LASER SEALED PACKAGING FOR MICROSYSTEMS

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Abstract Packaging is the last process of microsystem manufacturing. There are mainly two kinds of packages: plastic or metallic. The two main components of the package (base and cover) may either be glued or soldered. Each of these techniques has its advantages and drawbacks, and the choice should be driven by the functionality of the microsystem.

The advantage of gluing is that it is quite an easy production process. The drawback is that glue, like all polymers, is not hermetic on the long term. This is a problem when the package should protect the microsystem from oxygen or water vapour, an example being OLED displays (Organic Light Emitting Diodes).

The advantage of soldered metallic packages is that they are hermetic. The drawback is that the welding process takes place in an oven, and that the whole microsytem is heated to the fusion temperature of the joint. This is a problem for many microsystems, typically biomedical MEMS and OLEDS again.

The LPM-EPFL is working on the development of a two-part sealed packaging. One part of the package is metallic, the other part is made of glass.

The goal of the project is to soft solder the two parts of the package by the mean of a laser diode. The advantages of the laser soft soldered joint are :
– its water and air-tightness in regard to glue or a plastic joint,
– the possibility to heat only the solder joint, and not inside the package.

Keywords Microsystem assembly, packaging, hermetic sealing

1. INTRODUCTION

The goal of the study presented in this paper is to demonstrate the feasibility of a laser sealed packaging. First, a functional analysis of the packaging process is presented in section 2. The tools and setup are detailed in section 3. Two models developed to predict heating of the system during the packaging operation are presented in section 4. Section 5 presents the results of both models and experiments. Finally, future works are described in section 6.

2. FUNCTIONAL ANALYSIS OF THE PACKAGE AND THE PACKAGING PROCESS

Three main functions are searched for this packaging:
- thightness to O_2 and H_2O.
- heat control
- connection to the outside world

First of all, a long term hermeticity is needed. It cannot be achieved with the use of glue or plastics, which are porous to gas. An interesting point is that a 2µm joint of aluminium is tighter than 1mm of plastic. The choice is thus the use of metals and ceramics for the package, and tin soldering for the welding seam. In our case, the base is ceramic, the cover is glass, and the solder is screen printed on the ceramics.

Another main function of the packaging process is to control the heating of the microsystem during the sealing operation. Many microsystems, typically bioMEMS and OLEDs must not be exposed to temperatures above 70°C. A common solution is to do the soldering operation in an oven, but then the whole microsystem is heated during this operation. That is why the use of a laser diode in combination with temperature sensors allows to control the energy brought to the system during the sealing operation.

Finally, the sealed microsystem must be connected to the outside world. The type of connections depends on the application of the microsytem. In our case, screen printed electrical connectors have been tested.

The originality of the process is that the heating of the welding seam is achieved through the glass cover. The glass is transparent to the wavelenght of the laser (940 nm). A thin layer of black dielectric allows the insulation of the contacts needed for the connection and also the conversion of the light to thermal energy in order to melt the welding seam.

3. TOOLS AND SETUP

The LPM-EPFL is equipped with a laser diode used for tin soldering of printed circuit boards. The advantage of a laser diode is first of all the possibility to easily control its power. The low power density is also very well adapted to the process. Another advantage, is that its cost is about the half of a Nd:YAG or CO_2 laser. The laser must only bring the tin to its fusion point (180°C), higher power would provoke vaporization of the material which is not needed for our application.

Another point is the possibility to perform continuous heating, which is an advantage in comparison to point to point soldering, regarding tightness of the welding seam. The package to be soldered is placed on an x-y table, allowing it to be moved under the laser spot. Several cameras are used to visually control the process during the soldering operation. The whole setup is placed inside a closed container for security reasons.

4. MODELS

An analytical thermal model of the welding seam has been developed. This model allows to understand the influence of material choices on the quantity of energy needed to obtain the fusion of tin. The results of this model helped to chose materials in order to reduce the energy needed to heat the welding seam, and thus to reduce the heating of the microsystem. A second model was developed to determine the heating of the microsystem during the soldering operation. This model was compared to experimental results.

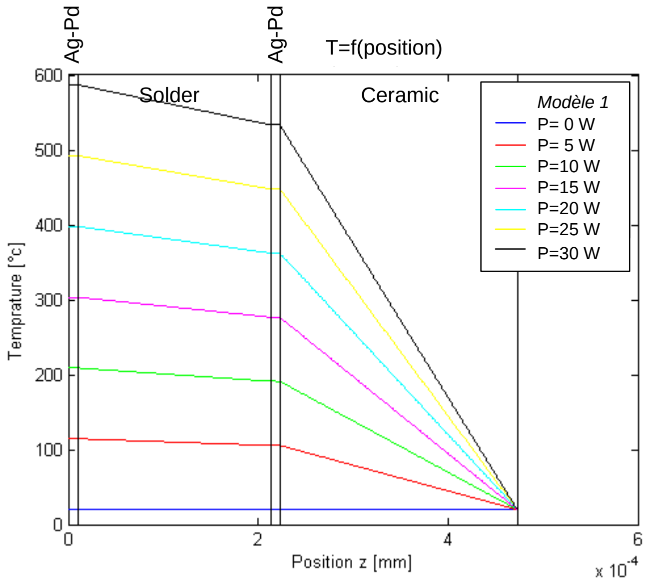

Figure 1. First model: temperature profile through the different layers for several powers of the laser.

