Performance of Zinc Oxide Coated On Copper Substrate in Generating Piezoelectric Energy

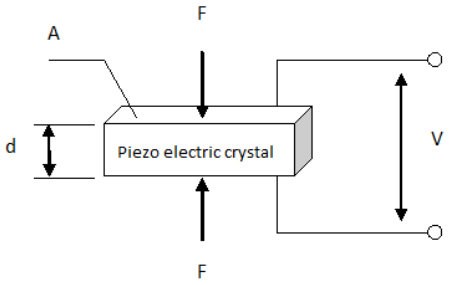
Hemakumar .V. S, Suresh. P

Abstract: ***The energy harvesting is one of the progressive multidimensional research themes over the world for variety of needs. The harvesting of energy increases demand from low power electronic devices to high power industrial needs for variety of applications. In this paper, the Zinc oxide Nanowires are grown on the surfaces of the metal substrate (copper substrate) using a solution based technique. The stress is applied on the substrate and the power generation capability of the Zinc oxide nano wires synthesized on the copper substrate were estimated. A low cost design and manufacturing is proposed to prepare the Zinc oxide based piezoelectric energy harvesting. The maximum output voltage obtained is about 153mv and current of 75nA is obtained for the copper substrate. The voltage obtained may be used for nano devices which require minimal voltage. The same setup is been simulated using* by *M/s.COMSOL Multiphysics software for various substrate sizes. Therefore the estimated design is able to study the capability of the zinc oxide in piezoelectric energy harvesting.***

Keywords**: Zinc Oxide, piezoelectric, copper substrate, energy harvesting.**

I. INTRODUCTION

More than a decade energy harvesting has high potential research work carried over the globe [1]from home need to industrial needs. The most considered external energy sources are wind, solar, vibration, thermoelectric, temperature gradient, radio frequency, acoustic etc., among this the prominent improvements are in low power consuming miniaturized wireless electronic devices for wider applications. More than a decade, enormous research has been carried out for energy harvesting using piezo electric transducers due to its advantages and its high performance in generation of power with limited conventional external force at zero cost based on vibration in high ratios. The basic principle of piezo electricity is shown in the figure below:



Where F- Force applied to the crystal
V- Output Voltage obtained
A- Area of the piezoelectric crystal
D- Thickness of the Plate

The piezoelectric material grows longer or shorter in dimension in the case of an electric field applied to it [3].The characterization of piezoelectric material is rigid and fragile with low toughness and ductility and the properties are depends on inter atomic bond structure, due to this it has high thermal stability and high performance [5]. The energy harvesting mechanism of piezo electric material is elaborated in [5]. Ilyas and Swingler [7] generated power of below 3mW with efficiency less than 0.12% experimentally using piezo electric from rain drop. The prototype devices which consume low power generated using piezo electric transducer experimentally with reference to theoretical calculation [8].Yang et al., and his team generated electricity by coupling nano generators and it is reported in [9] and it is highly important for developing the next-generation coupled energy harvesting devices [10] with piezo electric material. Due to enormous application it is necessary to develop low power-self generated devices for all applications. However, it is necessary to construct high performance piezo electric transducer with different materials combination. The common method to develop the piezo electric transducer is by coating zinc oxide on copper plate or carbon plate is widely followed among variety of researchers. The ZnO NWs have high impact because of its mechanical properties reported by Yang and his team in [10]. The main objective of this work is to enhance the power generation from piezo electric transducer developed by zinc Oxide with copper substrate for low power self-activated devices, the stress is applied on the copper substrate and the corresponding voltage is noted.

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The different sizes of the copper substrate is taken into consideration for the analysis.

II. EXPERIMENTAL SETUP

A. Synthesis of Copper substrate :

The copper substrate is taken into consideration, the image of the bare copper plate under optical Microscope is shown in the figure 1:

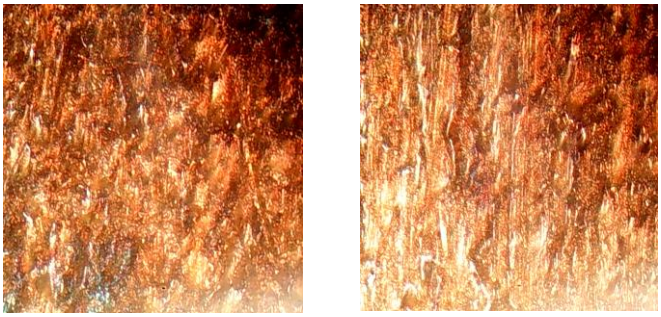


Fig. 1 : Copper substrate under optical microscope

The copper plate is coated with zinc oxide using a solution based technique under various processing conditions. The Zinc oxide coated copper plate is shown in the figure 2.

