

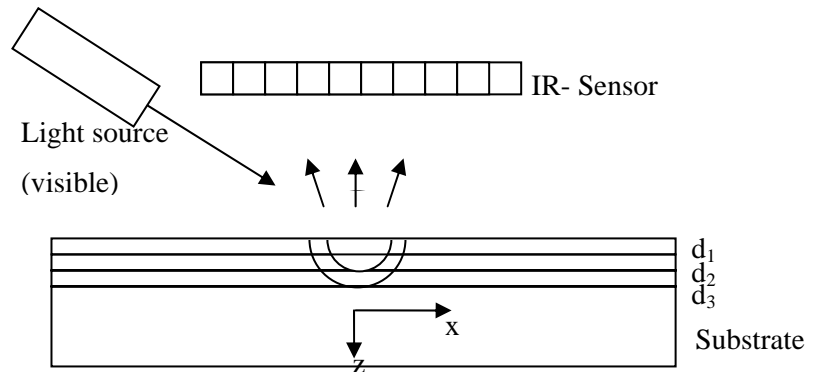
IR Feasibility: Physical Modelling

Summary for CTI

Introduction

As a preliminary study towards an IR layer-thickness sensor we developed a physical model of the following measurement principle:

1. A multilayer structure is exposed to a flash of visible light.
2. The flash light is absorbed in the structure and converted to heat.
3. The generated heat diffuses into the multilayer structure and is transferred to the environment by radiation and convection.
4. The radiation from the surface of the multilayer structure is monitored by an infrared sensor, which allows the determination of surface temperature

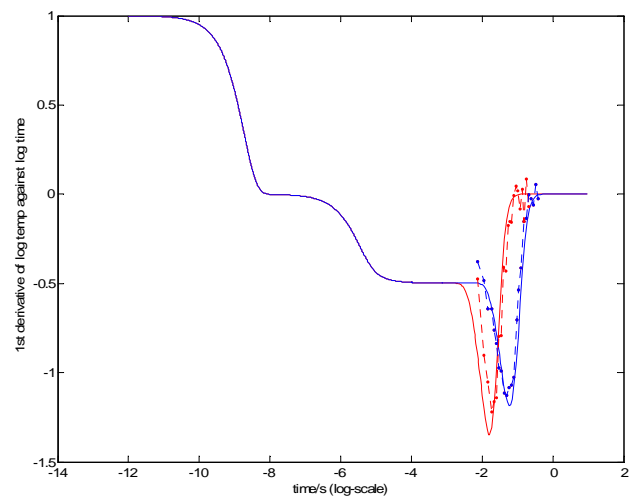


Model

We followed an analytical and a FEM approach to solve the heat conduction equation in a multilayer. Although for planar multilayer structures a closed analytical solution can be found the intuitive benefit of such a solution is limited. In the analytical solution a sum with infinite number of terms and relatively poor convergence characteristics occurs, therefore numerical evaluation of the FEM method is more efficient even for cases where analytical solutions exist.

A 1D and a 2D version of the FE model were implemented and the temperature curves for different multilayer structures were calculated. Then the different curve features were correlated with multilayer parameters. The influence of excitation pulse characteristics, radiation and convection losses

In order to validate the physical model multilayer structures were measured using a commercially available IR camera from "Varioscan". We showed that with this camera polymer layers of 50µm - 100µm thickness on a metal substrate can be measured. The curve features which characterise the polymer layer thickness were found in experimental data and correlated well with the model predictions.



Results

The theoretical analysis showed that the investigated measuring method has the potential to selectively determine layer thicknesses in a multilayer structure. A requirement for doing so is certain knowledge on material properties of the involved layers. At least one functional relation between heat capacity and thermal conductivity for each material must be known. Then, theoretically, the rest could be extracted from the temperature evolution curve. However, when considering the state of development of reverse algorithms, it is for the time being immanent to know heat capacity and thermal conductivity of all involved materials.

From theory we can also conclude that demands on the measurement setup strongly depend on the measurement task. As an example we can give some typical values for time resolution requirements:

Top Layer	Thickness	Accuracy demand	Required time resolution
Polymer	100 μm	+/- 1 μm	<~500 μs
Polymer	10 μm	+/- 1 μm	<~50 μs
Fe	100 μm	+/- 1 μm	<~3 μs
Fe	10 μm	+/- 1 μm	<~0.3 μs

The used sensor-technology did not provide the time and temperature resolution, needed for measuring fast systems (like metal-multilayers) nor could material transition of similar materials (like different kind of polymers) be measured. The requirements for such measurement tasks are a challenge for future sensor development.