Adhesive solutions for closed cavity packaging

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Abstract— ***The trend towards autonomous driving demands continuously increasing safety requirements and hence reliable components such as CMOS image sensors or communication devices. To provide such components, manufactures are facing ever greater challenges as the sensor packages need to be airtight sealed over their whole lifetime. Typical defects that can be observed when using conventional lid attach materials for closed cavity packages in tests at automotive level (e.g., according to AEC Q100) are pop-up effects and delamination. To avoid these defects and to meet the increasing reliability requirements of the semiconductor industry, DELO Industrial Adhesives has developed special adhesives that not only ensure reliable bonding while keeping narrow and high bondlines, but also improve process stability. Features such as light/heat B-stage or light fixation help to keep the attached lid in place during heat curing and other subsequent steps like temperature cycling, humidity storage and even reflow.***

Keywords—CMOS, image sensor, autonomous driving, DMS, LIDAR, ADAS, automotive, adhesive, bonding, MSL, closed cavity, airtight, sealed, AEC Q100, dual cure, B-Stage, reflow

I. Introduction

DELO responds to the needs of the semiconductor industry with the strategic development of new adhesives for airtight packaging, mainly for end applications like automotive image sensors. Previously existing solutions cannot withstand the ever-increasing requirements towards the needs of trends like autonomous driving whereby the AEC Q100 standard plays an important role [1]. The main challenge is to compensate the changing pressures inside the cavity while keeping the cavity airtight. In addition, outgassing must be reduced to a minimum to avoid contamination of other components inside the package [2].

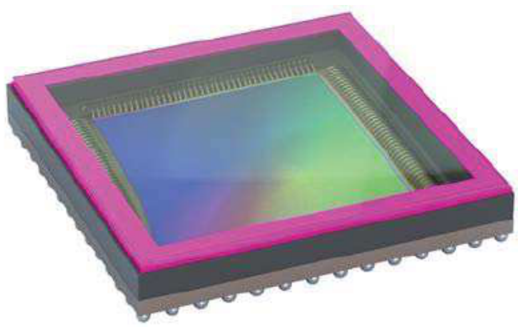

Figure 1: DELO Image Sensor Illustration

1) Defining the challenges

When working on "Lid Attach onto Housing applications", as shown in Figure 1, the same defect patterns often occur. A major challenge is the airtight design of the image sensors. Due to temperature changes, the air volume contracts at low temperatures, whereas it expands at high temperatures. Since the air volume is entrapped, the pressure decreases or increases. This leads to particular stress in areas where different materials are connected to each other, e.g., by adhesive processes. Typical defect patterns are cracks, which cause the joint to break, or tilt, in which the cover glass becomes misaligned. Both error patterns are judged as defects and must be avoided [1].

Furthermore, outgassing and bleeding of any kind are not acceptable [2]. All components that settle in the sensor in form of precipitation are an unacceptable problem. For example, this can cause corrosion on the wires or impair the image quality of the sensor.

Therefore, it is necessary to develop an adhesive solution that does not cause any of the described defects both during adhesive curing and in subsequent use.

2) Image Sensor assembly & reliability testing

The image sensors are typically manufactured at OSATs, which use equipment of the semiconductor industry. The singulated cover glasses are provided on a wafer and the packages are prefabricated on strips. In the first step, the image sensor dies are bonded into the cavities and electrically contacted with wire bonds. In the following process step, the lids are bonded. This is done on machinery such as the Besi Datacon Evo 2200, which is also used in this way in development at DELO. The machine is loaded with the housings as well as the lid-wafer, and the individual sensor cavities are then closed with the lids in a pick-and-place process. The dispensing process for the lid attach adhesive also takes place within the system. Typically, this is followed by the heat curing process in a convection oven.

Once the sensors are finished, they undergo a variety of reliability tests [3]. Of great importance from an adhesive point of view are those that can cause aging or degradation of the adhesive. These can be, among others, storage according to JEDEC MSL or also based on the AEC Q-100 standard. Both stress the packages with high temperature changes as well as the influence of humidity.

After the storage is completed, the condition of the respective package is finally examined. Special attention is paid to the sealing as well as to the general condition of the package. In addition to the visual inspection via microscope, the non-visible bottom interface of the adhesive line can also be checked for delamination using acoustic scanning microscope. Failure patterns can be identified under the microscope, for example. Here, among other things, delamination between glass and adhesive layer become visible. A good and a poor specimen is shown in Figure 2 a and b, respectively.

