Performance Study of Piezoelectric Nanomaterial with Ag/ZnO/ITO-Polymer Silicone

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***Abstract*-With the development of science and technology, people are paying more attention to the smaller-sized generators. The main purpose of this article is to manufacture the piezoelectric materials of Ag/ZnO/ITO, and introduce their working principle and focus on their performances. The results show that, by using the present nanomaterials, piezoelectric nanogenerator of Ag/ZnO/ITO can be prepared and the electrical energy can reached 40 μW, 150 nA and 309 μV. In ambient vibration condition, piezoelectric materials produce larger rated current and voltage. However, copper laps cutting magnetic line of force produce less rated current and voltage. So the piezoelectric nanogenerator can be used to supply power. It may produce higher voltage, current and power if piezoelectric nanogenerator is in series-parallel connection, there is a commercial value.**

Keywords- Ag/ZnO/ITO; Piezoelectric Materials; Nano; Generators; Power

I. INTRODUCTION

With the improvement of human life, litter, deft and high-capacity generate material is required to human health monitoring, environment monitoring, internet, military applications and so on, therefore seeking weighs less portable power supply becomes more and more important [1]. In the future, micro/nano-system technology will be widely used [2].

In 1880, Pierre Curie brother found some crystals having the piezoelectric effect, in their shape change produced current and was energized then they could produce the deformation [3]. In the year 2009, Yang et al. discovered that deformation in some nanoscale materials such as ZnO/ITO fiber produces electrical energy because of its piezoelectric characteristics (smallest electricity generators) [4]. In 2011, Yang et al. reported that direct and alternating current nano generators with ZnO/Pt materials were invented at their lab and they can get about 10 μV and 5 μA nano generators [5]. Moreover in 2013, Sheikh A et al. reported the same phenomena in ternary complex of Au/$ZnFe_2O_4$/ZnO and he measured their electricity performance [6]. This study showed higher generated power under vibration. These promising properties may increase the future research about micro/nano-system technology, however since the electrical energy of above nano generators is too small, we researched the piezoelectric nanomaterial of Ag/ZnO/ITO-polymer silicone, which may produce higher voltage, current and power.

II. EXPERIMENT

A. Materials

Nano-copper, UG-Cu01, Suzhou Gifted Zirconia Nano Material Co. Ltd., nano-iron, Chengdu Nuclear Eight Five Seven New Material Co. Ltd., nano single-walled carbon nanotubes, Shanghai kajet Chemical Technology Co. Ltd., nano metallic conductors, Shenzhen Xingguang Electrothermal Products Co. Ltd., insulation paint, ZM99-01, Beijing Zema New Technology Co. Ltd., metal platinum piece, Shanghai Sanguang Electric Engineering Alloy Co. Ltd., Zn(NO3)2.6H2O, Analysis of pure, Shanghai Yiping Industrial Co. Ltd., $(CH2)_6N_4$, Analysis of pure, Zhengzhou Xingchang Chemical Products Co. Ltd., indium tin oxides(ITO), Shenzhen Shuangming August Technology Co. Ltd., anhydrous alcohol, Analysis of pure, Suzhou Orient Chemical Co. Ltd., $AgNO_3$, Analysis of pure, Zhengzhou Kangyuan Chemical Products Co. Ltd., polymer silicone, Jiaxing Green Silicone Co. Ltd., carbon fiber, Shanghai kajet Chemical Technology Co. Ltd., fast quenching NdFeB magnets(20-50nm), Shanghai Ampere Magnetic Industry Co. Ltd., $BaTiO_3$ insulation paint(80nm), Dongguan Huahan Insulation Materials Co. Ltd., milli-tile voltmeter, Yueqing City Xisheng Electrical Co. Ltd., micro ammeter, Yueqing City Xisheng Electrical Co. Ltd., oscilloscope, XJ92D-42A, Yueqing City Xisheng Electrical Co. Ltd., SEM, S-4800, Hitachi High Tech. Co. Ltd.

B. Piezoelectric Material Preparation

The same amount of $Zn(CH_3COO)_2.2H_2O$ and ethylene glycol monomethyl ether are mixed by stir at 60℃, then a certain amount of ethanolamine is dropwisely added to above solution, the concentration of $Zn(CH_3COO)_2$ and ethanolamine are 1.2mol/L, the stir is stopped after 30 min, followed by stewing for 48 h. The cleanly ITO is spined with the above solution by 2000min^{-1} spin coater, it is dried 30 min at 150℃ in dryer, this process is repeated several times, then it is heated in muffle furnace for 30 min by 350℃, and then cooled under the room temperature, then we can get the ITO with nano seed layer of

ZnO [7].

