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## Laser soldered packaging hermeticity measurement using metallic conductor resistance

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**Abstract:** Packaging is the last step of the manufacturing process of Microsystems. The LPM is working on the development of a two-part soldered packaging. One part of the package is metallic; the other part is made of glass. The goal of the project is to solder the two parts of the package using a laser diode. The advantages of the laser soldered joint are its hermeticity to water and air in regard to glue and plastics, as well as the possibility to heat only the soldered joint, without affecting its contents. This work presents results of this packaging process, together with a method used to measure the hermeticity based on the oxidation of a heated metal conductor such as tungsten. The resistance of the conductor, which is encapsulated inside the package, increases as oxygen and water diffuse through the seal, which provides a convenient semi-quantitative measurement.

**Key words:** Packaging, hermeticity

### 1. INTRODUCTION

The goal of the study presented in this paper is to describe a packaging process developed at the Laboratoire de Production Microtechnique (LPM), together with a method used to determine the hermeticity of a two-part soldered packaging. First, a description of the packaging method is done in chapter 2. Chapter 3 describes currently used methods to measure hermeticity. Chapter 4 presents the proposed solution. Finally, conclusions are drawn in chapter 5.

### 2. DESCRIPTION OF THE PROBLEM

Packaging is the last step of microsystem manufacturing. There are mainly three types of packages: plastic, metallic or ceramic. 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.

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The experimental setup is composed of a 30W laser diode (Fig. 1). The advantage of the laser diode lies in the fact that the power can be easily controlled during the soldering process. The power density is also low, which is an advantage in our case. Another advantage is that the cost is about the half of a Nd:YAG or CO<sub>2</sub> laser. The beam of the laser is focused by a telecentric optics, and the path of the beam is controlled by a galvanometer head, allowing to follow the desired pattern. The package is placed on an x-y table allowing moving it under the optics for coarse adjustment. In order to measure the heating inside the package during the soldering operation, several thermistors are placed inside the package (Fig. 2). These thermistors are screen-printed low temperature thick-film devices, and therefore have negligible impact on the measurement.