In order to also make delamination between the housing and the adhesive layer visible, an acoustic microscope is used. This allows the package to be analyzed non-destructively. Delamination becomes visible in the form of light/dark distinctions, as shown in Figure 3 b. For comparison reasons Figure 3 a shows a bondline without delamination. The inspection is completed with the so-called "Red Ink Test", which finally ensures the tightness of the package by means of ink penetration.

In addition to the tightness and condition of the adhesive layer, the cover glass and image sensor are also examined for outgassing to ensure the optical performance of the sensor.

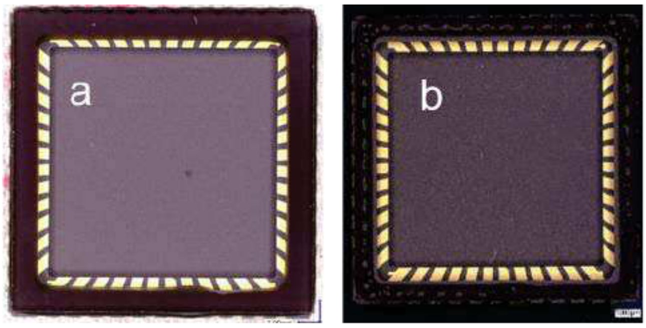

Figure 2: Bondline inspection by means of microscope on DELOs test vehicle

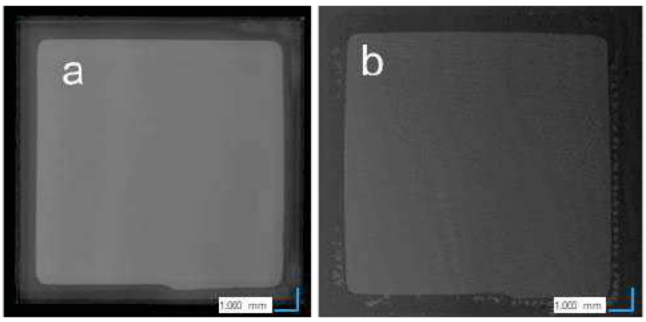

Figure 3: Bondline inspection by means of acoustic microscope on DELOs test vehicle

II. Adhesive development

For a targeted development of new adhesives, a precise set of requirements is essential. In addition, the definition of the curing process is also of great importance to identify or exclude suitable adhesive chemistries at an early stage. Furthermore, the tests of the adhesives for suitability in the application are defined and specified.

A. Curing process

Typically, heat curing adhesives are used in this application area [5]. The curing temperature range lies in a window between +100 °C and +150 °C with a curing time, depending on the chemistry, of approx. 1 hour to 3 hours. To counteract adhesive spreading, which can often be observed with heat curing adhesives due to viscosity reduction at elevated temperatures, dual curing is also considered in the investigations. The aim is to pre-fix the adhesive bead by fast UV curing within seconds to improve its dimensional stability before moving to final heat curing.

B. Definition of mechanical requirements

To define the target properties of new adhesives, the substrate materials and the conditions of use are first analyzed in depth. The two main bonding partners are the image sensor housing and the glass lid, which in most cases is a filter glass. The two main materials used for the housings are ceramics and epoxy mold [4]. To analyze the behavior of the materials at different temperatures, FEM simulation models, illustrated in Figure 4, are created which are fed with the respective material characteristics. Adhesives of different mechanical properties are tested on these test vehicles.
Since both, the filter glass and the housing materials, have very low expansion coefficients [6], the development of a low-modulus system with Young´s Modulus below 100 MPa and a low glass transition temperature of about -50 °C proved to be useful. The flexible adhesive is chosen to compensate pressure differences that arise during temperature changes, thus avoiding pop-up defects or delamination.

