This Film Conductivity Measurements

Adrian Keating, Nev Fowkes
University of Western Australia

January 3, 2019

Introduction: semiconductors

- Almost all electronic technology involves semiconductor devices: integrated circuits, memory chips, transistors, diodes
- They are thin silicon/germanium devices with altered electrical/thermal properties.
- Electrical properties vary from conductors to insulators
- Produced (usually) by chemical (stain) etching the surface (using HF acid/ethanol), and then doping (adding chemicals) to alter the conductivity over micrometer distances.

To design such devices/materials one needs to determine the thermal properties of very thin layers (porous silicon) on a substrate (silicon) with very different properties. Fast and contact free measurement is necessary.

How best to do this? Analysis: How to extract the thermal properties from the collected data? These are connected issues!

Adrian's setup;

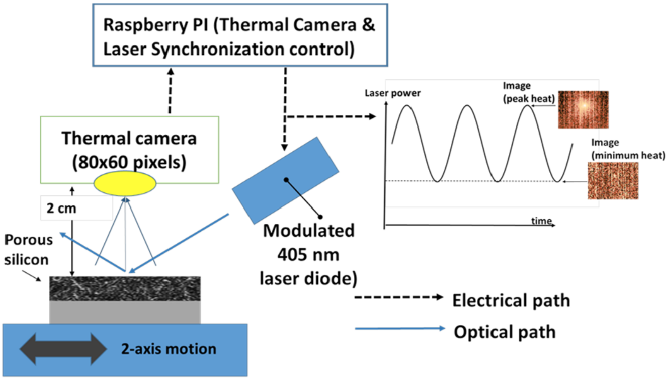

Figure 1: Optical system diagram for the thermography system developed as part of this work to investigate thermal characteristics of porous silicon. The physical housing of the system within a 20×20×13 cm³ IP66 rated enclosure.

Figure : The porous silicon layer conductivity (about) $k_s = 0.05\text{W/m.K}$. (silicon $k_s = 148$ W/m.K), film thickness 2.7 μm (substrate 5mm)

Issues

- There are heat losses
  - into the substrate (easy to quantify)
  - air in harder: Newtonian cooling is a very crude model and not possible to improve much!
- The cylindrical geometry complicates the physics/maths.
- In the presence of variability the cleanest possible experimental design is essential

It is important to get the physics straight: math complications imply data handling complications! Scaling

Wolf's arrangement

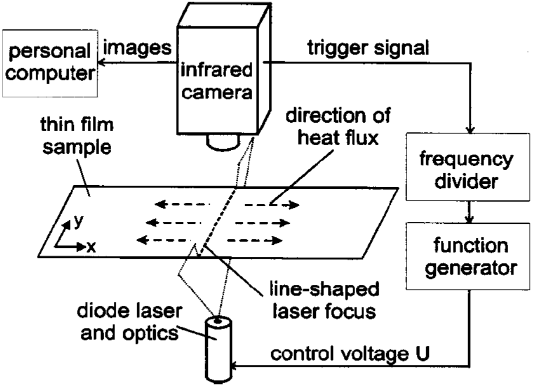

FIG. 1. Experimental setup: A sinusoidally modulated diode laser illuminates the backside of a thin film sample. The focus of the laser light is line shaped. The induced thermal wave is visualized by a lock-in procedure using an IR camera. The dashed arrows symbolize the direction of the heat flux.

Figure : Wolf cuts off the film and heats along a line: much harder experimentally, *much* easier analytically

Project Aims

- To determine temperature variations on the surface as a function of conductivity ratio (k_f/k_s), film/substrate thickness, $\cdots$, surface cooling parameters
- To explore how best to design the experiment to extract k_f ....

Mathematics Required: Linear PDE solution techniques (separation of variables, Fourier techniques, some Special functions). Algebraic package evaluations. We can fill in details if needed.

Suggested Path

1. Determine solution to Wolf and Adrian arrangements in the absence of heat losses. The results obtained represent an 'ideal'; hopefully later results can be related back to these basic results.
2. Obtain results for the Wolf arrangement in cases taking account of losses. Scale the eqns and seek perturbation results in cases in which the losses are relatively small. Look specifically at the large and small conductivity ratio cases.
3. Scale the equations in the Adrian arrangement and (hopefully) extend the results obtained in the Wolf arrangement.