Experimental study of Thermoelectric Energy Harvesting

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Abstract. Waste heat energy harvesting aims to supply electricity to electric or electronic systems from different energy sources present in the environment without grid connection or utilization of batteries. These energy sources are solar (photovoltaic), movements (kinetic), radio-frequencies and thermal energy (thermoelectricity). The thermoelectric energy harvesting technology exploits the Seebeck effect. This effect describes the conversion of temperature gradient into electric power at the junctions of the thermoelectric elements of a thermoelectric generator (TEG) device. This device is a robust and highly reliable energy converter, which aims to generate electricity in applications in which the heat would be otherwise dissipated. The significant request for thermoelectric energy harvesting is justified by developing new thermoelectric materials and the design of new TEG devices. Potential TEG applications as energy harvesting modules are used in medical devices, sensors, buildings and consumer electronics. Present work is experimental study and analysis of thermoelectric energy harvesting and their low-power applications, and calculation of figure of merit which is dimensional less number for deciding harvesting efficiency.

1. Introduction

Nanotechnology has become the latest promising technology. Nano technology deals with the Nano particles. Nano particles are the particles whose size lies between 1 to100 nanometers (nm). In nanotechnology a particle is defined as a small object that behaves as a whole unit with respect to its transport and properties. In the last decade, the Nano science and nanomaterials have been identified worldwide as the key to unlocking a new generation of devices with revolutionary properties and functionalities. Nanoparticles with unique properties have become an emerging interdisciplinary field involving [1,2] Solid state physics, chemistry, biology and material science. The copper nanoparticles are the important part of nanomaterial, with the potential for wide range of electronic, optical and communication applications [3,4]. Therefore the copper Nano particles are being paid close attention on its applications in various fields including film fabrication.

The synthesis of copper Nano particles is Solution combustion method has emerged as potential technique of preparing nanomaterial. The advantages of the technique are low cost, quite simple and fast, fast-heating rates and short reaction times than other techniques. Metal nanoparticles have been the subject of focused research due to unique their optical, electrical, mechanical and chemical properties[5,6] that are significantly different from those of bulk materials. For these reasons, metallic nanoparticles have found uses in many applications [7,8] in different fields. To the best of our

knowledge, at 6000 degC temperature the use of Ocimum sanctum leaf extract for greener synthesis of Cu/Ag nanoparticles has not been reported. Hence the present study was carried out to synthesize and characterize the copper nanoparticles using Ocimum sanctum leaf extract.

2. Methodology

The approach used to synthesis the copper Nano particles is bottom up approach, i.e. green synthesis method is used to synthesis the copper Nano particles. Green synthesis is a biosynthesis of Nano particles that has been proposed as a cost-effective and environmentally friendly alternative to chemical and physical methods. Plant-mediated synthesis of Nano particles is a green chemistry approach that connects nanotechnology with plants.

The methodology is explained the following

1. Copper nitrate [$Cu(NO_3)$ 2.3H$_2$O.] / Silver nitrate [$Ag(NO3)2$]
2. Plant leaf powder-Ocimum sanctum, Solanum lycopersicum.
3. Silica crucible – 50 ml.
4. Muffle furnace.
5. Distilled water.

The copper nitrate is mixed with plant powder and added distilled water to produce a gel / paste. Then the gel / paste is transferred to crucible and then heated at 600 °C for 20 to 25 minutes. At this stage the gel paste is converted to nano particles.

Table – 1. Composition of Elements considered

Elements	Sample-1	Sample-2	Sample-3
Copper	40% (45.51grams)	50% (45.51grams)	50% (45.51grams)
Selenium	40% (24.48 grams)	30% (24.48 grams)	30% (24.48 grams)
Graphene	16.7% (11.51 grams)	15% (11.51 grams)	10% (11.51 grams)
Silver	3.3% (53.34 grams)	-	-
CNT	-	5% (4.128grams)	10% (8.128grams)

Then by the density equation the mass of the each Nano powder is given as

Table – 2. Density of Elements considered

Elements	Density
Copper	8.96 g/cm^3
Selenium	4.819g/cm^3
Graphen	2.267g/cm^3
Silver	10.5 g/cm^3

3. Testing

The size of the Nano particles is tested by scanning electron microscope (SEM) and analyzed by x-ray diffraction. A scanning electron microscope (SEM) is a type of electron microscope that produces images of a sample by scanning the surface with a focused beam of electrons. The electrons interact with atoms in the sample producing images describing topography of the surface. The electron beam, which typically has an energy ranging from 0.2 Kev to 40 Kev, is focused by one or two condenser lenses to a spot about 0.4 nm to 5 nm in diameter where the specimen is kept, and the image of the Nano particles is collected along with its size.

4. Specimen Preparation

The preparation of the specimen by using the Nano powders was done by powder metallurgy technique, it this composition and mass of Nano powders are taken and mixed properly and then compressed in the die with the help of universal testing machine. The load is given in such a way that a proper compaction of the material and load should not exceed the compression force of the material, else it would lead to the formation of crack in the specimen. The dimension of the specimen the total volume of the specimen is = 5089.3 mm3

The specimen prepared by using the Nano powders is having three different compositions of samples are shown in the following table – 1.

