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Electrospinning Polyacrylonitrile to Make Carbon Nanofibers for Energy Conversion Applications

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Abstract

This work deals with the thermo- electric properties of Polyacrylonitrile (PAN) nanofibers were tested. The nanofibers were formed using the electrospinning process. Part of the material was heat treated to achieve stabilization then both samples underwent hyperthermia testing. It was observed that the PAN nanofibers did show a significant temperature response to the electromagnetic input.

Index terms— electrospinning, polyacrylonitrile (PAN), nanofiber, heat treatment, hyperthermia.

1 I. Introduction

anofibers have received much attention recently for their unique properties. They exhibit a high porosity and high surface area to volume ratio as well as unique thermal and mechanical properties [1]. The electrospinning process has made the production of nanoscale fibers cheaper and easier to accomplish than previously developed methods. Electrospinning is performed by exposing a small jet of the desired material to a relatively high voltage, usually in the range of 5kV to 30kV. This voltage causes the material to undergo stretching and bending as it gets farther away from the voltage point in the pattern of a Taylor Cone, as studied in depth by Sir Geoffrey Taylor [2]. The reduction of area is caused by instability of the material leading to a bending and stretching action, as confirmed by high speed camera [3]. The solvent is evaporated off during this process, leaving only the desired fibers on the collector. Fiber size decreases with a smaller initial jet and slower flow rate. Lower material concentration in the solution also decreases fiber size [4]. Nanoscale fibers have been achieved for many materials and the list is constantly growing. The new materials must be tested to find their respective properties before practical applications can be assigned. In this work, the thermo-electric properties of polyacrylo-nitrile nanofibers will be tested. Polyacrylonitrile (PAN) is commonly used to create carbon nanofibers. Due to difficulties in dissolving the material for spinning, no meaningful work was done creating PAN fibers until 1925 [5]. Since then, PAN fibers have found uses in a verity of fields. The porosity of PAN nanofibers have given them use in filtering applications. These applications already include air filtering [6] and heavy metal removal from water [7][8]. Unmodified PAN nanofibers have seen little practical use. Heat treatment is widely used to change the properties of the material to make them more useful. An initial stabilization heat treatment is performed on the fibers at a temperature above 260 o C [9].

To achieve carbon nanofibers, a higher temperature must be used. The PAN material undergoes full carbonization at around 1600 o C [10]. While strength can vary by fiber diameter, applied heat treatment, and experimental process, a controlled test found a tensile strength of 300-600 MPa and a Young's Modulus of 40-60 GPa for PAN nanofibers [11]. With a proper heating reaction from an electromagnetic field, PAN nanofibers could also be used in medicine delivery. The porosity of the material allows it to absorb a substance then be positioned in the body. The proper heating will cause the material to swell and release the absorbed material [12]. It has also been used to generate localized heating to combat cancer cells [13]. These ideas are directly linked to hyperthermia testing.

2 II. Experimental Procedures

The solution was prepared using 0.5g polyacrylonitrile powder (Mw: 150,000) and 5mL dimethylformamide. To ensure the powder was completely dissolved, the solution was heated in a water bath and mixed with a glass rod for approximately 30 minutes. The solution was loaded into a syringe and underwent the electrospinning process at a voltage of 7.5kV and a flow rate of 0.005mL/min. Portions of the specimens were taken for heat treatment. The material was wrapped in foil and placed in the furnace. The material was slowly heated to 500 o C then held at that temperature for 2 hours.Both original and heat treated specimens were subjected to hyperthermia testing. Non-heated material temperatures were taken with an infrared temperature sensor. The specimen was subjected to an electromagnetic field for a controlled length of time then temperature was measured again.

3 III. Results and Discussion

The hyperthermia test results can be found in the two tables below for the as-spun (Table 1) and heat treated (Table 2) specimens, respectively. The reason for 6 columns of temperatures is due to the following consideration. We took six representative points for 2. The reason for this increased hyperthermia behavior may be due to the composition change of the nanofibers. After the heat treatment, the nanofibers are carbonized. Polymeric carbon could be more sensitive to the external electromagnetic field than the precursor PAN polymer. This is because the carbon has better electrical conducting behavior. The electromagnetic wave energy is converted more effectively into heat since the better the conductive of the material, the more intensive of the inductive response.

4 IV. Conclusion

Both as-spun and heat treated polyacrylonitrile nanofibers showed a significant temperature response when subjected to an electromagnetic field. Both samples were subjected to the same field with controlled exposure times. The results showed an increased reaction from the heat treated material.

