EFFECT OF GALENA POWDER OF 63 MM PARTICLE SIZE AND LESS ON THE ABSORBITIVITY OF BLACK PAINT MIXTURE

Iessa Sabbe Moosa
College of Engineering, University of Buraimi, Sultanate of Oman,
B.O. Box 890, PC 512, Al- Buraimi,

ABSTRACT

In this article, addition of Galena Powder to black paint has been investigated, as a new selective solar absorber for water heating system. The used powder was prepared from an ingot of Galena, which was found to be almost about 85wt% of lead, 9wt% of sulfur, and some of other elements. Selective surfaces; pure aluminum, black paint, black paint with different percentage of Galena powder 5wt%, 10wt%, 12.5wt%, 15wt%, 20wt% were experimented. The results of this research showed that the maximum value of temperature has been achieved at about 10wt% of Galena with black paint. The temperature difference was around 6.5°C as an average value higher than the case of plain black paint. This remarkable result was reached with a particle size of Galena powder of around 63 μm and less. In addition, microstructure of the used bulk ingot and produced powder were investigated by using SEM. A maximum water temperature of around 97 °C was achieved in Al- Buraimi city, Sultanate of Oman.

Keywords: Galena Powder, Microstructural Investigation, Al- Buraimi City - Sultanate of Oman, Aborbitivity of the New Mixture.

HIGHLIGHTS

The effect of Galena powder on heating system for domestic use has been studied staring from as received Galena ingot. The microstructure and chemical composition of the used ingot were investigated. A particle size of about 63μm and less of Galena powder was mixed with the black paint in attempt to increase the aborbitivity of the paint. A maximum water temperature of about 97 °C was achieved with addition of 10wt% of Galena powder to the black paint.
1. INTRODUCTION

The sun is a sphere of extremely condensed hot gaseous matter with a diameter of around $1.39 \times 10^9$ m and the solar power that strikes the Earth is about $1.7 \times 10^{14}$ kW. This value and amazing theoretical and practical information about solar thermal collectors, history of solar energy and applications have been summarized by Soteris [1]. Excellent details about materials for heating system by solar energy have been almost fully reviewed [2]. In 1993, Shuchitangshu et al. have announced what they called it “Low cost solar selective absorbers from Indian galena”. Their technique was started from raw materials, followed by casting process under vacuum with the range of $1.33 \times 10^{-3}$ Pa and then ended by thin film route. The results of this work showed excellent absorbitivity (0.95-0.97) and very low emissivity (0.21-0.27) [3]. From pollution point of view, large scale of applications of hot water system in Europe has been published in 1998 by Fisch et al. [4]. Their main interest is that to replace fossil fuels which lead to reduce CO$_2$ emission by using solar energy with biomass or gas sources.

Materials with excellent absorbitivity in the solar spectrum and low emission with good stability at the using temperatures are required for manufacturing of heating system by solar energy. Characterization of Al$_2$O$_3$-Ni selective absorber material for solar thermal collection process has been studied by SÜzer et al. [5]. Their results showed that samples anodized under the same cases and pigmented with nickel acetate gave better thermal emittance compared with nickel sulfate. An improvement in the thermal emittance within the range from 0.41 to 0.16 was mentioned, which is very important factor to enhance the performance of the absorbing surfaces of solar energy applications. Using of a Ni pigmented anodized aluminum selective absorber has been reported by Wazwaz et al. [6]. The maximum conversion efficiency of their work was in the range of 0.73-0.78, and the absorbitivity was within the range of 92-97%. More work in the field of finding new selective materials and using solar energy for domestic applications have been done in Jordan and Sweden [7, 8].

Many countries with abundance of Sunshine started utilization of solar energy for water heating system for domestic applications [9-13]. A solar selective material is one of the most important filed of solar energy application for water heating system to avoid the use of the other energy sources. The main goal of workers in this field is to increase the absorbitivity and to find new materials with excellent efficiencies [14-17]. Coating material of NiAl alloy additive for solar water heating system has been studied by AlShamaileh [18]. This alloy was added as a powder to black paint and the results showed higher efficiency compared with black paint. This factor is extremely important in this filed, especially in the countries with low solar intensities. Adding some conductive metal powders to selective materials probably increase thermal conductivity of these materials [19].

This research is carried out in Al- Buraimi city at the north of Sultanate of Oman (Latitude: 24.2500° North, Longitude: 55.7500°E). so as the solar intensity is very high. This city receives the highest Sunshine hours/day compared with the other sites of Oman [20]. The Sultanate of Oman is among countries that receive the highest solar energy in the world [21]. The main aim of this work is to investigate the effect of Galena powder on the absorbitivity of black paint, as a new selective solar absorber for water heating system.