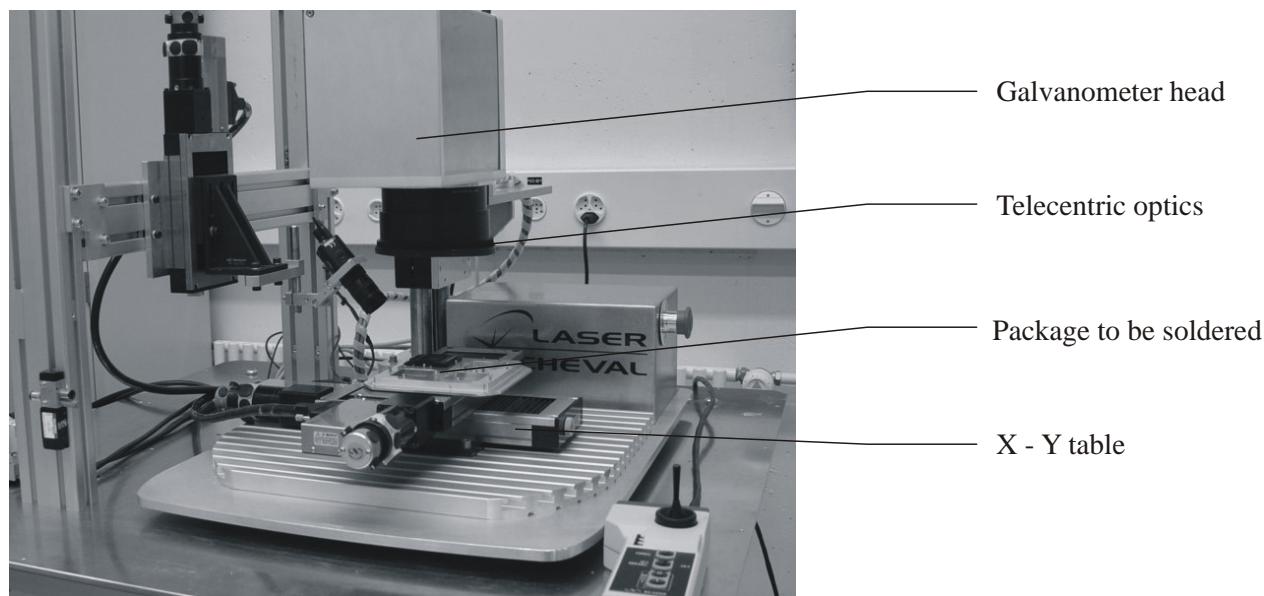


Fig. 1. Setup used for the tests

Two analytical models were developed in order to optimize the heating process. A first model allows determining the joint temperature during the laser shot. A second model is used to determine the temperature inside the packaging during the soldering process. Experiments have shown that heating of the centre of the package can be controlled to low values [2].

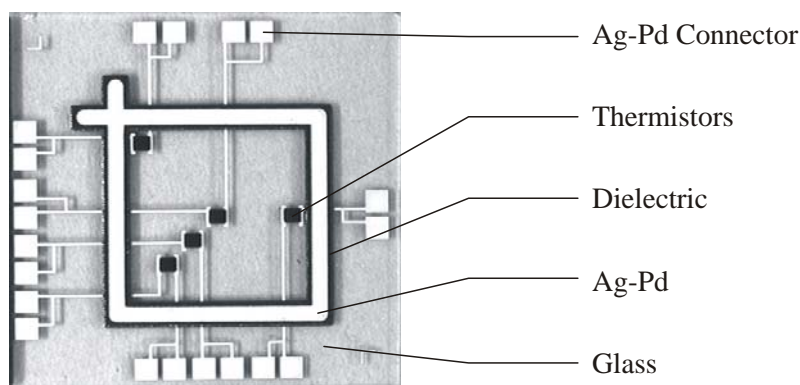


Fig. 2. Layout of the prototype used to measure temperature inside the package

### 3. HERMETICITY MEASUREMENT METHODS

The effect on hermeticity of several parameters like materials, solder joint geometry, heating times and heating strategies need to be tested. Therefore we need a convenient method to measure the hermeticity of the obtained seals. Several solutions are given here:

- Helium detection
- Calcium layer resistance
- FTIR spectroscopy
- MEMS resonator mechanical quality factor

### 3.1. Helium detector

This widely used method is based on the detection of helium, leaking through the packaging. It is quite difficult to use, as it requires a dedicated setup for this measure. The great advantage is that the He molecule is small, so that very small leaks can be detected. That is why it is more used for hermeticity measurement rather than for leaks detection.

### 3.2. FTIR spectroscopy

This method is based on the IR absorption properties of the gas inside the package [1]. The idea is to measure the gas concentration by Fourier-transform infrared spectroscopy. There are two drawbacks to this method. The package has to be transparent to IR, and the gas inside the package must be controlled. The package geometry might also create interferences.

### 3.3. Quality factor

This method is based on the quality factor of a resonator encapsulated inside the package [4]. The quality factor of a properly designed and fabricated MEMS resonator is very high in vacuum, and degrades as the pressure increases. This method is very sensitive, but only applicable to vacuum packaged devices.

### 3.4. Calcium layer resistance

This method bases on the degradation of a Ca thick film by reaction with oxygen and water, which translates into an increase of the electrical resistance. The main disadvantage is the fact that the calcium layer has to be prepared under controlled atmosphere, as the calcium layer is reactive even at ambient temperature.