0.01 mole $Zn(NO_3)_2.6H_2O$ and $(CH_2)_6N_4$ are taken respectively, and they are dissolved in deionized water, stir evenly, pour water kettle polyure, one side of ITO has a layer of ZnO nanoparticle seeds, and it is put into the middle of the above solution, and then they are put into thermostatic oven at 95℃ for 8 hours, ITO board is taken out after the completion, and it is washed by deionized water and anhydrous ethanol respectively, then it is dried backup at 60℃ in thermostatic oven as standby [8].

0.00004 mole $AgNO_3$ and anhydrous ethanol(20%v/v) are taken respectively, and they are dissolved in 20mL deionized water, the front handle nanowire arrays of ZnO/ITO board is immersed, and exposed to xenon lamp of 300W exposures to it for 3 min, and the Ag/ZnO/ITO board is washed by deionized water and anhydrous ethanol respectively, then it is dried backup at 60 ℃ in thermostatic oven as standby [9]. The production process is shown in Fig. 1 [10]:

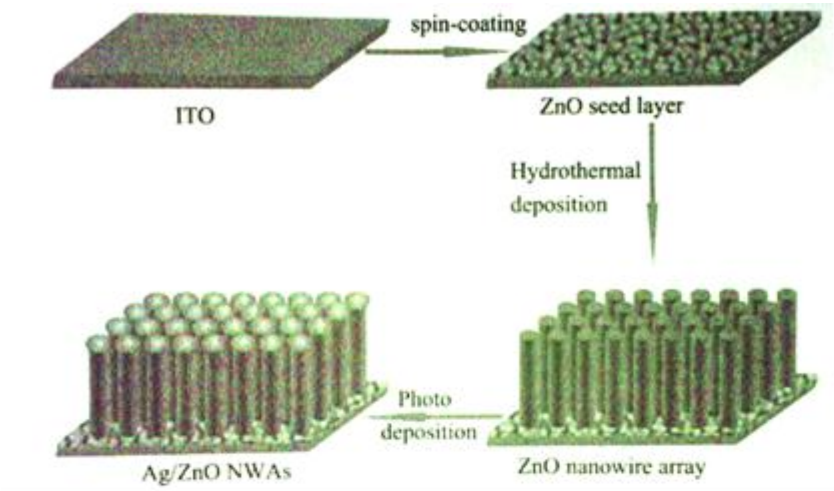

Fig. 1 The production process of Ag/ZnO/ITO piezoelectric material

C. Manufacture of Piezoelectric Nanogenerator

The N and S pole are produced by fast quenching Neodymium–Iron-Boron permanent magnets (20-50nm), the collector ring is constituted by nano copper, the vibrobatten for piezoelectric material elastic plate of Ag/ZnO/ITO board is winded by nano copper laps, the fixed holder is made of carbon fiber. Both copper laps and piezoelectric materials under micro vibrations can generate electricity [11]. Its work and measuring circuit are showed by Fig. 2. Before using piezoelectric material, the two floors of Ag/ZnO/ITO board on up and down are covered by polymer silicone board for protecting their mechanical capacity.

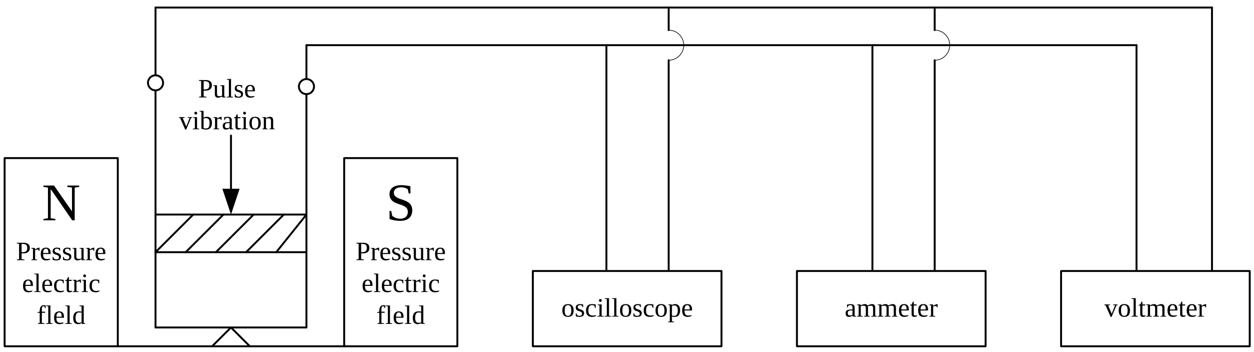

Fig. 2 The circuit determination schematic of piezoelectric nanogenerator under vibration

III. RESULTS AND DISCUSSION

With using SEM to observe surface of the Ag/ZnO/ITO board, the result is showed in Fig. 3 and Fig. 4. It can be seen that the Ag nanoparticles are loaded at the top of the ZnO nanowires, the ZnO nanowires grow in a good condition, it presents that the bottom is big and the upper is small. According to micro vibrations pulse (50 times/points) demonstration, the oscilloscope shows diphasic and sinuidal, waveform is big and smooth. The value of voltage, current, power and power factor are shown in Table 1.