2. EXPERIMENTAL METHOD

The experimental procedure was started by preparing the following stuff, equipments, and solar data:

- Black paint type Berger paint, product of Oman
- Thinner Liquid type Supreme, CCIA PV 274070, product of Italy
Homemade experiment wooden box with double glassing front side, about 1m of length, 15cm of depth, and 20cm of height. The air gap between glasses is of about 1cm

- Aluminum containers size of 15×10×4cm with top pipe of about 1.5 cm diameter and length of about 5cm for temperature measurements
- Digital thermometers
- Digital balance
- Galena ingot
- Stainless steel mortar with its hammer handle
- Stainless steel micro sieve of about 63µm
- Data of solar energy of Al Buraimi, Sultanate of Oman
- Lumps of the Galena with a diameter of about 1cm were obtained from public market in Ajman, UAE. Some lumps of these as - received ingots are shown in Fig.1.

Microstructural investigation and chemical analysis were carried out by using scanning electron microscope (SEM) together with Energy Dispersive X-ray analysis (EDAX).

After obtaining the ingot of Galena, the following steps were used for preparing a powder of this ingot:

(i) The lumps of Galena were mechanically crushed to a size of about 1mm and less.
(ii) The crushed small pieces were then manually pulverized by using a stainless steel mortar for about one hour.
(iii) The powder thus obtained was sieved by the stainless steel micro-sieve of 63 µm, prior to mixing process with the black paint.

Specimens of fracture surface and sieved powder were prepared for SEM tests. Five cases of mixing process of the black paint with different percentage of Galena; 5wt%, 10wt%, 12.5wt%, 15wt%, 20wt% were prepared. About 40g of black paint of each case was weighted by digital balance and about 5g of thinner liquid was added to each case and then mechanically mixed with the produced powder to be ready for painting process. The aluminum containers were well cleaned, painted, and dried in the normal atmosphere. The painted containers were filled with water and then fixed in the ready wooden box prior to water heating by solar energy.

The heating process was conducted repeatedly by setting up the experiments prior to begin at 9:00 am. Starting temperature \( T_0 \) was measured by using the digital thermometer, and then the wooden box was exposed to solar radiation for about 7 hours. The water temperatures as a function of time were measured whilst the box was almost perpendicular to the direction of the solar beam.
during the period of measurements. Meanwhile, the climate temperatures were measured at the same time of measuring the temperatures of the water in all containers. The results were tabulated and then the water temperatures as a function of exposure time were drawn to study the effect of the Galena powder on water temperatures for different cases compared with plain black paint.

3. RESULTS AND DISCUSSION

At the beginning of this work, solar energy profile of Al-Buraimi city was plotted. Fig.2 shows the average monthly direct radiation, diffused radiation, and global radiation, from which it can be concluded that the maximum value of solar radiation in this city is in June, which is about 9.87 kWh/m²/day. Furthermore, Al-Buraimi city is classified as a city of highest value of solar radiation in Sultanate of Oman [19].

![Fig. 2 Irradiation of Al-Buraimi, Sultanate of Oman During 2012](image)

The results of the SEM of Galena showed brittle behavior fracture surface. Micrograph illustrating fracture surface of Galena lamp at low magnification is given in Fig.3. Also, the Galena ingot was found to be almost compound of PbS with about 85wt% of lead and around 9 wt% of sulfur. A chemical composition of the used Galena lumps is summarized in table1, and the EDAX spectrum of this ingot is shown in Fig.4.

![Fig. 3 SEI Micrograph of A Fracture Surface of an As-Received Galena](image)
Table 1 Chemical Compositions of Used Galena

<table>
<thead>
<tr>
<th>Element</th>
<th>Weight%</th>
</tr>
</thead>
<tbody>
<tr>
<td>C K</td>
<td>4.45</td>
</tr>
<tr>
<td>O K</td>
<td>1.58</td>
</tr>
<tr>
<td>S K</td>
<td>8.69</td>
</tr>
<tr>
<td>Pb M</td>
<td>85.29</td>
</tr>
<tr>
<td>Totals</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Fig. 4 EDAX Analysis of The As - Received Galena Ingot

The study of microstructure of the produced powder of Galena showed wide range of particle size, and most of the particles have sharp edges as glass behavior fracture. It seems that this nature of fracture is due to the brittleness of this ingot. Fig. 5 gives a general idea about the microstructure and particle size distribution of the produced powder.

Fig. 5 SEM Micrographs of Produced Powder after Sieving Process

For water heating system, aluminum containers were used because aluminum is highly corrosion resistant in many environments with good thermal conductivity [22]. However, the first attempt was carried out on the date of 17-02-2015 by using two cases; an aluminum and black painted aluminum containers to perceive the difference between these cases on the water temperatures. The result of this experiment is given in Fig.6, from which it can be concluded that the maximum temperature in the case of the aluminum is about 80°C whilst in the case of the black painted aluminum is around 92°C.
The outcome of this experiment is very important so as these values of water temperatures can be achieved during the winter of Al-Buraimi by using very simple facility. These values of temperatures are more than enough for house purpose, therefore black paint aluminum solar heating system is very sufficient in Al-Buraimi, and probably in many cities elsewhere in Sultanate of Oman.