4.1. Sample – 1:

the mass of each specimen for the total volume is calculated based on that the required percent of each materials is 40% copper + 40% selenium + 16.7% graphene + 3.3% of silver. The mass of the sample - 1 is based on the percentage of elements with mass of elements are (40 % *45.51), (40%* 24.48), (16.7 % *11.51) and (3.3% *53.34). The total mass of Nano powder of the specimen- 1 is = 31.624 grams with similar condition 5 samples were prepared.

4.2. Sample – 2:

The mass of each specimen for the total volume is calculated. Then we have the required percent of each materials is 50% copper + 50% selenium + 10 % graphene + 10 % of CNT. The mass of the sample -1 is based on the percentage of elements with mass of elements are (50 % *45.51), (50%* 24.48), (10 % *11.51) and (10 % *8.128). The total mass Nano powder required for the specimen - 2 is = 36.8 grams. with similar condition 5 samples were prepared.

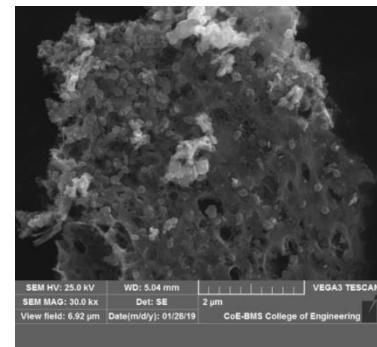## 5. Results and Discussion

By the SEM analysis the size of the copper Nano particles are found as about 40nm to 60nm and silver Nano particles are found as about 25nm to 60nm.
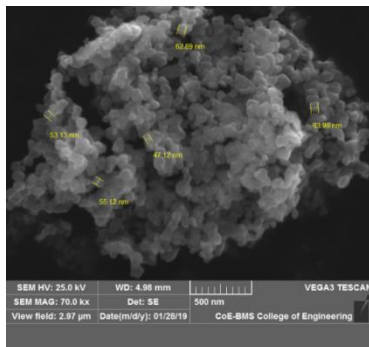
Figure 1. SEM images of Copper after synthesis
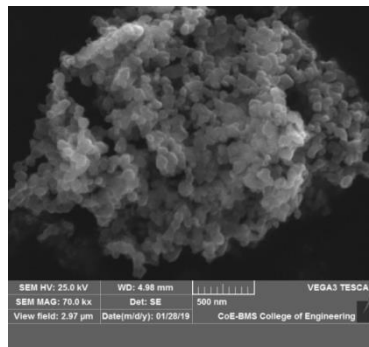
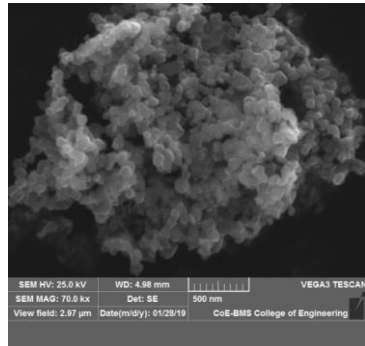**Figure 2.** SEM images of Copper after synthesis

Figure 3. SEM images of Copper after synthesis

From the Fig. 2 the SEM analysis it is seen that the Silver Nano particles are synthesized by green synthesis method.

Thermoelectric materials convert heat energy to electrical energy based on Seebeck and Peltier effect. This leads to utilize hardly usable or almost lost thermal energy into productive applications as efficient as possible. The efficiency of conversion of heat is characterized by the figure of merit zT which is related to the Seebeck coefficient S, thermal conductivity k, electrical conductivity σ and absolute temperature T by the following relation:

$$ZT = \frac{S^2 \sigma}{k} T \qquad (1)$$

Figure of merit (ZT),Seebeck coefficient(S). Operating temperature(T),Thermal conductivity(K) , Electrical conductivity(σ)

Figure 4. SEM images of Silver after synthesis
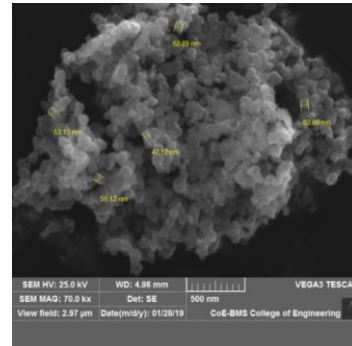
Figure 5. SEM images of Silver after synthesis

5.1 Specimen 1

(Cu = 40%, Se = 40%, Gr= 16.7%, Ag = 3.3%).

$$\text{Figure of merit ZT} = \frac{S^2 \sigma\, T}{K} = \frac{(5.8*10^{-3})^2 * 172.24*355}{1.7} = 1.256$$

$$\text{Specimen 2(Cu = 50\%, Se = 30\%, Gr = 10\%, CNT= 10\%)}$$

$$\text{Figure of merit ZT} = \frac{S^2 \sigma\, T}{K} = \frac{(6.509*10^{-3})^2 * 93.33*322}{1.4} = 0.965$$

After testing the specimen properties by using this converted thermal energy into electrical energy

6. Conclusions

Green synthesis routes are cheap, environmentally sustainable, and can lead to the fabrication of nano-objects with controlled size and shape. highly stable and sensitive Nano composite of Cu and Ag are developed. It has been considered as an alternative method to all existing methods The ratio of the oxidant to the fuel was taken in the ratio of 1:0.21 then it is getting maximum yield. The energy harvested by using the specimens for charging the electrical battery of capacity 10V.

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