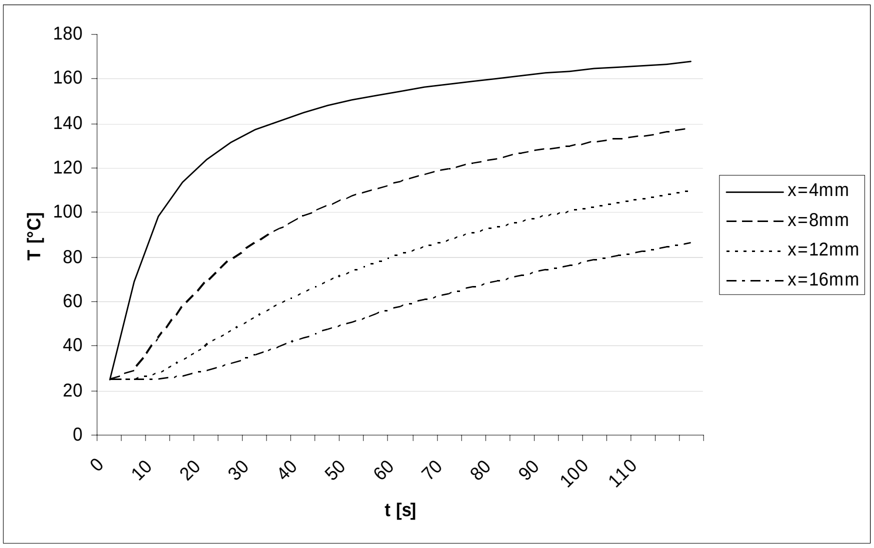

Figure 2. Second model: theoretical evolution of temperature inside the package for several distances from the laser spot.

The second model allows to determine the temperature inside the package during the soldering operation (see Figure 2). The model is quite accurate for the first 10 seconds. For longer times, a gap can be observed between the predicted and measured temperatures. It is due to the fact that this model is one-dimensional. It is not an issue, because the soldering operation should not take longer than 10 seconds.

A prototype has been developed in order to validate the models. The different layers needed for the connections are made by screen printing. The welding seam is also screen-printed. This allows a good repetitivity in the geometry of the joint. The main drawback of this method is its lack of flexibility concerning the shape of the welding seam.

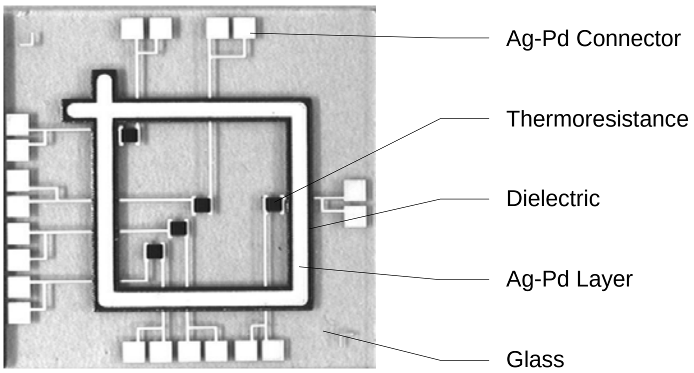

Figure 3. Layout of the prototype

Figure 3 shows the layout of the prototype. Note the thermoresistances used to measure the temperature inside the package during the soldering operation. These thermoresistances are needed for the development of the process.

Figure 4 shows the different layers and their functions. The first layer of Ag-Pd is used for the electric connections. They are insulated from the welding seam by a layer of dielectric.