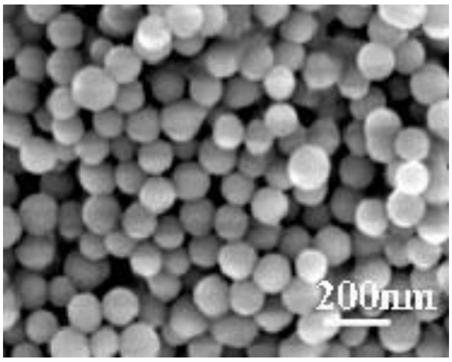

Fig. 3 The SEM of surface of Ag/ZnO/ITO board

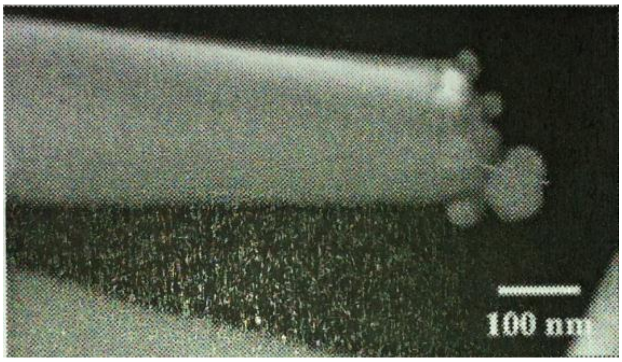

Fig. 4 The SEM of surface in one array of Ag/ZnO

TABLE 1 THE CURRENT, VOLTAGE AND POWER OF NANOBATTERY UNDER VIBRATION IN PRESS AND CHANGE ELECTRIC FIELD

Project	First determination	The second determination	The third determination	Average	Standard deviations
Nominal voltage（μV）	300	320	308	309(106)	±10
Current rating（nA）	150	148	152	150(50)	±5
Power（μW）	38	42	39	40(8)	±5
Power factor	0.85	0.88	0.84	0.85(0.85)	±0.05
Frequency (HZ)	52	50	48	50(50)	±5

Notes: The values in brackets are the values of our previous prepared ZnO nanowires.

It is showed that piezoelectric nanogenerator under vibration having larger voltage, current and power compared with previous material by Table 1, the rated current is 150 nA, rated voltage power is 309 μV, and power is 40 μW, and power factor reaches to 0.85, all of generating efficiency is higher than our previous work which can be compared from the average values in brackets [12]. It is observed by oscilloscope waveform, in ambient vibration condition, piezoelectric materials produce larger rated current and voltage. However, copper laps cutting magnetic line of force produce less rated current and voltage. So the piezoelectric nanogenerators can be separately used to supply power. Multiple piezoelectric nanogenerator in tandem may produce higher voltage, current and power. But because piezoelectric materials have large surface area, if multiple piezoelectric nanomaterials are in series, surface area may be reached to several dozens of square centimeters, however, this kind of generator is only suitable for large surface area, such as underground sidewalk, platform bridge and stair tread etc., the piezoelectric nanomaterials laid in the next can light the road lamp up. Some papers reported that a kind of nano piezoelectric materials they found had achieved 3-6 mV output, but our experiment is showed which the Ag/ZnO/ITO board piezoelectric nanogenerator under vibration is only 309 μV. It is the average of our prepared Ag/ZnO/ITO board piezoelectric nanogenerator.

IV. CONCLUSIONS

The paper introduces the working principle about the nanogenerator of Ag/ZnO/ITO-polymer silicone under ambient vibration, and the nanogenerator of Ag/ZnO/ITO-polymer silicone is produced, its performance is studied, the results are given below:

The piezoelectric nanogenerator of Ag/ZnO/ITO-polymer silicone can be prepared using nanoscale piezoelectric materials, the electrical energy can reached 40 μW, 150 nA and 309 μV, the generating efficiency is higher than our previous work. In ambient vibration condition, piezoelectric materials can produce larger rated current and voltage. Duo to the factor that less rated current and voltage are got for copper laps cutting magnetic force line, so the piezoelectric nanogenerator can be separately used to supply power. There is much higher voltage, current and power by series multistage of many piezoelectric nanogenerators. Another advantage is that the electrical energy of Ag/ZnO/ITO-polymer silicone nanogenerator has greater improvements compared with the previous material.

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