A Study for Developing a Cryostat for Circuit Testing at Low Temperatures

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Abstract

A simulation study has been performed using COMSOL Multiphysics software for cooling and heating a FR4 PCB and thereafter developing a controller for maintaining the PCB at a fixed temperature for circuit testing at low temperatures. Experimental arrangement was made to cool the PCB and then heating back to room temperature. Experimental results are in reasonably good agreement with simulation curves obtained for cooling and heating the FR4 PCB.

Details of setup for simulation studies: Arrangement for cooling and heating the FR4 PCB (36 micron Cu double cladded, size : 75mm×62mm×1.6mm) was made by placing an heating element 3 mm above the PCB board with the support of M4 steel screws as shown in Figure 1. The heating element was made by winding 12 rounds of a nichrome wire of 20AWG (0.81mm) around a rectangular mica sheet and the model in COMSOL Multiphysics was done using 12 cylindrical sections with 5 mm gap between each cylindrical section. This section is then united with 11 smaller cylindrical sections. The heating element along with the FR4 PCB is supported using a holding arrangement made of stainless steel as shown in Figure 2.

The material properties of FR4, holding fixtures were defined. In cooling simulation, only conduction mechanism was considered while we considered both radiative and conductive processes in heating simulation. Figure 3, shows temperature distribution on the surface of FR4 PCB at a certain time. A Cut Point 3D was defined at the point as shown in Figure 3, and variation of temperature vs. time was studied at this point.

Experimental Details: Experimentally a constant current source of 4A is used to supply the power to the heating element. An RTD (Pt100) was placed at the point where the Cut Point 3D was defined. The holder along with the heater was kept into an evacuated chamber as shown in the Figure 2. The chamber containing the heating arrangement was first cooled with the liquid nitrogen and then heated using heating arrangement. The corresponding resistance change of RTD was noted with a multi-meter and the corresponding temperature variation was noted with time.

Results: Plot for temperature variation with time while cooling and heating is shown in Figure 4

where legend 'K' is different thermal conductivity of FR4 material considered in the simulation. We find cooling process slower than simulated result. Studies varying other parameters in the simulation are in progress. While heating also, we find that initially results are in agreement with simulation but temperature achieved is lower than simulated result at a later time.

From 2D simulation, Figure 3 after cooling for 4 hours, temperature variation over PCB surface is about 2K. While the temperature variation over the surface is ~15 Kelvin after the FR4 as PCB is heated to room temperature.

Conclusions:
The simulations are in reasonable agreement with the experimental results and further simulation is in progress to understand the slower cooling and heating rate with time so that a high quality controller can be designed.

Reference

1. Robert Royds, 1921, Heat Transmission by Radiation, Conduction and Convection, D. Van Nostrand, Harvard University
2. Jakob Dieterle, 2010, Heat Management in Printed Circuit Boards, Lund University, Sweden
3. Charles Mauney, Thermal Consideration for Surface Mount Layouts, Texas Instruments

Figures used in the abstract

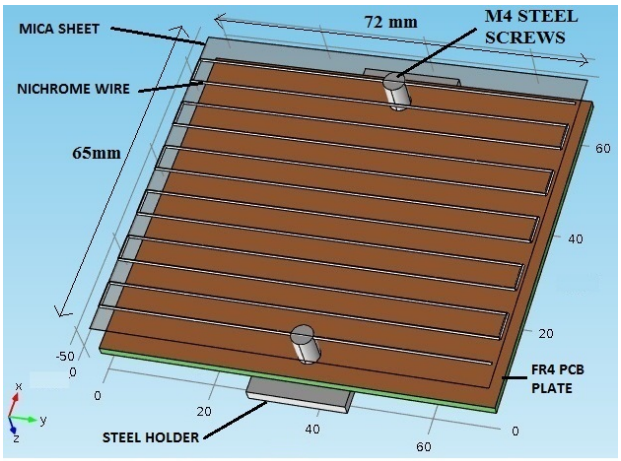

Figure 1: Heater along with PCB

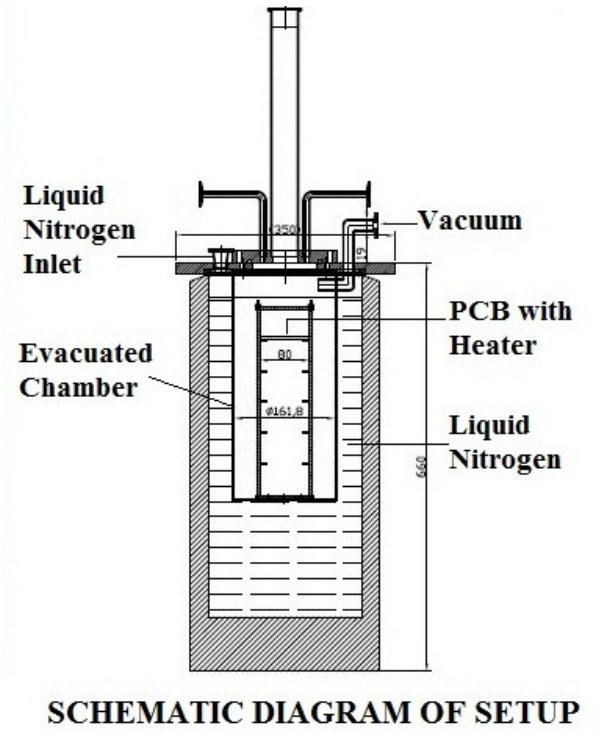

Figure 2: Experimental Setup

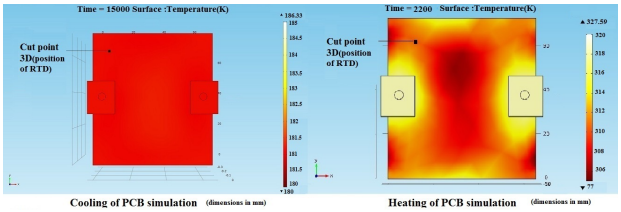

Figure 3: Surface Temperature Distribution

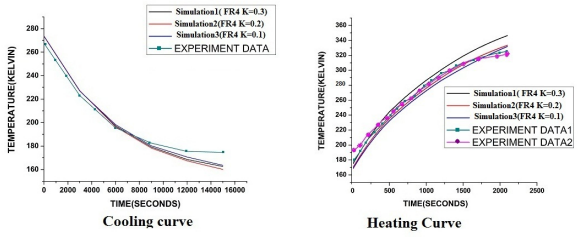

Figure 4: Temperature vs. Time Plot