IMPORTANCE OF MATERIALS IN SOLAR ENERGY CONVERSION

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ABSTRACT

Materials play a key role in various aspects of solar energy conversion. Presently available materials are generally deficient in performance, cost. stability or some combination thereof. New materials systems (guided by the interplay between rational design, high throughput screening and theory), are needed to improve the performance of light absorbers, photovoltaic materials and photo-electrode catalysts thermo electrics and infrastructural aspects of solar energy conversion systems. Further polymer solar cells and diselenide solar cells are being studied with great interest all over the world. They have the great potential and the introduction of nanotechnology also has raised a lot of expectations.

INTRODUCTION

Renewed interest in solar energy conversion has been inspired by the concerns regarding carbon dioxide pollution, job creation, and market instabilities due to the geopolitics and widespread consumption of fossil fuels. This interest is likely to be self-sustaining due to larger economics of scale, new materials and processes. Thus a fundamental understanding of the basic properties required for solar energy converters that are both economical and efficient [1-3]

Supply chain and materials availability issues are of particular concern as the solar industry matures (4,5) Materials play a key role in solar energy conversion to electricity, fuels, and heat. Materials used in photovoltaic have traditionally been derived from research and development advances in other technology fields (e.g. . Si from microelectronics industry, GaAs from optoelectronics industry), as a result, the range of materials currently available for use in photovoltaics is highly limited compared to the enormous number of semiconductor materials that can in principle be synthesized for use in photovoltaics. Similarly, high-efficiency thermoelectric and thermophotovoltaic converters coupled to solar concentrators have the potential to generate electricity with efficiencies from 25 to 35%.

Determining the suitability of materials for photovoltaic had not been a systematic process. For example, one of the most widely used semiconductors for thin film photovoltaic cells is copper-indium gallium-diselenide (Cu_x,Ga_{1-x}, $InSe_2$). It was unexpectedly discovered that small area Cu_x Ga1-x, $InSe_2$, cells work very well, despite being polycrystalline and containing many point defects. The reason being, sodium diffuses from glass substrates into the Cu_x,Ga_{1-x},,$InSe_2$, film, interacts with grain boundaries, and reduces recombination Had the initially undesired sodium diffusion not occurred, it is not clear whether Cu_x, Ga_{1-x} $InSe_2$ technology would have reached its current state of development This example points out the importance of experimentally testing films with many combinations of elements. even if there is no underlying heuristic or formal theoretical prediction suggesting that such combinations might have desirable properties. Since there are enormous numbers of alloy compositions to try, high-throughput screening methods are needed. [6,7]

Furthermore, promising polycrystalline thin-film solar cells based on CdTe and $CulnSe_2$, are dramatically affected by the grain structure resulting from growth on foreign substrates, intentional or unintentional doping by impurities, the nature of the active junction, and ohmic contacts; all these processes and effects are poorly understood. A basic understanding of these issues would facilitate a revolutionary advance in the performance and economic viability of polycrystalline thin-film PV.

HIGH THROUGHPUT EXPERIMENTAL SCREENING METHODS FOR DISCOVERY OF DESIGNED MATERIALS

A big research challenge here is to find appropriate and efficient tests of specific photovoltaic properties that enable testing for millions of material combinations. The more difficult challenge is often to develop experimental methods for properties based materials selection. As an example, the energy band gap of the materials could quickly be determined by measuring the absorption spectrum Some information on the rate at which recombination occurs could be determined by measuring the photoluminescence efficiency. Conceivably, arrays of solar cells could be made to directly determine quantum efficiency, fill factor, spectroscopic techniques and open circuit voltage. In this case, contactless methods for properties measurements would be highly desirable. Ideally, such screening methods will identify good options for more thorough photovoltaic testing [8]

It has been demonstrated experimentally that the phonon thermal conductivity of super lattices can be significantly smaller than the theoretical minima of their constituent bulk materials. [9] Modeling suggests that it is the incoherent superposition of interface reflection of phonons that is the major cause of phonon thermal conductivity reduction. We need to gain a basic understanding of novel materials for spectral control. [10-11] Photonic crystals, plasmonics, phonon polaritons, coherent thermal emission, left handed materials and doping with lanthanides are concepts from the optics community that can be exploited for the spectral control components required in TPV systems [12].

