AME 30334

Special Project

Spring 2014

Design of a Thermal Management System to Maximize Concentration of Solar Radiation for a Photovoltaic Cell

As described in Problem 7.19, the electric power generated by a single photovoltaic cell can be enhanced by using a focusing lens to concentrate the incident solar radiation. Your task is to design a cooling system that maximizes the concentration factor (ratio of the area of the lens to the area of the cell) and hence the power generated by the cell.

Consider the 100 mm by 100 mm cell of Problem 7.19 and, at least initially, the specifications (thicknesses and thermal conductivities of the glass, adhesive, solder and substrate layers) provided in Example 3.3. The incident solar irradiation can be fixed at G_S = 700 W/m^2, with allowance for 10% absorption by the lens, no absorption by the glass cover but 7% reflection from its top surface. As in Problem 7.19, you may assume convection cooling by air in parallel flow over the top surface and consider the effects of varying the air temperature and velocity within reasonable ranges. You may also assume radiation exchange between the top surface of the glass and the lens, which may be approximated as large surroundings. A maximum allowable silicon temperature of $T_{si,\,max}$ = 400K is prescribed as a design criterion.

Your efforts will focus on means by which heat transfer from the cell can be enhanced at the bottom surface by attaching a heat sink to the surface. Two options should be considered, one involving air cooling in a heat sink with extended surfaces and the other involving water flow through channels machined in the heat sink. In each case, parametric calculations should be performed with coolant and heat sink operating and design conditions varied within appropriate ranges. The calculations should include coolant pressure losses, as well as thermal considerations. Minimization of the contact resistance between the heat sink and substrate should also be considered, as well as options for reducing the contact resistance between the silicon and the substrate and the conduction resistance of the substrate itself. Your analysis will culminate in a recommended set of design and operating conditions and the maximum allowable concentration factor.

You are to work independently on the project and reports are due on **Monday, March 31.** Your report should begin with an executive summary, not to exceed three double-spaced pages, in which you provide key results and conclusions. Subsequent sections should provide supporting information including designs, mathematical models, algorithms and the results of parametric calculations in tabular and/or graphical form. Reports will be judged on the basis of technical content, organization and clarity and will be graded on a 100 point scale.

You should review the material in the text on fin arrays (Section 3.6.5), and should you to use IHT, you may want to access the *Extended Surface/Fin Arrays* modules in the *Models* menu of the *Advanced* version.

This project provides a good learning experience on a subject that is very much at the heart of managing thermal conditions in devices experiencing high heat fluxes. You can Google "concentrated PV systems" to learn more about the subject of this project.

The student submitting the best project report will receive the Jerome L. Novotny Design Award in Heat Transfer, established in memory of a deceased AME faculty member. The award includes a plaque and $100 to be presented at the 2015 AME graduation ceremonies.