Development of skills and tools for micro opto-electrical integration on wafer level

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Abstract: *New devices for a digital lifestyle like augmented reality (AR) glasses may find their wide spread use only if consumer relevant pricing can be achieved. Low cost RGB-light sources are a key element for AR. assembly productivity for these micro opto-electrical RGB-light sources and a further reduction in their package dimensions. We present our new approach to build miniature RGB-light sources on structured silicon wafers and elaborate the required skill set and our future process infrastructure based on our existing high volume capable optical packaging platform. The platform provides an optical bench with integrated heat spreader and emission windows enabling miniature hermetic housing for laser diodes assemblies on 8" wafers.*

1. Introduction

The challenge in the production of small form factor RGB-laser light engines are the hermetic optical packaging. The package form factor should enable a straight forward integration into a projection system with an overall size that matches typical glasses frames. Light weight, ultra-low power consumption and ruggedness are further demands. Wafer Level Packaging (WLP) as a new concept realizes assemblies with good thermal properties high optical precision and low inductance for ultra-high speed laser emission control. The possible high bandwidth will be particularly important for 2k to 8k video resolution at more than 50 images per second. The beam characteristics of the light engine may be customized to the projection system requirements. In this paper we describe a novel lateral emission based glass-silicon wafer level assembly and packaging technology for laser diodes and the functionality of a customer specific precision opto-device mounter.

2. Motivation and concept

A miniaturized hermetic laser diode package can be realized by a Wafer Level Packaging approach (Fig. 1). A transparent glass cap with an integrated vertical window protects especially the blue and green laser against premature failure (Fig. 2). Hydrocarbons have been identified to be a root cause of laser diode degradation [1].

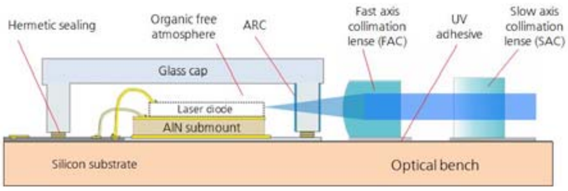

Fig. 1: Schematic cross section of a miniaturized WLP laser module with an optical bench.

Our hermetic packaging concept relies on joining material selections that reduce possible hydrocarbon outgassing's within the sealed housing.

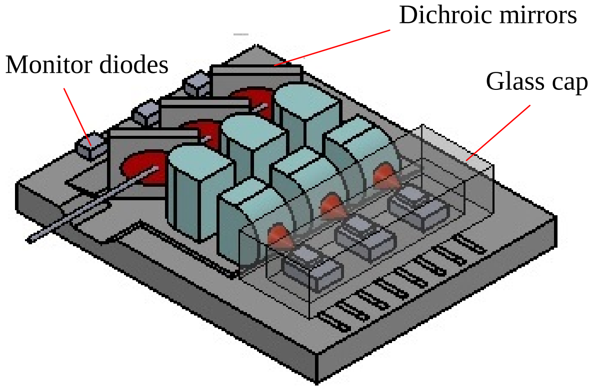

Fig. 2: Schematic overview of a first generation multi-color construction of a miniaturized laser module with lateral emission window. The laser diodes are hermeticaly sealed under a transparent glass cap. The protection cover is not shown.

Specific filler gas compositions may be enclosed within the cavity to further improve the environmental conditions for robust laser performance. The lateral emission enables the beam shaping by low cost optics placed outside of the hermetic laser package area. To further reduce the efforts for lens mounting, a hybrid FAC/SAC lens is in planning for second generation light engines (Fig. 3), that will also help to reduce the package width.

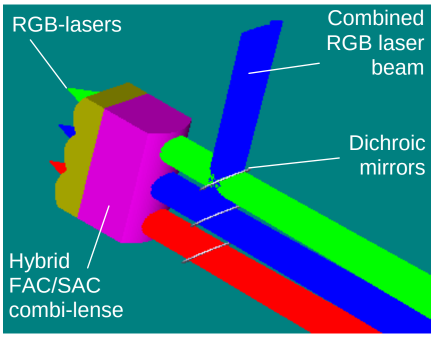

Fig. 3: ZEMAX simulation of a hybrid lens design for second-generation multi-color laser light engines.