The findings of this work suggest possible use of PAN nanofibers as a drug delivery system and localized cancer treatment. The porosity of the material has already found use as filters. With the proper heating, PAN fibers could be used to hold and release medicine inside a body when subjected to an electromagnetic stimulant. The rapid heat reaction could also be used to locally combat cancer in sensitive areas of the body. However, further study should be completed on specific material amount, desired field strength and frequency, and porosity response to temperature change before used in either of these methods. [1]

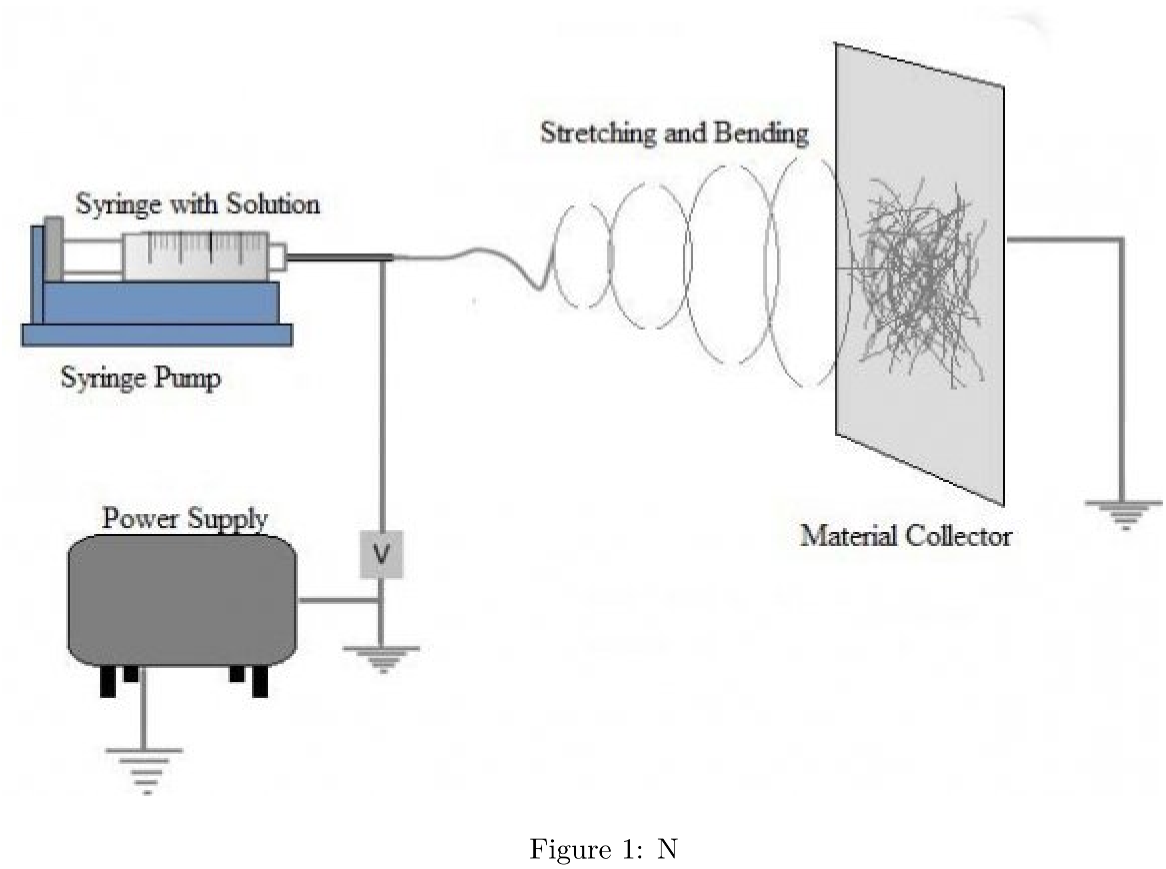

Figure 1: N

1

Time (s)	Temperature (o C)						Avg.
0	22.4	22.4	22.4	22.4	22.4	22.4	22.4
5	22.6	22.6	22.6	22.6	22.6	22.6	22.6
10	25.8	25.8	25.4	25.4	25.4	25.4	25.5
15	29.6	29.6	29.6	29.6	29.6	29.6	29.6
20	36.6	35.4	35.2	35.4	36.6	35.2	35.7
30	41.4	41.4	39.2	39.2	39.8	40.6	40.3

Figure 2: Table 1 :

2

Time (s)	Temperature (o C)						Avg.
0	21.4	21.2	21.6	21.2	21.2	21.2	21.3
5	22.0	22.2	22.2	22.2	22.0	22.0	22.1
10	25.2	25.2	25.2	25.2	25.0	25.0	25.1
15	27.0	27.0	27.0	27.0	27.0	27.0	27.0
20	33.6	33.6	33.4	33.4	33.4	33.6	33.5
30	45.0	46.4	46.4	46.6	46.0	46.0	46.1

Figure 3: Table 2 :

.1 V. Acknowledgements

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