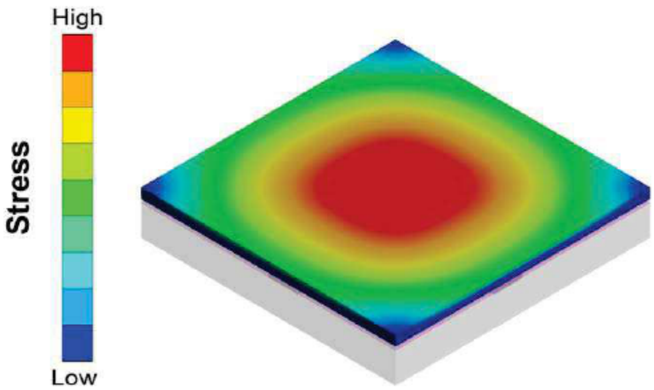

Figure 4: Filter glass deformation at elevated temperature in FEM simulation

C. Material properties check

The Young's modulus and the glass transition range are investigated by means of a DMA (Dynamic Mechanical Analysis) over the temperature range from -55 °C up to +125 °C (according to AEC Q 100 Grade 2). The thermal expansion of the adhesives is determined using TMA (thermomechanical analysis). The data obtained are fed into the simulation model and tested again for suitability in the closed cavity package application. In addition, the new developments are subjected to adhesion tests in form of die shear (silicon die, 2x2 mm², polished) on the relevant substrate materials such as glass or ceramics.

D. Built of dummy image sensors & failure analysis

To ensure that the new developments also properly work in the application, dummy packages, as shown below in Figure 5, very similar to the final product were set up and used as internal test vehicles. The manufacturing process mimics the production conditions of the CMOS image sensors and uses comparable equipment such as the Besi Datacon EVO 2200 for assembly. After testing the bondline shape such as width and height via 3D microscopy in the liquid state, testing is also carried out after final curing. As described above, microscopy, acoustic microscopy and red ink test are available for this purpose. If the packages are intact after finishing the curing process, they pass through the qualification process based on the AEC Q100 standard with a subsequent repeated check of the bondline. AEC Q100 reliability testing includes MSL storage plus additional temperature cycling, high temperature storage, and moisture storage of varying intensity depending on the quality requirements.

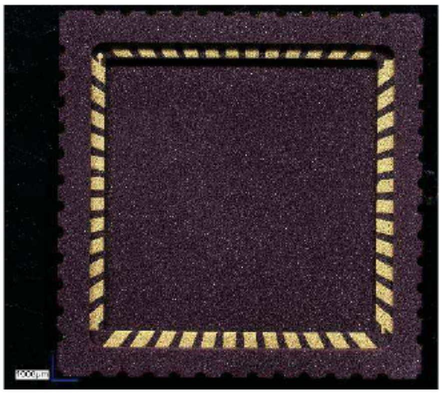

Figure 5: DELOs test vehicle for closed cavity packaging

III. Conclusion

After completion of all tests, DELO DUALBOND materials, based on a patented chemistry, seem to be very suitable for airtight bonding of image sensors and similar closed cavity packages. Its high flexibility, with a Young's modulus of < 10 MPa at room temperature in combination with its glass transition temperature of below -50 °C (which is outside the usual range of application), as shown in Figure 6, make it possible to compensate for the changing pressures inside the package. These required properties can be achieved thanks to DELO's patented chemistry and are therefore unique. Even after completion of the AEC Q100 tests, based on Grade 2, no defects could be detected in the bondline which proves the compatibility with typical Semicon standards. Contents of this investigation are MSL3, 1000 temperature cycles from -55 °C to +125 °C, 1000 hours of storage at +125 °C and a temperature / humidity storage for 1000 hours at +85 °C / 85 % r.h..

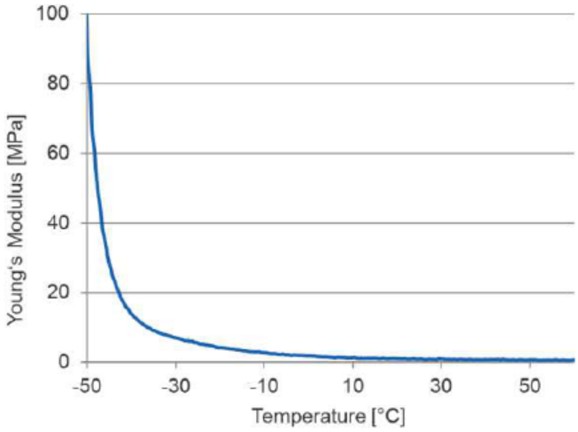

Figure 6: Young´s Modulus over Temperature

Acknowledgment

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