Heat transfer surfaces for water heaters call for polymer/composites with high mechanical strength, UV degradation resistance, high thermal conductivity, and concentrator support structures requiring polymers with high mechanical strength and a low thermal expansion coefficient. The thermal conductivity of most polymers is 0.2 to 0.4W/m K. An order-of magnitude increase in thermal conductivity is needed to make polymers competitive. New composite materials hold the promise of high mechanical strength and high thermal conductivity. Surface modifications are needed for photon and thermal management. Mirrors and glass that are dirt repelling can significantly increase efficiency and reduce cleaning cost. Surface engineering is also needed to prevent scale formation in solar thermal heat exchangers. Fundamental research on particle-surface interactions and solid precipitation and deposition processes can help in solving these challenges.

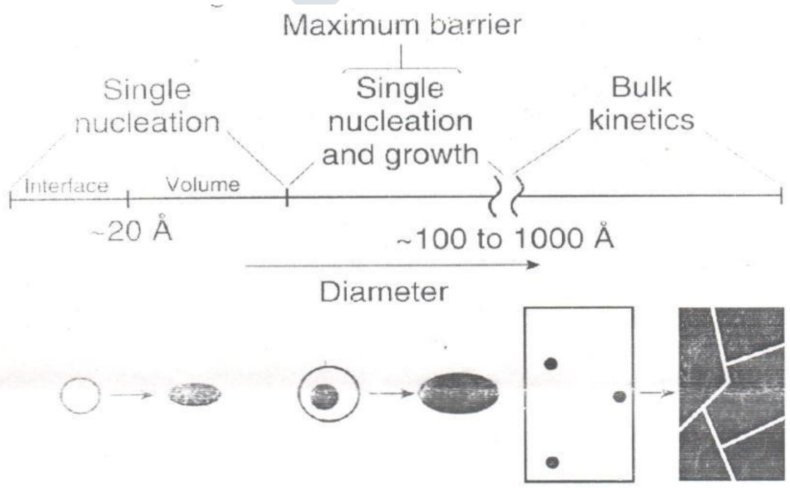

Illustration of various size regimes of the kinetics of solid-solid phase transitions. Defects which act as nucleation sites are indicated by round marks in the cartoon of the bulk solid.

Thermal Storage Materials must have high latent heat density (>0.3 MJ/kg) and sufficiently high thermal conductivity for enhanced thermal energy charge/discharge processes. Recent developments of nanocrystal polymer composites can be the key to a stable cycling solution for thermal storage. The unique characteristics of solid-solid structural transformations in nanocrystals can lead to a new generation of thermal storage materials. Present thermal storage materials are limited by the lack of reversibility of structural transformations in extended solids. In contrast, Nano crystals embedded in a "soft matrix" can reversibly undergo structural transitions involving a large volume change per unit cell. This is because a structural transition in a Nano crystal may proceed through a single nucleation event per particle (see figure). Further, a Nano crystal can change shape and volume without undergoing fracture or plastic deformation .In addition, the barrier to a structural transition depends strongly on the size of the Nano crystals so that the hysteresis and kinetics of the structural transition can be controlled

POTENTIAL IMPACTS & CONCLUSION-

An R&D investment in basic science and technology targeting solar-related materials is extremely relevant to the efficiency and cost goals in the solar area. Although there are several materials available to make thin-film PV cells today, an ideal material has not yet been found. Experimental and theoretical screening could discover several direct band-gap semiconductors that have band-gaps ranging from 0.7 eV to 2.5 eV function well in PV cells and are made from elements abundant in the Earth crust .New materials could lead to the development of devices that enable the achievement of a ~35% efficient power conversion in concentrated solar systems.

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