Department of Civil Engineering and Engineering Mechanics
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Fabrication, characterization, and modeling of functionally graded materials for energy efficient buildings

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A hybrid solar panel has been invented to integrate photovoltaic (PV) cells onto a substrate through a functionally graded material (FGM) with water tubes cast inside, through which water serves as both heat sink and solar heat collector. Therefore, the efficiency of PV cells can be improved by temperature control while the heat conduction to the substrate can be minimized for saving of air conditioning. Solar panel prototypes have been fabricated and tested at different water flow rates and solar irradiation intensities. The temperature distribution in the solar panel is measured in experiment and simulated to evaluate the performance of the solar panel by the finite element simulation. The understanding of heat transfer in the hybrid solar panel prototypes will provide a foundation for future solar panel design and optimization.

To scale up the manufacture of the FGM, a simple, economic, and scalable material manufacturing method of sedimentation has been investigated in the laboratory and will be implemented in solar panel production. The size effect of aluminium powder on the material gradation in the depth direction is investigated when the mixture of aluminium and high-density polyethylene (HDPE) powder is uniformly dispersed in ethanol and then subjected to sedimentation for a certain period respectively. A Stokes' law based model is developed to simulate the sedimentation process, the concentration variation further affects the effective viscosity of the suspension and thus changes the drag force of particles. The numerical simulation demonstrates the effect of manufacturing parameters for sedimentation and predicts the graded microstructure of deposition in the depth direction. To study particle sedimentation behaviour, a new approach based on Eshelby's equivalent inclusion method is presented to derive the Stokes flow of sphere in homogeneities moving in a Newtonian fluid at small Reynolds number. The beauty of this work is that the present solution satisfies all continuous conditions along the interface but the classic solution allows both slipping along the interface and normal stress discontinuity across the interface. The present method is general and can be used in studies of different shapes of particles and the interaction among multiple particles with arbitrary positions.