ELECTRON TECHNOLOGY
ISSN 1897-2381
http://www.ite.waw.pl/etij/
Internet Journal

LASER SOLDERED PACKAGING HERMETICITY MEASUREMENT USING METALLIC CONDUCTOR RESISTANCE

F. SEIGNEUR, T. MAEDER, J. JACOT

Ecole Polytechnique Fédérale de Lausanne, IPR, LPM, 1015 Lausanne, Switzerland

Received Oct. 20, 2006; revised Nov. 23, 2006; accepted Nov. 24, 2006; published Nov. 29, 2006

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.

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. The possibility to use the solution as a getter material is discussed in chapter 5. Finally, conclusions are drawn in chapter 6.

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 micro-system.

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 oxygen in regard to glue and plastics, as well as the possibility to heat only the soldered joint, without affecting its contents.

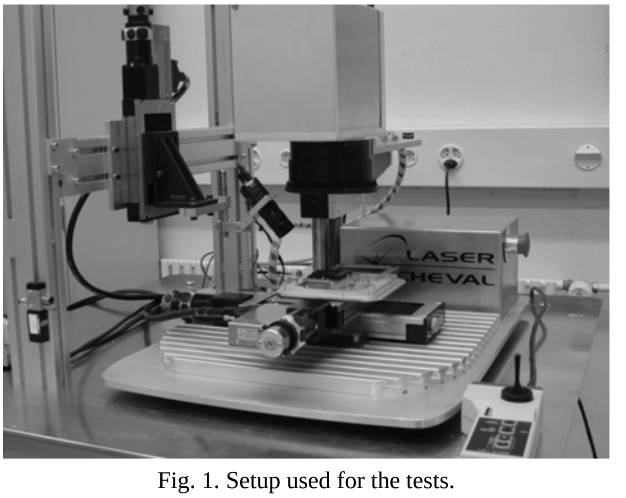

Fig. 1. Setup used for the tests.

The experimental setup is composed of a 30 W 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_2 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 to be soldered is placed on an x-y table, allowing coarse adjustment of its position. In order to monitor the temperature rise 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. The thermistor leads are electrically separated from the soldered joint by a layer of dielectric. The solder used for the tests is a lead-free low-melting (138°C) eutectic Sn-Bi solder. It was reflowed using a typical reflow profile.

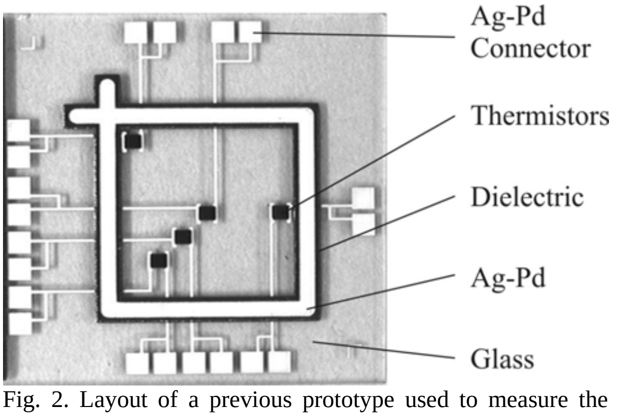

Fig. 2. Layout of a previous prototype used to measure the temperature during the soldering process

Two analytical models were developed in order to optimize the heating process. A first model allows determination of the joint temperature during the laser shot. A second model is used to determine the temperature inside the package during the soldering process. Experiments have shown that the temperature of the centre of the package can be controlled to low values during the soldering process [1].

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,
- FTIR spectroscopy,
- MEMS resonator mechanical quality factor,
- calcium layer resistance.

3.1. Helium detection

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 leak detection. Moreover, this method is difficult to use for long term measurement.

3.2. FTIR spectroscopy

This method is based on the IR absorption properties of the gas inside the package [2]. 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. Mechanical 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 thick-film technology or LTCC (low-temperature cofired ceramic). 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 operating cost is also an advantage, as it allows multiple samples with several parameters.
- Possibility to operate both in vacuum and inert atmosphere packaged devices.
- Preparation conditions should not be too stringent.

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.

