INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title: THIN FILM HEAT TRANSFER GAUGES FOR SHORT DURATION TRANSIENT MEASUREMENTS

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SHORT ABSTRACT

Surface temperature or heat flux measurement has always been one of the major requirements in many scientific and engineering applications and will continue to claim its position in the coming decades too. Certain applications demand transient measurements even in the order of milliseconds and accordingly the techniques used there must have response time fast enough to trace similar variations. In this regard, thin film sensors are the most suitable candidates because of their extremely small thickness which allows them to measure temperature quickly yet accurately. Several practical purposes starting from measurement of surface temperature, heat flux in internal combustion (IC) engines, gas turbine blades to high speed flight experiments utilizes thin film sensors, better known as thin film gauges (TFG).

These TFGs are inherently resistance temperature detectors (RTD) consisting of a thin metallic film (silver/copper/platinum) topped over the surface of substrates of low thermal conductivity (pyrex/macor). They are advantageous in terms of response time, application range and small dimensions. However, these gauges are passive in nature and need to be powered by a constant current source. Furthermore, the measured time-dependent surface temperature of the gauge with the known thermal properties of substrate material, allows estimation of heat flux applied (both steady and transient) on the surface from any source. The purpose of this thesis is to provide a mature approach to the fundamentals of TFGs, right from their modeling, fabrication, characterization to application. Sufficient effort has been laid in this thesis to achieve some amount of expertise in fabricating efficient TFGs.

Various types of TFGs are developed in-house with different techniques during the course of the study. Static calibrations of individual sensors are done using an oil-bath calibration set-up prepared especially for calibration of the gauges. A hot air gun and laser setup set the convective and radiation type of environment, for carrying out dynamic calibration of the gauges. Static calibration is done to determine sensitivity or temperature co-efficient of resistance (TCR) whereas dynamic calibration is done to check gauge response in real-time environments. The performance capacity of different TFGs is compared and methods of improving sensitivity/TCR are explored. Few such methods used for efficiency enhancement of TFGs are addition of nanoparticles with base film material, study relation between film thickness and resistivity, deposit films on substrates in different ways etc. Numerical analyses have been done to verify the gauge response subjected to transient heat load, using an in-house developed code. Both the dynamic calibration setups are analyzed numerically using commercial software to validate the experimental results.

In the latter part of the study, utilization of soft computing techniques in deriving heat flux from the temperature histories has been attempted. The method is established as a novel and quick technique for heat flux determination compared to the usual lengthy and complicated analytical techniques based on one-dimensional heat transfer in semi-infinite gauges. The study gets further extended to modeling of thermo-electrical properties of the TFGs.

Finally, carbon nanotubes (CNTs) are grown (in-house) over Si substrates using a catalyst assisted low pressure chemical vapor deposition (LPCVD) system with a view to building multilayer films for multilayer TFGs. The final multilayer structure comprises of alternate layers of Ni and multi-walled carbon nanotubes (MWCNT); its position as a temperature sensor being adjudged with single layer Ni/CNT structure. Various characterization techniques like Raman spectroscopy, scanning electron microscopy (SEM), X-ray photoelectron spectroscopy (XPS), Auger electron spectroscopy (AES) and optical spectroscopy are performed to get a detail idea about the film structure, quality of nanomaterials grown, thickness, chemical bonding etc. The electrical properties of the CNT films are investigated by a Van der Paw setup. TCR and Hall coefficients (change of resistance with change in magnetic field in a magnetic environment) measured, confirm that these materials are apt candidates for temperature sensing. Films of bi and few layer graphene are also grown but electrical measurements on them are not possible since they grew in separate domains instead of continuous films. Continuous graphene films for temperature sensing can be considered a total new domain of future prospects of this study.