Graphene spin-coated electrode for polyacrylonitrile acoustic nanogenerators

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Research Article

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Abstract

In recent years piezoelectric nanogenerators, due to their more durability in high dust or humidity are more attractive than triboelectric ones. So, increasing their outputs is the subject of much researches. I focused on electrodes of the acoustic nanofibers nanogenerators for the first time. Here, I introduced a new electrode that is cheaper and does not result in lower outputs. Here for the first time graphene spin-coated ink was used for polyacrylonitrile-based acoustic nanogenerator. The results of the tests compared with the in-situ synthesis of nickel nanoparticles on the layer and using graphene spin-coated screen ink and conductive tapes. Finally, producing sound by this graphene ink was done too.

Introduction

Acoustic nanogenerators were first introduced in 2010 [1], and PVDF nanofibers nanogenerators were first introduced in 2016 [2]. Finally, as the best of all PAN nanofibers nanogenerators introduced in 2020. So, here I have chosen PAN nanofibers for making acoustic nanogenerators. Up to now, the effect of using nanofiber or film, reducing the diameter of the nanofibers, increasing the orientation of nanofibers webs, the addition of additives to nanofibers, increasing the nanofibers porosity, presence of beads in nanofibers, testing conditions (for example, frequency, sound pressure, and presence of hole on the electrode) and thickness of the layer has been investigated [2-4] but the effect of electrodes has not been investigated for nanofibers based nanogenerators. So, I have to focus on it. Two electrode applying methods were used, which were not being used for acoustic nanogenerators of polyacrylonitrile (PAN) nanofibers before. One of them was the spin coating of the graphene ink on the polyester (PET) thin film (PAN/G), and the other was in-situ synthesis of nickel (Ni) nanoparticles on the PAN nanofiber web and using the above electrode as its electrodes (PAN/Ni/G). Results showed that graphene ink is good enough to choose as electrode of these devices with the benefits of low cost, more simple way and it can produce sound by piezoresistive property so, higher conductivity of Ni conductive tapes do not play an important role in a higher output of these devices and there is no reason to choose their tapes. So, graphene ink was good enough to be used as an electrode, and in-situ synthesis of Ni nanoparticles on the layer could reduce the outputs but the process is wet and is a bit hard.

Materials

PAN pellets with a molecular weight of 230000g/mol were prepared from Sigma Aldrich Company with the analytical grade, DMF with the analytical grade, was prepared from Merck Company. Graphene ink, hydrazine, nickel acetate were prepared from Kara Pajohesh Company (Iran), Merck company, and Merck company, respectively.

Instruments and sample preparation

Two nozzles horizontal electrospinning (model, drum collector, voltage supply with voltage range of kV) were used to prepare the PVDF nanofiber web. 0.3g PAN dissolved in 3ml DMF. The electrospinning

condition was 11cm, 0.2ml/h and 10kV [5]. Electrospinning continued for 3.5h. Rectangles with 3*4cm² dimensions cut from resultant web and then followed by in-situ synthesis of Ni nanoparticles on it for penetrated electrodes (same as the previous work of Moazzenchi and Montazer done [6]).

Samples characterizing

FESEM images of the nanofibers prepared. Nanofibers diameters measured with Image-J Software. An average of 100 nanofiber diameters was used. Histograms were drawn with Minitab 19 Software. Acoustic tests did by speaker and multimeter.

Morphology of the nanofibers

The results of FESEM images and nanofiber average diameter are presented in table 1. From the results, it is clear that in-situ synthesis of Ni resulted in wider distribution and higher average diameter of nanofibers.

Table 1 shows the average diameters of the nanoweb.

Piezoelectric tests

The results of measuring the electric output of the nanofiber web by both electrodes for sound pressure are presented in table 2. In-situ synthesis of Ni on the nanofibers resulted in lower output. So, this way is a good one for getting a non-piezoelectric PAN nanofiber. It may happen because Ni nanoparticles are disturb for piezoelectric effect.

Table 2. Electric outputs of nanofiber web.

Sample code	Electric output	Sample code	Electric output
PAN/G	10-60mV (44-330Hz, 81-114dB)	PAN/Ni-Cu	10-120mV (44-330Hz, 81-114dB) but 120 reduced to 60 for second, third, and fourth repeats
PAN/Ni/Ni-Cu	Very low or zero		

PAN/G is PAN nanofibers with graphene ink electrode, PAN/Ni-Cu is PAN nanofibers with Ni-Cu conductive tape, and PAN/Ni/Ni-Cu is PAN nanofibers with the in-situ synthesis of Ni on them and Ni-Cu conductive tape.

The results showed that the graphene ink electrode had high output (similar to source number 7 [7]). So, it can be a good alternative for metal-based electrodes with higher costs, and in-situ synthesis of Ni nanoparticles on the nanofibers resulted in higher outputs.

Results

In this work, comparing two ways of electrode apply was done. The best electrode for acoustic PAN acoustic nanogenerator was found, which is simple and cheap compared to other methods, and it had the advantage of producing a sound that was good enough compared to other works. For further work, using ILS surfactant as a doping agent is the best way. Studies [3, 8, 9] showed that the best way for improving the output of acoustic nanogenerators is to choose an appropriate additive for adding to the electrospinning solution. Attention if the dopant is not good enough, you can see only a bit of change in the output [10]. ILS was suggested because it could increase the output of piezo tests very well [5], and now there is a time to test it for acoustic tests. The electrodes of nanogenerators are not very important for increasing the output of nanogenerators but the cost of them makes researchers find the cheapest, and easiest way [7]. Among different electrode applying methods, printing and using nanomaterials have got lots of attention in recent years [11]. So, the two above methods were investigated in this work. In the first work in this area, finding the best nanofiber web's parameters include nanofiber diameter, the thickness of the nanofiber web, nanoweb area, presence of hole on the electrode, and the area of the hole, and its position, and the kind of chosen polymer found important [2], and they found that the output is higher in special sound pressure, sound frequency, and way of applying sound on the layer which should be optimized. In further studies, this group found that increasing the numbers of the hole and making them smaller can help higher outputs [12]. In the last work of this group, PAN nanofiber web found better outputs than PVDF copolymer [13] so, another subject for writing an article is to do the bests of this article for PAN nanofiber web, which was done here. Also, in-situ synthesis of Ni on the nanofibers was a way to reduce the piezoelectric output.

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Table 1

Table 1 is available in the Supplementary Files section.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Table1.docx](#)