PREPARATION AND APPLICATIONS OF LEAD SULFIDE IN PHOTOTHERMAL AND PHOTOVOLTAIC ENERGY CONVERSION

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ABSTRACT

Selective surfaces are used in flat-plate collectors to convert solar energy into heat. They are characterized by their hign absorptivity in the visible region of the solar spectrum (0.3 to 2.5 microns) and low emissivity in the thermal infrared region (2.5 to 25 microns), compared to a black body which is highly absorbing in the visible and also highly emitting in the infrared. Lead sulfide which has a direct band gap of 0.4 eV, when deposited on a highly reflecting metal like aluminium, satisfies the criterion for a selective surface. Because it has a band gap of 0.4 eV, which lies in the transition region between visible and thermal radiations, it absorbs the visible radiations completely and transmits the infrared. Since PbS is transparent to infrared and the metal is highly reflecting, the net result is low emissivity. Even though the bulk PbS has a large refractive index of 4.7 which might result in low absorptance due to the reflections of the visible radiations, the PbS in the film form has a porous structure and the resultant refractive index becomes low and increases the absorptance.

In this thesis, two methods of preparation of PbS films have been described. In the first method, PbS has been prepared by spray pyrolysis technique. A solution of lead acetate and thiourea in water, was sprayed from a double nozzle sprayer, on to a hot substrate. The substrate temperature was monitored by a uniformly heated hot plate. Substrate temperature, spray rate, the mole concentrations of the initial solutions and the thickness of the film were optimized to get high solar absorptance and low thermal emittance. It has been found that a substrate temperature of 200°C with a spray rate of 5 ml/min gave a high absorptance of 0.93 and an emittance of 0.15 for an initial solution of 1L3T composition where 1L3T stands for 1 part lead acetate and 3 parts thiourea. The thickness was optimized to get destructive interference in the visible region of the spectrum.

In the second method, PbS was deposited by vacuum evaporation of PbS powder on metallic substrates like Al, galvanized iron, mild steel etc. The films were deposited at a lower rate (20 A°/sec) because a higher deposition rate gave sooty films and were non-adherent. Both absorptance and emittance increase with increase in thickness. Maximum selectivity (α/ϵ) obtained was 25 for a film thickness of 400 A°, but the absorptance was only 0.8 for this thickness. Coatings with α greater than 0.9 were used for further studies.

It was found that the emittance increases with temperature in sprayed as well as vacuum evaporated coatings. In the case of evaporated coatings, the increase in emittance with temperature was mainly due to the increase of emittance of the bare metal. Stagnation temperatures were measured for both sprayed and evaporated coatings. Sprayed coatings gave a stagnation temperature of 120°C and the evaporated coatings gave 130.2°C. The higher stagnation temperature in evaporated coatings is due to better selectivity. Electron micrographs have revealed that the evaporated coatings are more porous in nature than the sprayed coatings which results in the better absorptance of the evaporated coatings. A new technique is reported to measure the emittance of the coatings using Golay detector.

Accelerated life testings were done on both sprayed and evaporated coatings. The coatings did not deteriorate appreciably due to thermal cycling upto 200°C and started deteriorating if the upper temperature was further increased. The coatings were also stable if annealed below 200°C . Ultraviolet irradiations in air causes photo oxidation of PbS to $PbSO_4$ and increases the emittance of the coating because $PbSO_4$ has an absorption band around 9 microns. In vacuum environment coatings were stable under UV irradiations. High percentage of relative humidity corrodes the substrate and increases the emittance.

PbS was also tried as a junction material in heterojunctions for photovoltaic energy conversion of solar radiations. Since the lattice parameter can be varied in $Cd_{1-x}Zn_xS$ by varying the composition, it is possible to match the lattice parameters and electron affinities of n-$Cd_{1-x}Zn_xS$ and p-PbS, so that CdZnS - PbS cell gives better opencircuit voltage. A voltage of 0.5V was obtained for a CdZnS - PbS cell compared to 0.39 V for a CdS-PbS cell for an illumination intensity of 100 mW/cm^2. The cell did not deteriorate in 4 months of time.

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