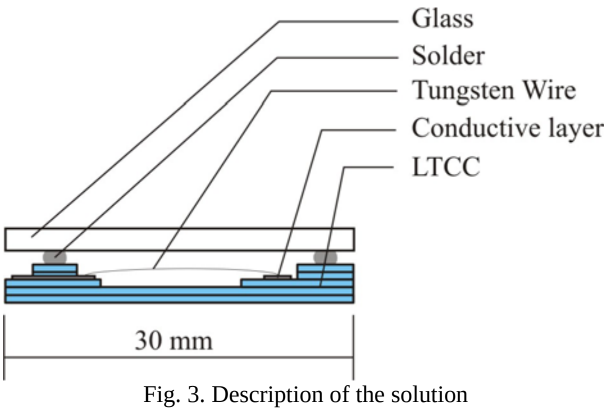

Fig. 3. Description of the solution

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 complete oxidation of tungsten in air may be written as follows:

$$2W + 3O_2 \rightarrow 2WO_3.$$

This is complicated by the existance 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^3 of oxygen at ambiant conditions.

5. Use of the solution as a getter material

The proposed solution to measure hermeticity can also be used as a getter material. Several getters are used for applications that require vacuum for their successful operation, for example X-ray tubes, lamps, flat panel displays and some MEMS [7]. The proposed solution has some advantages, they are the following:

- gas pumping selectivity,
- ponctual long-term measurement,
- low thermal impact.

By choosing the apropriate material, the getter can be selective. This can be useful for non-vacuum applications, where it is important to selectively pump active gases in a nitrogen atmosphere [8].

The other advantage is the possibility to easily reactivate the device, either for a measurement or for pumping impurities. This activation can be done for several times, allowing controlling hermeticity of the package during its lifetime, but also for absorbing active gases which could have diffused through the seal or outgassed from the package surface.

Finally, the activation of the getter has a low thermal impact on the packaged device. Usual getters are evaporated on the inner surface of the package, or are activated by heating the whole package, thus heating the encapsulated device. The proposed solution is independent of the package, and can be activated electrically, reducing thermal impact on the device. That way, hermeticity can be measured at several times during the lifetime of the package, without affecting the encapsulated device.

The first measurements allowed observing longer life-time and less oxidation of the wire for hermetically sealed packages. In hermetic packages, oxidation is observed due to entrapped impurities.

6. 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 determine which parameters are critical concerning hermeticity. A future development will concentrate on making the method more quantitative. The idea would be to separate the activation and the measurement. Two conductors would then been needed, one to heat and the other to measure. Then conductors could be screen printed on a thin bridge of LTCC to reduce thermal mass.

Further tests will allow determining whether the embodiment of the metallic conductor is well adapted to these measurements.

REFERENCES

1. F. SEIGNEUR, *Laser Sealed Packaging for Microsystems*, IPAS, Bad Hofgastein, 2006.
2. D. VEYRIÉ et al., *FTIR Spectroscopy for the Hermeticity Assessment of Micro-Cavities*, Microelectron. Reliab, 2005, **45**, (9–11), 1764–1769.
3. F. SEIGNEUR, *Polymérisation de colle époxy par laser*, [in] Actes de la première journée sur la modélisation et l'analyse dimensionnelle – organized by EPFL, 2005, 17–20.

4. A. JOURDAIN, *Hermeticity Investigation of Sealed 0-Level Packages Based on the Damping Characteristics of the MEMS Device*, EMPC, 2005.
5. W. G. MOFATT (Ed.), *The Handbook of Binary Phase Diagrams*, General Electric, USA, 1982.
6. D. R. SPARKS, S. MASSOUD ANSARI, N. NADJAFI, *Chip-Level Vacuum Packaging of Micromachines Using NanoGetters*, IEEE Trans. on Advanced Packaging, 2003, **26** (3), 277–282.
7. R. RAMESHAM, *Getters for Reliable Hermetic Packages*, Jet Propulsion Laboratory Publ., USA, D-17920, 1999.
8. C. BOFFITO, B. FERRARIO, P.DELLA PORTA, L. ROSAI, *A Nonevaporable Low Temperature Activatable Getter Material*, J. Vacuum Sci. & Technol. 1981, **18** (3), 1117–1120.