After the first experiment, another attempt was employed with different percentage of Galena powder together with the black painted aluminum to study the effect of the powder of this ingot on the water temperature. The feedback of this attempt showed that the maximum value of water temperature was with black paint plus about 10 wt% of PbS powder as shown in fig.7. The novel result of this work is that the maximum temperature of the water in the container of 10 wt% of PbS was higher than that of black painted by about 6.5°C.

Fig. 6 Water Temperatures Against Exposure Time of Two Cases; An Aluminum And Aluminum Black Painted Containers. Date: 17-02-2015, Sunny Day

Fig. 7 Water Temperatures against Exposure Time For Different Cases, Sunny Day

Fig. 8 shows another case of water heating from which it can be noticed that the value of ΔT between black paint and black paint plus 10wt% of Galena powder is about 7°C. At the first hour of exposing time, the increase in temperature is almost the same for both cases, and then starts to increase gradually to the maximum value. This behavior is probably due to the change of the
aborbitivity of the new mixture with temperature. A value of maximum temperature of about 96 °C was achieved by black paint plus 10 wt% of Galena powder.

![Graph showing temperature vs. time for black paint and black paint with 10 wt% Galena powder.](image1)

**Fig. 8 Black Paint and The Black Paint Plus 10 Wt% of Galena Powder Curves To Distinguish The Difference Between These Cases. Date: 13-02-2015, Sunny Day**

Physically, the PbS compound has been classified as a semiconductor of which the thermal conductivity of this material in the most cases increases with temperature increase within the range of room temperature and above, and hence this behavior may be help to explain the increase of the aborbitivity with temperature increase.

Some experiments in this research revealed that even during cloudy days, a temperature of around 75 °C can be obtained. Fig.9 shows this case of cloudy, windy day with wind speed of about 32 km/h (≈8.89 m/s), with maximum temperature of about 76 °C, and then dropped down because of the absence of solar radiation entirely within the last two hours.

![Graph showing temperature vs. time for black paint and black paint with 10 wt% Galena powder.](image2)

**Fig. 9 One Case of Measurement of Cloudy Day as Recorded In the Figure, Date: 21-03-210**

In general, the addition of Galena powder found to be enhancing the aborbitivity of the black paint at certain weight percentages. The maximum of ΔT was about 6.5 °C at around 10%, of Galena powder with particle size of about 63µm and less when the maximum temperature is greater than 90 °C, while this value may be less when the maximum temperature was about 70 °C. These values are higher than that value reported by AlShamaileh which was about 5 °C in the case of adding of Ni-Al powder [18].

66
In reality, the results obtained by this work of research very clearly reveal that even with the black painted solar system of water heating for domestic use, a temperature of about 90 °C can be achieved in Al-Buraimi city. In addition, the solar energy in the most of the provinces in Sultanate of Oman is high; therefore the use of solar energy is extremely important to reduce the use of electricity for heating system. This subject must be given more attention to be studied in Sultanate of Oman in the nearest future. The maximum temperature reached in present work was about 91 °C with black painted container, while with one with 10wt% of Galena was about 97 °C as shown in Fig. 10.

![Graph showing heating process results](image)

Fig. 10 Shows Three Cases of Heating Process, Fully Sunny, Date: 01-04-2105, Climate Temp.: About 36 °C.

Studying the effect of particle size of Galena powder reduced to nano-scale on water temperature is extremely important, and that is the plan of the near future.

4. CONCLUSION

The most important conclusion of this modest work is that in Sultanate of Oman, even a pure aluminum or black painted aluminum heating system is enough for domestic use. The result of this work also showed that the water temperature can be increased by addition of Galena powder to black paint. A temperature of about 97 °C can be achieved by mixing a 10wt% of produced Galena powder with the black paint. Furthermore, research groups in this field focus their work on improving the absorbitivity and increasing the efficiency of the heating systems. However, most of the places in Sultanate of Oman should use solar heating system for domestic use because of the abundance of solar energy even during the winter season. The effect of particle size of Galena powder on water temperature by using solar energy will be the next plan of research in this field.

5. ACKNOWLEDGEMENTS

The author would like to thank Dr. Hussein Kadhem of Sohar University, Sultanate of Oman for his helpful discussions and providing the solar radiation data. Many thanks to Dr. Ahmed Al Rawas of the Sultan Qaboos University, Sultanate of Oman, Physics Department for his great help to use the SEM for microstructure and chemical analysis. Also, many thanks to my students Amal Al Ghailini and Abdol Aziz Al- Saadi for their appreciated help in this work.
6. REFERENCES


