AgNW coated on poplar fibres for flexible capacitors

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Abstract Recently there has been great interest in flexible electronics and wearables. Traditional electronics fail to satisfy that demand due to being rigid and uncomfortable to wear. As an important element of electronic systems, flexible capacitors are needed in the application of wearables. Poplar fibres, which do not have any usage are in industry, perfectly suit with the demand of market owing to their unique properties. Silver nanowire coated non-woven poplar fibre webs exhibited very good electrical properties and they were quite sensitive to loads.

***Keywords*—Poplar fibres, Silver Nanowires, coating, capacitor, flexible.**

I. INTRODUCTION

FLEXIBILITY lexibility of traditional electronics are quite poor, which restraints feasibility of them in numerous applications so that lately, there has been great interest in flexible electronics [1–5]. Flexible capacitor, which are one of the most essence part of flexible electronics, have attracted attention from many researchers because of their potential employment in wearable electronics, robotics and many more applications. [6–8] Researches showed that capacitors [9], field-effect transistors [10], piezoresistive materials [11] and triboelectric nanogenerators [12] can be employed as flexible capacitors. Besides, carbon nanotubes [13,14], silver nanowires [15,16], gold nanowires [17] and graphene [18,19], whose main task is to increase electrical conductivity of matrix materials, are used to create flexible capacitors. However, when cost and efficiency parameters are taken into consideration, difficulties, expensiveness and complexity of many applications are faced. Moreover, sustainability of some of aforementioned methods are rather controversial. Since usage of hazardous chemicals, nonbiodegradable materials and high energy consumption heavily undermine ecology and depletes natural resources. Hence, developing flexible and sustainable capacitor at low cost still stands as a big challenge. The fibres produced from poplar seeds are short, hydrophobic, porous, lightweight and abundant in nature [20]. Additively, they possess a similar morphological structure to kapok fibre [21]. Poplar fibre that consists mainly of lignocellulose exhibits favourable physical properties, which are highly suitable to create flexible capacitor. Despite having very good physical characteristics, every year tons of poplar fibres are treated as waste material due to not being employed in any industrial application [21]. Herein, we demonstrate a simple method to create flexible capacitors by coating non-woven raw poplar fibre web with AgNWs. Non-woven raw poplar fibre webs were prepared via spray coating a polymer solution on aforementioned fibres, where poplar fibres serve as a skeleton and spandex fibres as binder. Coating porous non-woven raw poplar fibres with AgNWs formed a conductive network on the surface of poplar fibres. This study shows that AgNW coated nonwoven raw poplar fibre webs exhibit good electrical conductivity and flexibility, besides capacitors made of them are quite sensitive to loads.

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II. EXPERIMENTAL

A. Fibre preparation

The raw poplar used in the experiments was harvested during the middle of May in Istanbul. On account of, raw poplar fibres contain some amount of undesired foreign particles, mechanical cleaning was applied prior to following stages in order to prevent undesirable results. The poplar fibres were freed from the remnants of seeds, leaves and small particles with the help of steel tweezers and then placed in a glass container. After all, clean raw

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poplar fibres obtained to be used in the experiments.

B. Preparation of non-woven web samples

B1. Preparation of solution for spray coating

Commercial spandex fibres and Dimethylacetamide (DMAc), which were obtained from Hyosung and Sigma Aldrich Company, respectively, were put into the Erlenmeyer flask at the concentration of 0.04 g/ml, where 2.7 gram of spandex and 65 ml of Dimethylacetamide were used. Immediately after, the solution was placed on the magnetic stirrer whose rotation speed was set to 250 rpm at 50 °C. The Spandex/DMAc solution stirred on the magnetic stirrer for 2 hours to completely dissolve spandex fibres in Dimethylacetamide. The colour of the Spandex/DMAc solution became creamy white at the end of 2 hours and the whole spandex fibres were fully dissolved in DMAc.

B2. Spray coating

MagicBrush CP-101 Airbrush air compressor, which has ability to blow 350 mL air per second, and MagicBrush Airbrush Kit AB-125A gun, whose hose nozzle is 0.33 mm and reservoir capacity is 5 cc were used to carry out spray coating process. The reservoir of air gun was fully filled with of the Spandex/DMAc solution. After weighting each poplar specimen, the cleaned raw poplar fibres were finely placed in a long glass beaker for the purpose of giving smooth shape to non-woven webs. The air gun was set to a constant height of 50 cm and the Spandex/DMAc solution was sprayed at constant speed onto poplar fibre specimens. Poplar, which serves as a base fibre, covered with the Spandex/DMAc solution. The front and back surfaces of poplar specimens were held in the range of the gun of the air compressor for 15 minutes, evenly. Non-woven raw poplar webs formed after the spray-coating process were rested for 1 hour in an attempt to dry up the remnant DMAc.

C. Coating with AgNWs

The non-woven raw poplar webs were soaked in a glass container filled with AgNW/Ethanol solution at the concentration rate of 0.0175, where 0.35 gram of AgNW and 20 mL of C2H6O were used. Subsequently, the glass container was gently located in sonicator with the intention of increasing interaction of AgNWs and non-woven raw poplar web truly.

