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Analysis of evaporation rate in the solar still by using the synthesized SnO_2 sensor device

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The SnO_2 nano particles were prepared by microwave technique. The particle sizes of SnO_2 were confirmed by XRD and TEM analysis. The prepared nano particles have good humidity sensing property which will be adopted for analyzing the evaporation in the solar still. The humidity measurements are carried out by fixing the nano particle pellet inside the solar still at the required place. The humid variations are measured inside the solar still with respect to the water and air temperatures.

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1. Introduction

Sensors prepared many aspects of modern living, many application demand miniaturization to reduce power consumption for integration into portable device. Sensors support applications across the economy industrial process, and those in construction, extractive industries, agriculture, and health care. SnO_2 nanoparticles have been paid more attention for their unique properties. Tin oxide is a widely used and intensively studied n-type semiconductor. The research on tin oxide semiconductor has been growing due to the wide range of applications, especially humidity sensor. Also, it has been used as electrode materials [1], photovoltaic's devices [2], photo sensors [3], catalysts [4] and antistatic coating [5]. Tin oxide materials have been prepared by different techniques. Such as sol-gel [7], co-precipitation[8], microwave technique[9], solvothermal[10], hydrothermal[11], sonochemical[12] and mehcanochemical[13]. Our work was mainly focusing towards the preparation of highly pure and crystalline property of SnO nanoparticles by the simple process of digestion of amorphous stannic hydroxide gel under refluxing condition at 90ºC. The SnO_2 nanoparticle was obtained by simple sintering process at moderate temperature.

Our work was mainly focusing towards the preparation of highly pure SnO_2 nanoparticles by the simple process. The variation in humidity was recorded by using the SnO_2 nano sensor and the evaporation rate is analyzed.

2. Synthesis technique of SnO_2 nano particle

A 0.1 M solution of tin (II) chloride was prepared. The pH of the solution was maintained between 7 to 9 using liquid ammonia diluted with water. The resulting precipitate was washed out with water more than ten times until no chloride ions detected. The resulting precipitate was irradiated with microwave radiation for ten minutes.

3. Humidity measurement

The experimental work is carried out in Sri Ramakrishna Mission Vidyalaya College of Arts and Science. The solar still of area 0.25 m^2 is fabricated. The saline water is poured inside the still through the separate port. A convenient solar still is simply an air tight basin, usually made up of iron sheet in rectangular shape. The successfully prepared tin oxide nano particle pellet kept over the water surface. The other end of the device is connected with the LCR meter. Two K type thermocouples were used to measure the water and air temperature inside the still. The entire system is closed without any air leakage with the surrounding. When the water reaches the optimum evaporation temperature, it gets escape from the water surface due to latent heat release. At the same time, some fewer amounts of moisture contents are absorbed by the tin oxide sensor. The water molecules donate the electron to the semiconducting oxides.

The electron injection was observed due to adsorption of water on hydroxilated surface of the sensor. The injection of electron was not only from the water molecules and also from the absorbed oxygen ions. Further the adsorption of electron from donor molecules (water) results in a conductivity change. Fig. 1 shows the photographic view of sensor device setup.

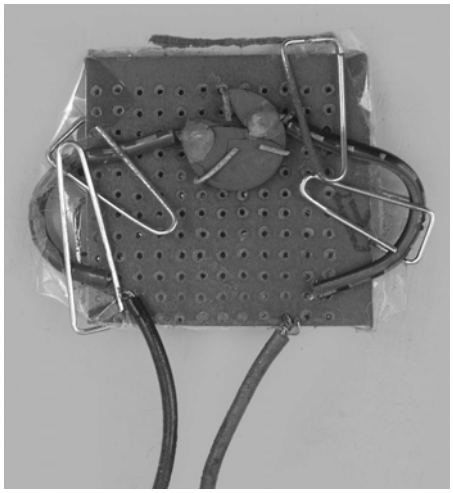

Fig. 1. Photographic view of SnO_2 nano particle sensor device.

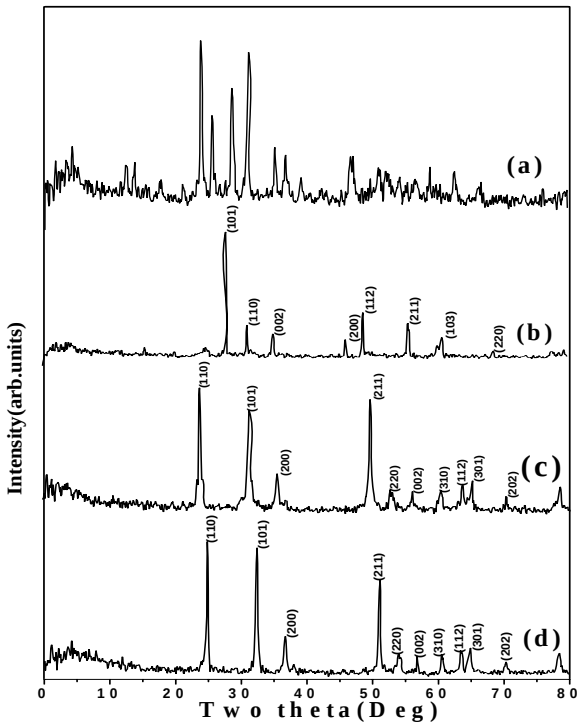

Fig. 2.The X-Ray diffraction pattern of tin oxide nanoparticle (a) Before refluxing process (b) After refluxing process (c) sintered at 300 ºC and (d) sintered at 600 ºC.