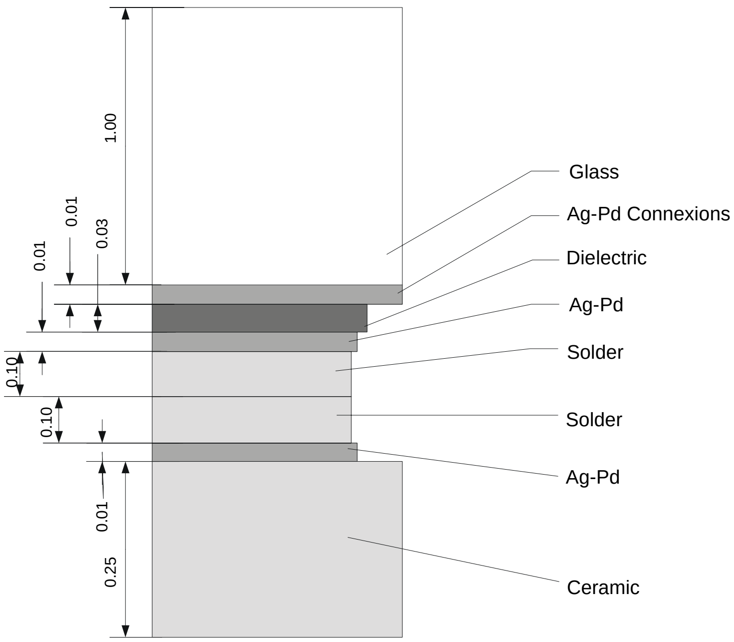

Figure 4. Section of the package

5. RESULTS

The first observation concerning the first model (see Figure 1) is the effect of the ceramic layer. It allows to have a low thermal gradient in the solder. For example, the thermal gradient in the solder for a temperature of 100°C is about 1°C/mm. This allows to have a homogenous solder joint. The second observation is that the power needed for a fusion temperature of 200°C is about 10W. This is higher than what has been observed practically. This may be due to the fact that the welding seam initial temperature is set to 20°C. It doesn't take into account the fact that the welding seam is being heated not only under the laser spot, but also due to it's thermal conductivity.

The first tests showed that it was possible to heat the welding seam through the glass. However, it was critical concerning temperature, the glass part often broke depending on heating temperature and mechanical preloading on the package. The use of low fusion temperature soft solder might be a solution to improve this critical point.

The main difficulty is to obtain a good wettability of the tin on the glass part of the packaging. A lack of wettability was often observed during the soldering process. This wettability is obtained through metallization of glass, but this method still has to be improved.

Temperature inside the package was measured with temperature sensitive resistances. Figure 5 shows the temperature reached 4mm away from the welding spot. Temperature as low as 45°C was reached at the center of the package (9mm away from the laser spot).

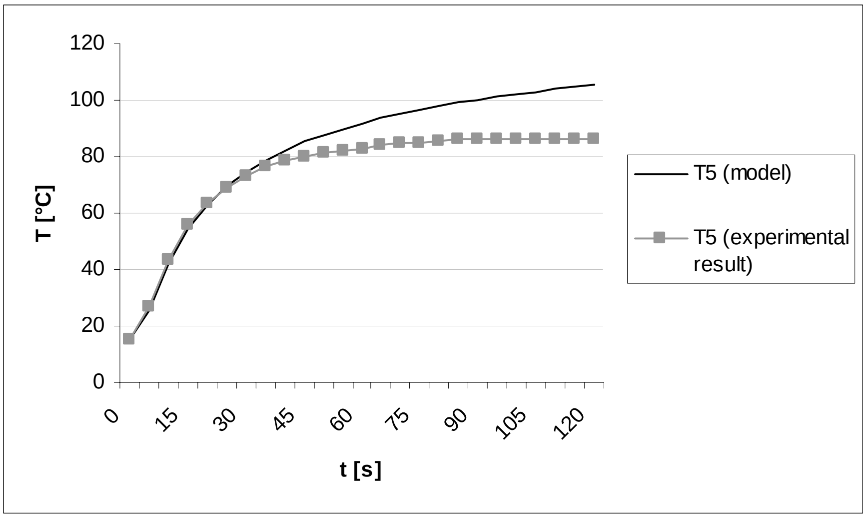

Figure 5. Second model: temperature inside the package for P=1W

Our first practical tests allowed us to compare the models to the experimental situation. The model concerning heating of the microsystem is well adapted for times shorter than 10 seconds. It was also possible to determine which parameters were significant regarding to the welding process: power, focusing and feed speed of the laser, but also composition and width of the welding seam. The tightness of the package has not been measured yet.

6. FUTURE WORKS

The feasibility of laser diode soldered packaging has been shown by soldering the two parts of the package together. The following steps need to be investigated in order to propose a robust solution.

First of all, the use of a special optics allowing to follow the shape of the welding seam will be investigated. The goal of this optics is to allow soldering of more complex welding seams geometries and also to increase the scanning speed of the laser spot. The idea would be to heat the whole welding seam simultaneously by scanning it at high frequency. This would reduce constraints in the welding seam during the soldering process.

Development of soft solder will also have to be done. One objective is to reduce the fusion temperature in order to reduce the constraints in the glass, and also the temperature inside the package. Another goal is to obtain a low degassing soft solder. The wettability of the solder on the glass part of the package has to be increased.

Another step is to control the atmosphere contained in the package. Leak rate will have to be measured. The effects on the hermeticity of several parameters like materials, geometries of welding seam and getter materials will also be investigated.

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