## 4. DESCRIPTION OF THE PROPOSED SOLUTION

All these solutions have advantages and drawbacks. In our case, several functions need to be fulfilled. They are the following:

- Possibility to measure both large leaks and slow diffusion over time.
- The solution must be adapted to several types of packages. The LPM is able to produce the two parts of the package by screen printing or LTCC. The solution has to be independent of the production method.
- As we want to measure the effect of several parameters, the solution must be easy to use. A low operation cost is also an advantage, as it allows multiplying the measures with several parameters.
- Possibility to operate both in vacuum and inert atmosphere packaged devices.
- Preparation conditions should not be too stringent

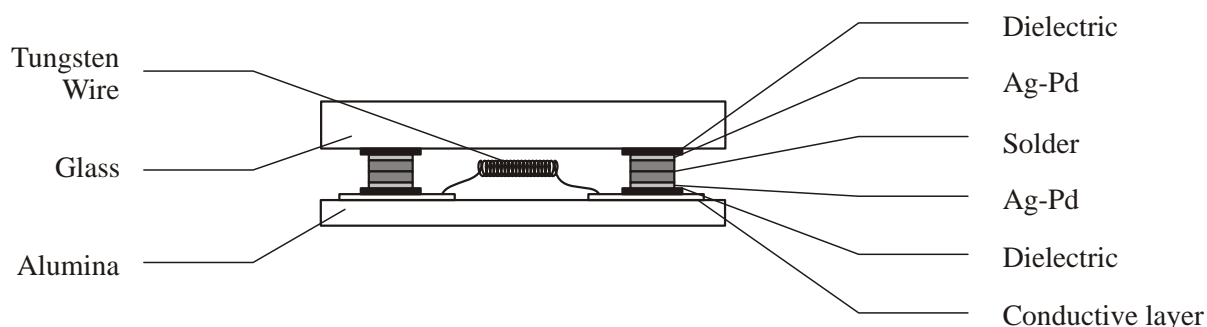
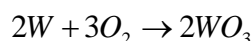


Fig. 3. Description of the solution

To this end, we propose to measure the oxidation of a heated metallic filament or film, encapsulated inside the package. The resistance of this wire increases as oxygen and water diffuse through the seal, which provides a convenient semi-quantitative measurement.

Appropriate embodiments are filaments or films of tungsten, molybdenum or other metals that are stable near room temperature, but oxidize very rapidly at high temperature. Tungsten filaments are very convenient due to their widespread use in lamps. Compared to Ca, which rapidly degrades in ambient conditions, W, Mo, Ti, Ta, Nb, are all stable to 300°C and in humid atmosphere, allowing their use to characterize a wide range of packaging methods. Moreover, part of the metal or a second such device may be used as a getter material to eliminate residual oxygen and water in the package.

For our study, we selected a 5 µm diameter tungsten wire as measuring element. For a length of 10 cm, the resistance of such a wire is about 20 ohms, which is convenient for the measurement. The oxidation of tungsten in air may be written as follows:



This is complicated by the existence of several suboxides in the W-O phase diagram ( $WO_2$ ,  $W_{12}O_{49}$ ,  $W_{20}O_{58}$ ) [5]. This problem is unfortunately present in many refractory metals, making this a semi-quantitative method only.

The ratio between the volume of tungsten and the volume of consumable oxygen is about 3800. In the case of the proposed wire, it is equivalent to 10 mm<sup>3</sup> of oxygen at ambient conditions.

## 5. CONCLUSION AND FUTURE WORK

The development of a new packaging method is drawn by the need in microsystems technology. BioMEMS are sensitive to water and oxygen, and also to temperature. The proposed packaging method might be used for such systems, allowing long term hermeticity and low closing temperature.

We propose a method to measure hermeticity of a packaging for microsystems. This method is an alternative to helium detection or Q-factor of MEMS. Due to functional analysis of the problem, the solution is simple and well adapted. It will allow to easily determining which parameters are critical concerning hermeticity.

The first tests will allow determining if the embodiment of the metallic conductor is well adapted to the measurement.

## 6. REFERENCES

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