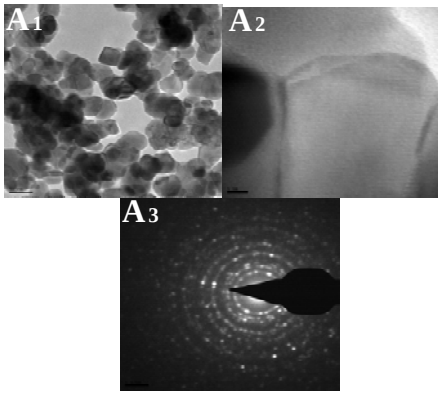

Fig. 3. TEM micrograph of SnO_2 nanoparticle (A_1), (A_2) Selected Area Electron Diffraction (A_3)

The TEM micrograph of SnO_2 nanoparticle and its SAED pattern are shown in Fig. 3. According to TEM micrograph faceted surfaces was confirmed as high stability nanocrystalline grains ($4A_2$). The uniform particle size and morphology of the tin oxide particle are observed ($4A_1$). The corresponding ring pattern of SAED ($4A_2$) confirmed the presence of single crystalline Cassieterite SnO_2 phase nanoparticles. The TEM micrograph allow us to compute the statistical grain sizes and it reveals the presence of non-agglomerated tin oxide nanoparticle with uniform particle size, which is ranging from 30 to 50 nm. This is well matched with the particle extracted from the XRD measurements. This was also confirming that the presence of single-crystal SnO_2 nanostructure.

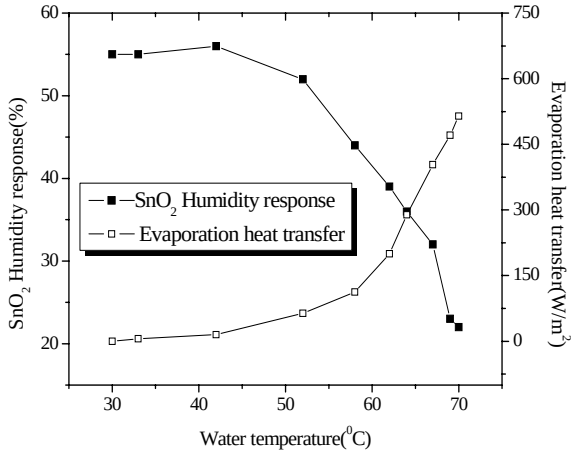

Fig. 4. Variation humidity response and evaporation rate with respect to water temperature

4. Results and discussion

The calculated particles size from XRD investigation matches well with the particles size observed from TEM micrograph. These results suggested the formation of

monocrystalline tin dioxide nanoparticles. The average crystalline size and structure were calculated from X-ray diffraction pattern which is shown in Fig. 2 The XRD pattern of SnO_2 samples before microwave treatment show the presence of tin hydroxyl groups and the pattern matches well with the $Sn_6O_4(OH)_4$ structure. Hydroxyl groups at the surface of the crystal cause lager crystalline size for before microwave treatment rather than after microwave treatment. The morphology and particle size of the tin dioxide nanoparticles were analyzed from TEM micrograph Fig.3. The presences of mono-dispersed spherical shaped particles with particles size range 10 to 11 nm were observed. Fig. 4 shows the variation of water temperature with respect to tin Oxide sensing result and evaporation heat transfer. The evaporation rate is predicted by the sensor which resulted about the maximum value of 55% at low temperature and decreases to 21% at higher temperature. At higher temperature humidity percentage decreases but the distillate yield is changes due to higher temperature difference. The increase in water temperature induces the evaporation rate inside the still. This brief analysis helps to get the exact humid range for the higher distillate output. Thus Tin Oxide nano sensor plays a vital role to predict the humid variations inside the solar still. If any air leakage and heat losses from the still can also be identified easily by the indication of change in resistance in SnO_2 nano particle sensor.

5. Conclusions

The tin dioxide nanoparticles were synthesized by microwave-assisted technique within 10 minutes. The formation of single crystalline tin dioxide nanoparticles has been confirmed from TEM and XRD measurements. SnO_2 material was having better humidity sensing property towards the moisture. Thus the material exhibits a potential candidate for sensing humid response.

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