UPPSALA UNIVERSITET

Laboratory instruction

Ångström-laboratoriet

Materials Science

Laboratory Experiment

Paraffin Microactuator

Course

Sensors and Actuators

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Contents

Literature:
BETA Mathematics Handbook, Physics Handbook

Name		**Supervisors Comments**
Grade		
Date	**Group**	
Passed	**Signature**	

1. Introduction

One of the reasons for using paraffin wax as actuator material is its huge volume expansion when melted, 10-20%. Paraffin wax can also be loaded with hundreds of MPa and still show a useful expansion. Scaling of a thermal actuator is also favourable looking at activation time and power consumption making it interesting for a microactuator. By combining the paraffin with simple materials and processes, such as printed circuit board and UV-curable adhesives (Epoxy), prototypes can be realized quickly.

In this laboratory experiment a thermal paraffin membrane actuator is fabricated using UV-curable epoxy on a PCB with copper heaters. The actuator is characterized and tested with the aid of a contact probe.

Do the preparation tasks!!!

2. Theory and preparation tasks

Paraffin waxes are the name for hydrocarbon chains C_nH_{2n+2}, and its mixtures. Chains with more than 20 carbon atoms are solid in room temperature and therefore interesting to use in an actuator. The melt temperature is dependent of the length of the carbon chain. A longer molecule chain gives a higher melting temperature.

The reason for the huge volume expansion in paraffin when melted is that paraffin is crystal in its solid form, i.e. the molecules are packed close together. The more crystal in solid phase the larger volume expansion is to be expected at transition. By mixing different paraffin waxes properties as melt temperature and expansion behaviour can be affected.

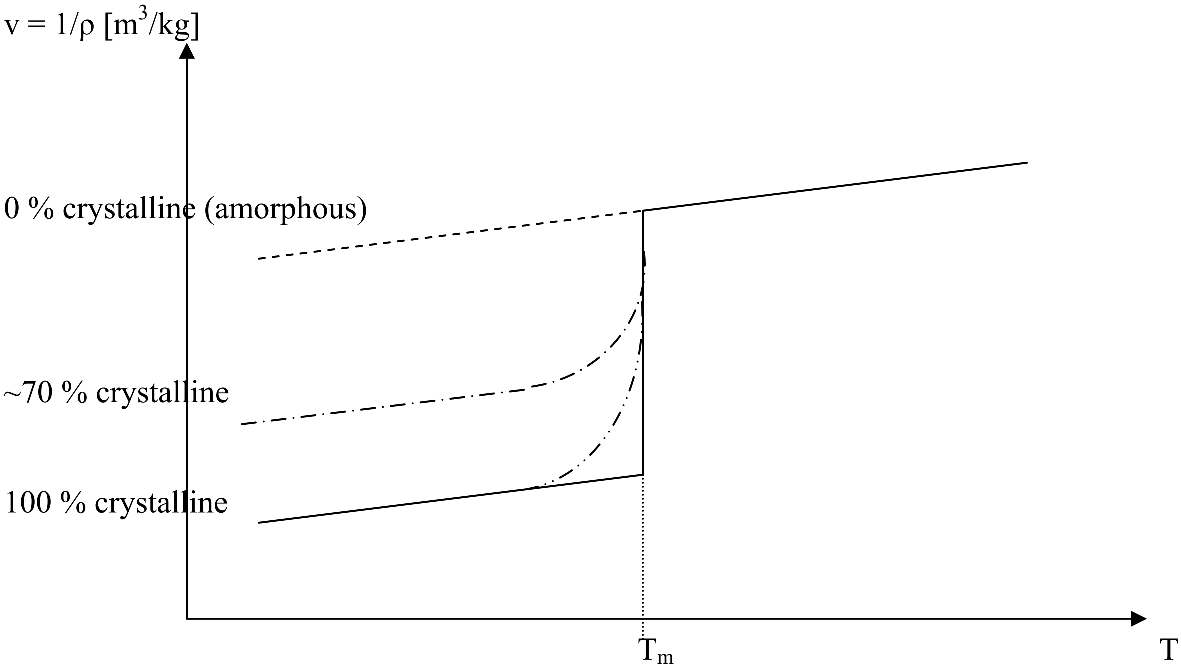

Figure 1. The specific volume, for a crystalline polymer, as function of temperature. T_m is the melt temperature.

The paraffin used in this experiment has a melting temperature of 44-48°C, the volume expansion is approximately 10 %.

The heat flow from a body to the surrounding, Fig. 2, can be described by Newton's law for external heat transfer

$$G_n = \alpha(T - T_0) \qquad (1)$$

where α is the heat transfer number and T_0 the temperature of the surroundings. Having the normal component of heat flow from a body as:

$$G_n = -\frac{1}{A}\frac{\partial Q}{\partial t} = -\frac{1}{A}\frac{mcdT}{dt} \qquad (2)$$

where A is the area, m mass, c is specific heat capacity, and dT the decrease in temperature. Combining Eq. 1 and 2, integrating from $T_1(t = 0)$ to $T(t = t)$ an expression for the temperature can be derived.

