability, chemical stability, nonflammability, low toxicity and straightforward recycling process (Armand et al. 2009). Examples of ionic liquids that are successfully used in producing nanofibres using electrospinning process include 1-ethyl-3-methylimidazolium, 1-decyl-3-methylimidazolium chloride and N-methylmorpholine-N-oxide with co-solvents such as dimethylsulfoxide (DMSO), N,N-dimethylacetamide (DMAc) and N,N-dimethylformamide (DMF) (Freire et al. 2011).

APPLICATION OF ELECTROSPUN NANOFIBRES CELLULOSE

As a material with exceptional properties, there are wide spectrum of applications for nanofibres cellulose. Figure 4 shows the applications of electrospun nanofibres cellulose. In biomedical field, cellulose has been studied for wound dressing application due to its high surface area-to-volume ratio, good mechanical integrity, and its ability to imitate the topographical attribute of human skin that allows ample space for tissue regeneration (Gao et al. 2019). In cosmetic applications, there are growing interests in fabricating facial mask from nanofibres that are encapsulated with skincare products (Manatunga et al. 2020). In food packaging applications, nanofibres act as a reinforcement to strengthen the properties of a matrix material. Cellulose nanofibres can also increase the efficiency of gas and vapor permeability by introducing it as interlayers or coatings in the packaging (Torres-Giner 2011). Last but not least, cellulose electrospun nanofibres has also been in research spotlight for wastewater treatment. In one of the researches, they found that cellulose electrospun nanofibres exhibit good hydrophilic properties, robust dye adsorption and photocatalytic degradation which are good for the complex treatment of a wastewater system (Lu et al. 2021).

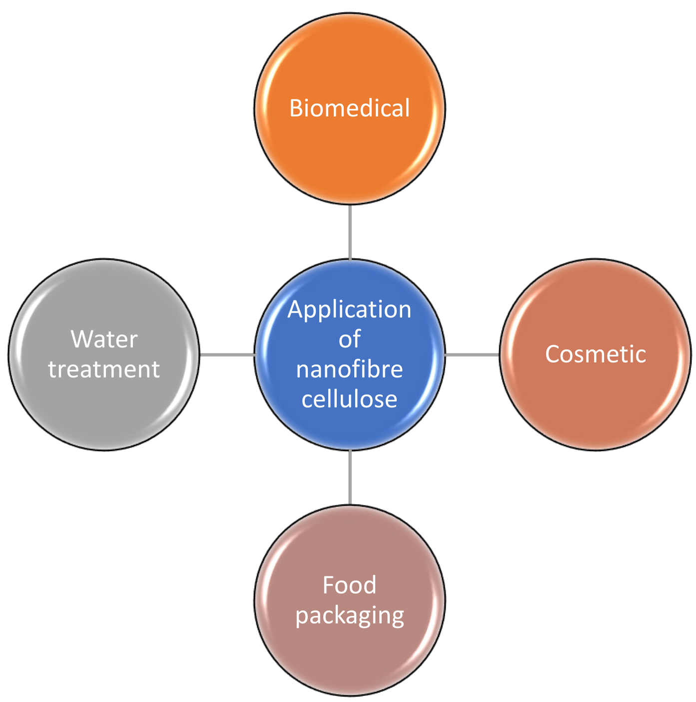


Figure 4 Application of electrospun nanofibres cellulose

CONCLUSION

At present, the usage of nanofibres cellulose is expected to emerge in many applications due to its unique attributes. In addition, cellulose is an alternative material to replace plastic for a sustainable future.

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Due to its remarkable features such as high surface area-to-volume ratio and superior porosity, electrospun nanofibres have gained the interest of many researchers in recent years. Aside from being facile to fabricate, the wide range of materials that can be used to generate nanofibres are also a draw for researchers. However, there have not been many studies on cellulose electrospun nanofibres due to the fact that cellulose is a difficult substance to be dissolved in order to electrospun. In this paper the research related to cellulose electrospun nanofibres and their applications are explained.

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