The choice of glass as a capping material is based on its low permeability for water and gases and by the high optical transparency. The good optical quality of the emission window in respect to roughness and flatness is achieved by fusing two glasses with different softening points.

3. Optical Glass Cap Technology

Our glass cap production technology is based on hot temperature viscous glass micromachining with glass and silicon wafers [2]. Figure 4 shows a schematic of the fabrication process flow for the optical cap with inserted vertical emission window.

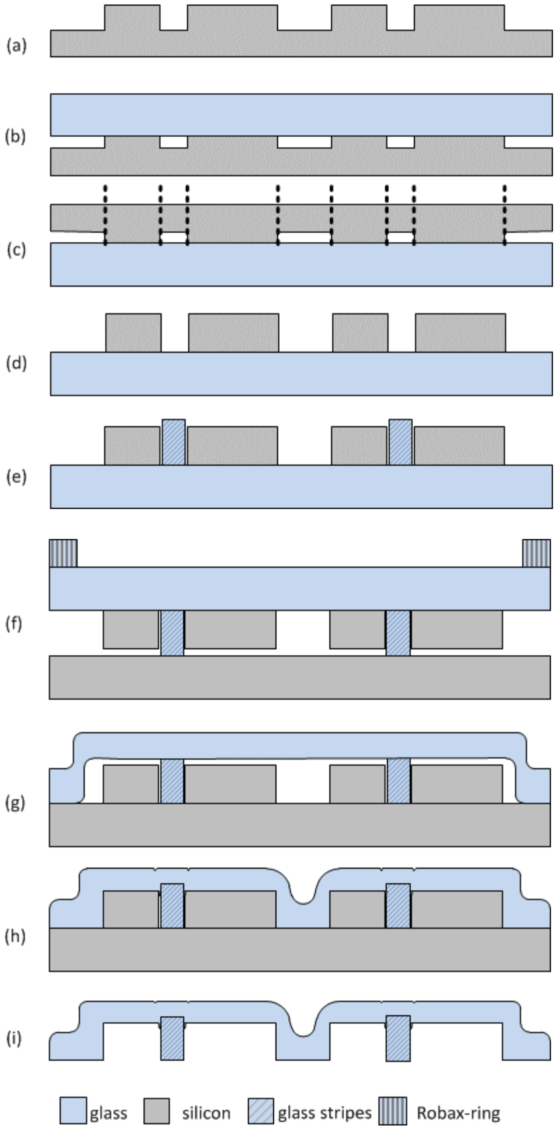

Fig. 4: Schematic of the process flow for the glass wafer with vertical windows.

Step (a): etch cavities into silicon
Step (b): anodic bonding of this structured silicon wafer with a borosilicate glass wafer
Step (c): mechanical dicing to define the pinboard
Step (d): pinboard wafer
Step (e): inserting of high melting glass stripes
Step (f): apply a further silicon wafer, flip the complete stack, depress the glass edge of the peripheral area in vacuum, a ROBAX®-ring coated with boron nitride is placed on the stack
Step (g): perform the annealing under the transformation temperature of the high melting glass
Step (h): annealing under atmospheric pressure until the glass is completely flown
Step (i): remove the silicon selectively in a KOH wet etch step, release the complete silicon from the cap wafer, two sided grinding step, apply a double side anti-reflective coating to improve the transmission, deposit a seal frame metallization on the cap wafer

4. First packaged laser diodes with glass cap with vertical emission window

First simplified demonstrators were built on a silicon wafer with AuSn metallized solder pads and metal seal frames to prove the feasibility. Eutectic AuSn bonding is a joining technology widely used in opto-electronic packaging. While we used contact heating for first demonstrator assemblies, our aim is the development of in-situ laser soldering technologies for both the submount and the laser diode soldering. A sample with metallic seal bonded glass cap is shown in Fig. 5.