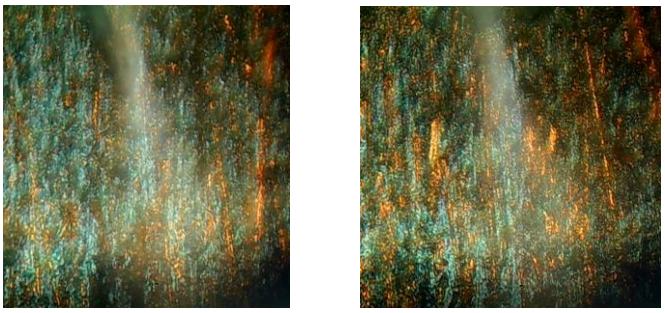


Fig 2 : Copper substrate coated with ZnO nanowires Under optical microscope

The stress is applied on the copper substrate which was coated with zinc oxide and the voltage is obtained as output. It is recorded in the multimeter. The voltage obtained for the copper plate with zinc oxide coated with size 1x1cm is 103.4MV and the voltage obtained for the copper plate with zinc oxide coated with size 1x 2 cm is 153.1mV. The electrodes are arranged as shown in the figure 3

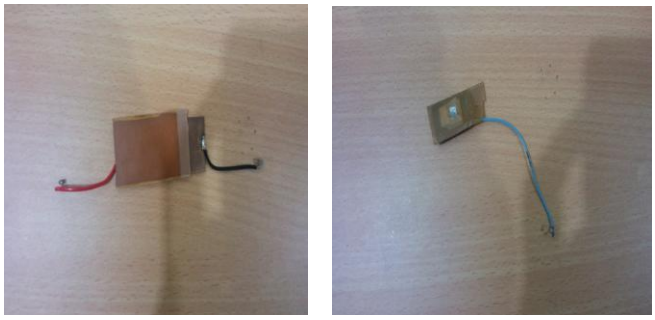


Figure 3 : Samples – Cu with ZnO

B.Electrical characterization of ZnO NWs nanogenerators

The Electrical characterization of the proposed nanogenerator was studied by applying stress on the coated surface, corresponding voltage is recorded in the Multimeter. The output voltage, short circuit current and power were characterized using this experimental setup for the ZnO nanowires based piezoelectric nanogenerators, of which is described in the results and discussions.

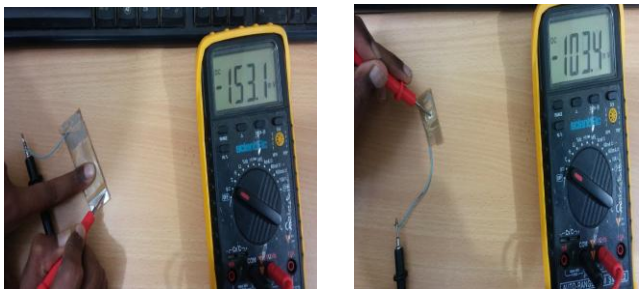


Figure 4: Output voltage measurement with DMM.

III.SIMULATION PART

The experimental set up is also verified by the Simulation tool provided by M/s.COMSOL Multiphysics, Here the layer 1 is considered as Copper plate with dimensions 20mm x 20mm and 2mm thickness , the layer 2 is considered as zinc oxide and is kept on the copper plate with dimensions 20mm x 20mm and 1mm thickness.

Sample 1

Material	Width (mm)	Length (mm)	Thickness (mm)
Copper	20	20	2
Zinc oxide	20	20	1

Sample 2

Material	Width (mm)	Length (mm)	Thickness (mm)
Copper	20	20	2
Zinc oxide	20	20	1.5

Table 1: Dimension of the substrate

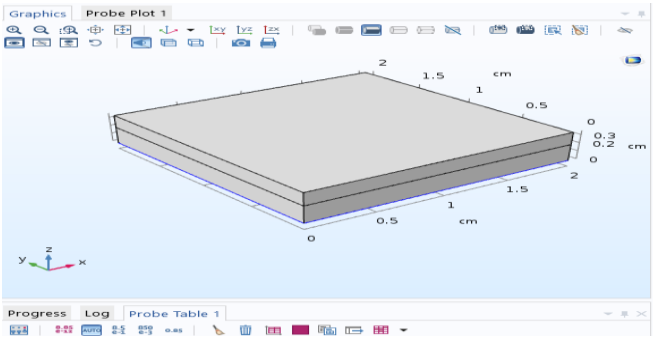


Fig 5. Layer 1 copper plate and layer 2 zinc oxide

The stress is applied on the zinc oxide layer at a single point, the output voltage is obtained in the range of milli Volts. The screenshot images are taken from the simulation software M/s.COMSOL multiphysics while applying the stress to zinc oxide material.