PREPARATION TASKS

i. Derive an expression for the temperature during cool-off for an arbitrary shaped body using Eq. 1 and 2.

ii. A cylindrical shaped paraffin body with diameter of 2 mm and 500 µm high melts and deflects a membrane of the same diameter. How large will the deflection of the membrane be if the paraffin has a volume expansion of 10%? Hint: Use the volume for a segment of a sphere. Mathematics Handbook BETA.

3. Design and fabrication

A schematic view of the completed actuator is shown Fig 2. When a heater is activated it melts the paraffin above it. The paraffin expands when melting and pushes the membrane out. When the heater is shut off the paraffin solidifies and pulls the membrane back in.

Heaters are photo-lithographed and etched on a PCB substrate. Cavities are formed over the heaters on the PCB using selectively masked UV-curable epoxy. The cavities are then sealed with a membrane film. Paraffin is then filled into the cavities through the filling channels, shown in Fig 3, and wires are soldered to the circuit board.

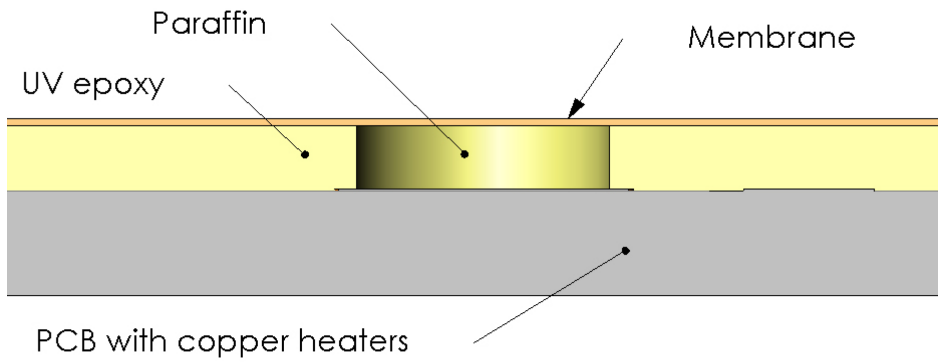

Figure 2. Sketch of a paraffin actuator with polyimide membrane and PCB substrate with copper heaters. The paraffin is capsulated in UV-curable epoxy.

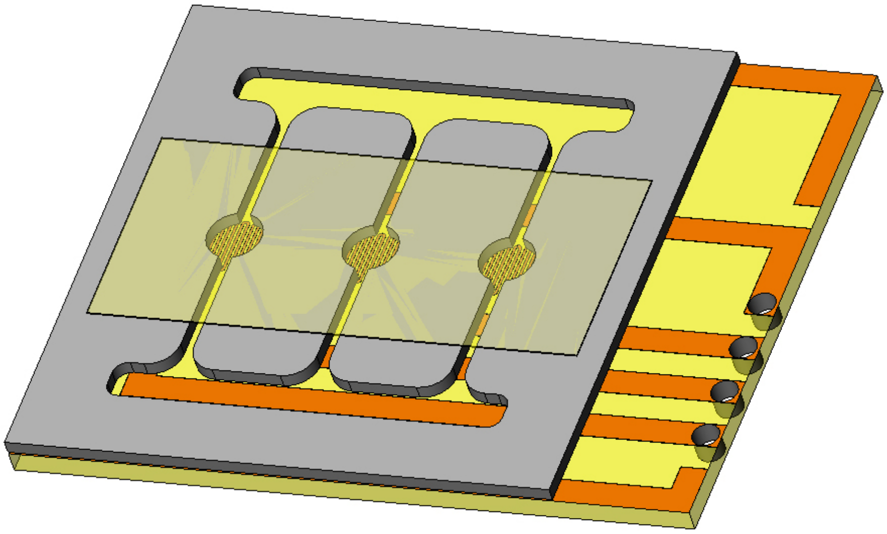

Figure 3. 3D-sketch of the paraffin actuator chip showing 3 actuator cavities in the centre with channels for filling paraffin.

4. Characterisation

- Connect the actuator to a power supply and study the melt behaviour using a stereo microscope.
  1) How much power is needed to melt the paraffin wax?
  2) How long time does it take to melt the paraffin wax?
  3) How long time does it take for the paraffin wax to coagulate when the power is switched off?

- Measure the deflection of the membrane using a Haidenhain contact probe.
  4) What is the deflection for different input power (plot the deflection versus power)?

- Questions:
  5) What is the volume expansion of the paraffin wax? How does this match with the expected value (Why?)?
  6) How can the speed for a thermal actuator be improved (heating, cooling)?
  7) What are the advantages/drawbacks using a paraffin actuator compared to a piezoelectric or a SMA actuator?