Synopsis

The quest of travelling beyond earth, preludes with ground based experimental studies, detailed analysis and accurate calculations in the aspects of having a safer design of flying vehicles. As the vehicles plunge into the dense atmosphere with greater velocities to hypersonic Mach numbers, the shockwave produced ahead of the aerodynamic body becomes highly intense producing volatile conditions at a temperature of several thousands of Kelvins. Predominantly the unsteady effects are dominated by radiations in the velocities which are greater than 6km/s. During such high enthalpy flows, the atmospheric molecules which cross the strong shockwave are excited to higher energy states. Therefore the shocked gas ahead of the space vehicle is at a state of chemical and thermal non-equilibrium. To attain equilibrium condition, energy is released from high enthalpy fluid to surroundings. The aerodynamic body which faces this energy release is heated by all modes of heat transfer. Behind the normal shock, excited molecules relax to lower levels by energy releasing mechanisms including emission of radiation. In this process, initial photons emitted are absorbed by other molecules further raising its energy levels leading to dissociation and ionization. During recombination of molecular species more photons are released. Such radiations from molecules and shock wave reach the surface of the aerodynamic body. Collective absorption of all incident radiation heats up the surface of planetary entry body. In particular, the radiative heating predominates at very high velocities. Direct measurement of total radiative heating is highly challenging due to the complexity in finding out a proper measurement device. Existing literatures show that only a partial amount of radiative heating could be measured by thin film gauges, since the efficiency of thin film based measurement technique depends on the absorption of sensing element used and the wavelength range of the radiation.

In the present work, it is attempted to measure the radiative heat flux over aerodynamic body in the hypersonic flow condition. To overcome the limitations imposed by the existing measurement technique, a novel thermal sensing element based on Carbon is devised, which is denoted as Large Carbon Cluster. LCC is prepared by single step pyrolysis technique with benzene and ferrocene as precursor mixture. The ratio of precursor mixture is varied to find the proper LCC layer to be formed on a ceramic substrate to get a particular electrical resistance in order to use it as a thermal sensing element. Calibration of the devised carbon allotrope i.e. LCC is found to be having very good thermo-electric characteristics.

Several thermal gauges are developed based on LCC for aerodynamic models to test them for the total heat flux rate in Mach 8 hypersonic flow generated in hypersonic shock tunnel – HST2. The performance of the gauges is compared with the existing platinum based thin-film thermal gauges. It is found that the LCC based thin film gauges perform better than platinum thin-film heat transfer gauges. The durability of LCC is also found to be better than platinum.

The main aim of finding LCC is that it has good optical absorptivity than any other thermal sensing element; therefore it can be used in radiative heat flux measurements. Aerodynamic models are prepared with the radiative thermal gauges based on LCC and these models are tested in different atmospheric hypersonic test flows. The results reveal that radiative heat flux rate is significantly measured even at lower velocity hypersonic flow conditions. This gives a great confidence on using the LCC based thermal gauges for higher velocity flow conditions and to real time test flights.