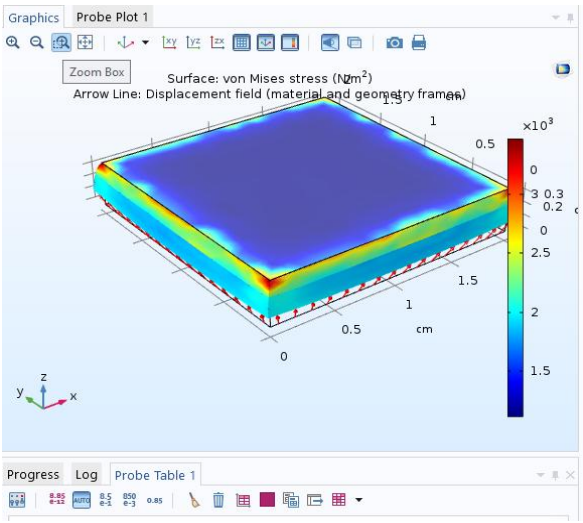


Fig 6. Stress applied on the zinc oxide layer

The simulation is repeated for various values of stress and the output voltage is recorded. A sample screen shot represents the output voltage obtained in the simulation method.

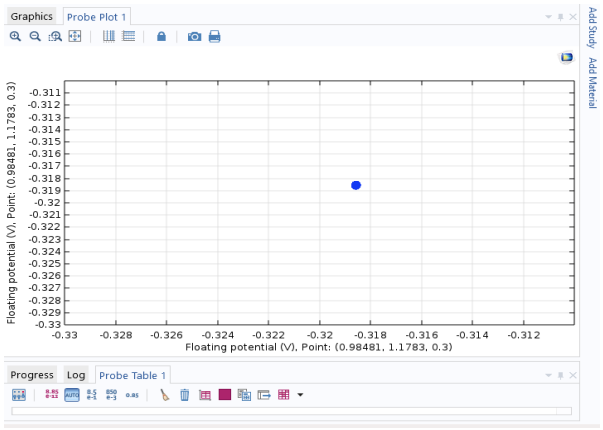


Fig 7. Voltage obtained on applying stress to zinc oxide

IV. RESULTS AND DISCUSSIONS

The experimental setup for the zinc oxide coated on the copper substrate was prepared , the stress is applied on the substrate , and an output , voltage is obtained . The experimental analysis is performed on the zinc oxide coated on the substrates with size 1 cm x 1 cm and the another size with 1cm x 2cm . The output voltage is shown in the table .

S.No	Design	Output voltage
1	Copper substrate (both electrodes) –ZnO powder, active area – 1cm x 1cm,	103.4mV
2	Copper substrate (both electrodes) –ZnO powder, active area – 1cm x 2cm,	153.1mV

Table 2 : Output Voltage obtained

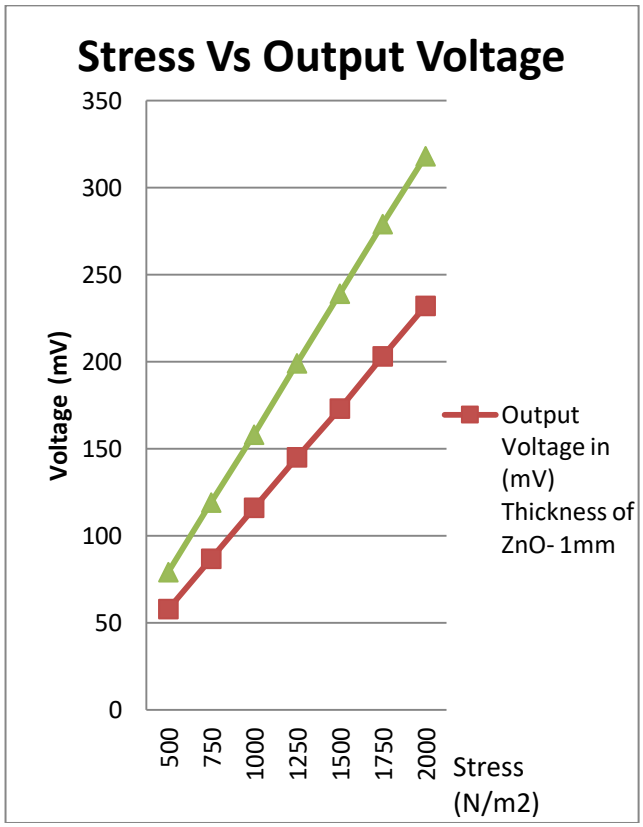
The output of the simulation software provided by M/s.COMSOL Multiphysics for the various values of Stress and corresponding Voltage is noted. The summary of the result obtained is shown in the table below :

Sl. No.	Stress (N/m2)	Output Voltage in (mV)	
		Thickness of ZnO- 1mm	Thickness of ZnO- 1.5 mm

1	500	57.8	79
2	750	86.7	119
3	1000	116	158
4	1250	145	199
5	1500	173	239
6	1750	203	279
7	2000	232	318

Table 3 : COMSOL output value

The voltage obtained for thickness of zinc oxide 1mm and 1.5 mm are graphically shown in the figure.



V. CONCLUSION

It is concluded that the voltage obtained is proportional to the stress applied on the zinc oxide layer. It is also evident that the area of the Zinc oxide coated on the copper substrate increases the voltage generating capacity and it satisfies the principle of piezoelectricity. In the experimental setup, after applying the stress, the maximum voltage obtained using copper substrate coated with zinc oxide is 153.1mV and in the simulation software it is 318mV.

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