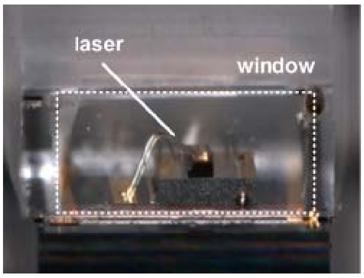

Fig. 5: Front view through the emission window on a packaged laser diode.

5. Assembly concept and infrastructure

The demand for a miniaturized multi-color laser engine requires further improvements in assembly technologies. An investment into a new ultra-precision assembly machine (Fig. 6) as part of the “Forschungsfabrik Mikroelektronik Deutschland” (FMD) is going on.

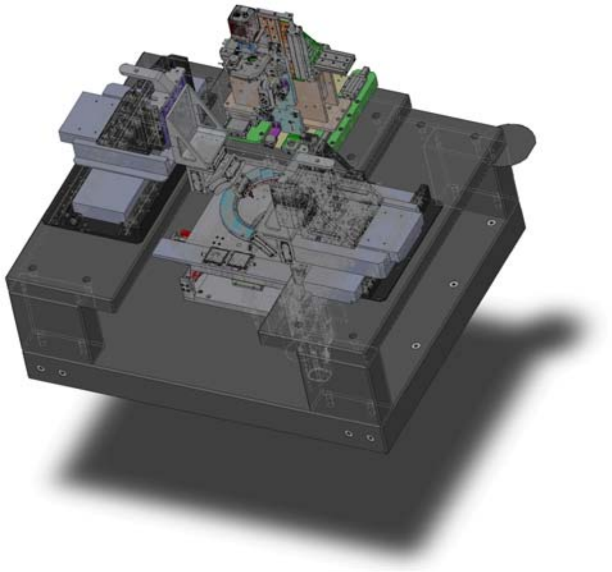

Fig. 6: CAD construction overview on functional modules in a new ultra-precision assembly station with integrated in-situ laser soldering and active alignment functionality. [3]

Considering a number of possible joining techniques, we prefer in-situ laser soldering with direct heating of selected mounting positions to reduce the heat spreading (Fig. 7). This will reduce thermal effects on neighboring metallization's and mounted components, prevent premature alloying and increase the eutectic soldering throughput. The aim is to reduce the chip gap to around 100 µm with a chip position accuracy of around 0.5 µm. The laser focus will be programmable within a spot size of 400 µm to 3000 µm.

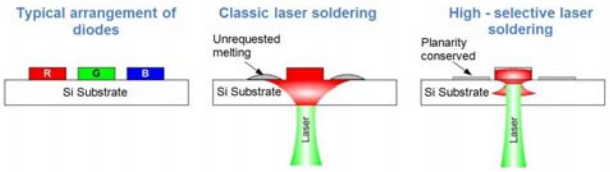

Fig. 7: Concept of in-situ laser soldering with direct heat transfer to the soldering pad of a laser diode to further reduce the placement pitch by reduce heat spreading.

Most of the assembly job should to performed in a passive alignment strategy and finalize the assembly with only a limited number of active aligned components. This will balance the demand for throughput with the requirement to achieve well defined beam properties. Experiences have to be gained, which optical components have important influence on the optical performance and therefore define the yield.

The machine platform, built by ficonTEC Service GmbH in Germany, incorporates a beam characterization unit to allow active alignment jobs. The machine is in the specification process right now and will be available for research activities in early 2019.

6. Conclusions

Our new hermetic glass-silicon packaging platform enables miniature laser packages. Going from a single laser die assembly to a full optical multi-color system is a challenge in a number of technological topics. The actual work is focused on the machine specification, the definition of optical elements based on ZEMAX simulation and purchasing of these optical components.

7. Outlook

The development of a low temperature sealing technique for hermetic glass cap sealing applied to our first generation light engine concept is planned. In future, we will integrate vertical vias in the substrate wafer to achieve SMD-compatible packages.

8. Acknowledgements

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