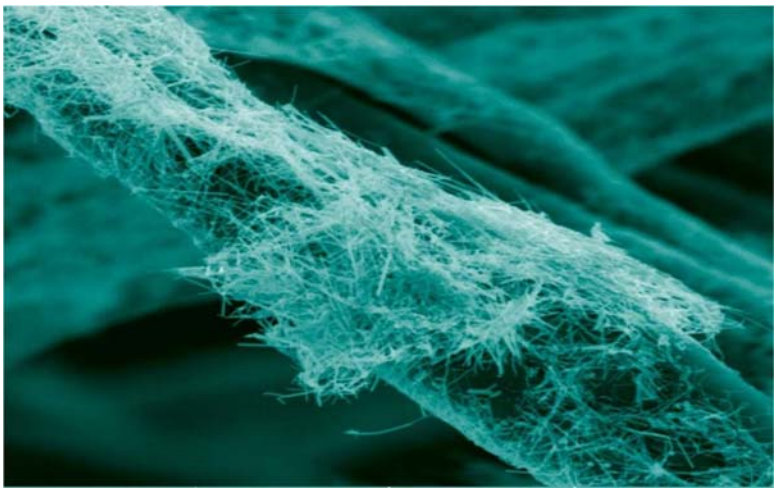

Fig. 1. SEM image of non-woven poplar capacitor under magnification rate of 5000X.

III. RESULTS AND DISCUSSION

As clearly seen in Fig. 1, the surface of poplar fibres covered with AgNWs via aforementioned continuous experimental methods. The conductivity of non-woven poplar fibre webs range from 6-15 Ω which indicates the success of methodology. In Table 1, the electrical conductivity range of five nonwoven poplar fibre web sample demonstrates the good electrical property of non-woven poplar fibre webs. Besides, standard deviation of average electrical conductivity of non-woven poplar fibre web is 1.78.

TABLE I
ELECTRICAL CONDUCTIVITY OF NON-WOVEN POPLAR FIBRE WEBS

Sample	Average Resistance (Ω)
Non-woven poplar fibre web-I.	6.80

Non-woven poplar fibre web-II	11.45
Non-woven poplar fibre web-III	8.80
Non-woven poplar fibre web-IV	10.35
Non-woven poplar fibre web-V	8.75

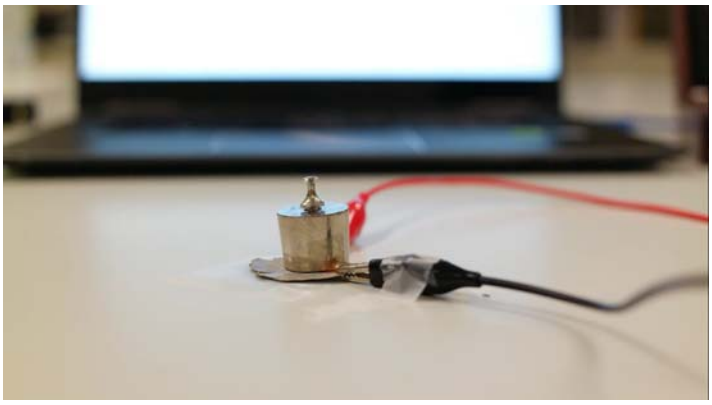

Fig. 2. An image of non-woven poplar capacitor during determination of capacitance values under precise weight.

As seen in the Fig. 2, several precise load are put onto non-woven poplar fibre webs in order to collect data about sensitivity of them. In the Fig. 3, the collected data about non-woven poplar fibre capacitors turned into weight versus time graph which indicates sensitivity of non-woven poplar fibre capacitors. Moreover, they can exhibit rather well properties by being sensitive even to small amount of loads such as 0.1 gram.

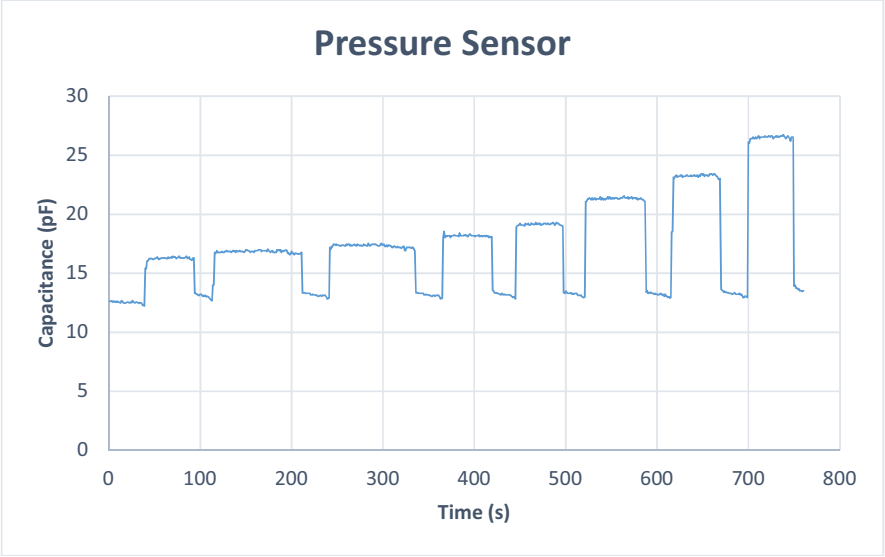

Fig. 3. Capacitance versus time graph of responds provided by non-woven poplar fibre web.

IV. Conclusion

In conclusion, non-woven poplar webs treated with AgNWs can be used in wearable and many more applications thanks to their flexibility, good electrical conductivity and hydrophobicity. Utilization of populus fibres has significant favourable impacts on the environment and wearable electronic industry because carbon emission is utmost minimized and biodegradability of product is achieved. Hopefully, this study can bring a bio-waste into the world of wearable electronics industry.e either SI (MKS) or CGS as primary units. (SI units are strongly encouraged.)

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