The number of sub cameras on the market is estimated to be around 210 millions. Cost and size are the major issues here. These low-cost cameras also serve as the primary camera in budget phones, webcams, security, toys and mobile gaming platforms. Therefore the industry puts a lot of effort into improving performance and optimizing the manufacturing method of these cameras. Wafer-Level Camera (WLC) is supposed to be the technology of choice to address the technical issues and, more importantly, the requirement for a low cost manufacturing method.

New wafer-based manufacturing technologies like SUSS MicroTec Lens Imprint Lithography (SMILE) and wafer-level packaging (WLP) support the WLC idea.

To build a wafer-level camera all components are manufactured on 8” wafer by microlens imprint lithography, deposition, lift-off, screen printing, powder blasting and glue dispensing. The optical wafers are then mounted together with micrometer accuracy in a mask aligner. The camera wafer stack is mounted by wafer-level packaging onto a full CMOS image sensor wafer, or the camera wafer stack is diced into individual optics modules and then mounted onto individual CMOS image sensors. The complete mobile phone camera, including colour filters optics, is manufactured and packaged on wafer-level using wafer-based technology.

Despite the fact that WLC technology is still under development, an estimated 80 million WLC modules have been delivered in 2009. The expected growth rate for WLC is so attractive, that most CMOS camera suppliers are now investigating WLC solutions.

Typical Wafer-Level Camera design

Typically a wafer-level camera consists of two main pieces, the image sensor and the optics. Fabrication of optical components via UV replication

Key enabling technology for WLC is the cost-efficient manufacturing and packaging technology for lens, pupil and spacer wafers. The most promising technology is UV replication technology supported i.e. by SUSS microlens imprint lithography (SMILE), where a liquid polymer is dispensed on the wafer and the lenses are imprinted by using a transparent stamp or mold and UV-light for curing. Microlens Imprint Lithography allows the manufacturing of lens arrays with a sub-micron lateral accuracy on 8” wafer-level in a mask aligner. Accurate wedge error compensation and gap setting are crucial for microlens imprint lithography.
The master tool generation is a critical key technology for microlens imprint lithography. Master lens arrays consisting of aspherical microlenses with profile deviation below 50nm (rms) and surface roughness below 2nm (rms) were demonstrated on full 8” wafer scale by SUSS MicroOptics, Switzerland. Recently Kaleido Technology, Denmark, presented a first 8” diamond milled lens master in brass, providing spherical, aspherical and free-form lenses with better than 2 µm lateral position accuracy. The wafer-scale master wafers are then transferred into a soft stamp, usually made of Polydimethylsiloxane (PDMS) by casting. The PDMS layer serves as the stamp. Finally the UV replication process can be performed in various approaches. One approach involves squeezing a dispensed polymer droplet over the wafer area. Alternatively, polymer droplets are pre-dispensed on the wafer substrate prior to the actual imprint or even dispensed into the PDMS stamp cavities.

The polymer lens material must be suitable for high throughput imprint lithography, reflowable and must have long-time stability in harsh environment (heat, humidity and sunlight). For a long time, the choice of suitable lens material for microlens imprint lithography was very limited. Front runners in WLC kept their material a secret. Encouraged by high demand for microlens imprint lithography, other suppliers like DELO, Germany and Asahi Kasei, Japan, are now supplying suitable lens material to the market.

Wafer-Level Packaging of opto-wafers

Camera systems consist of several optical elements that need to be assembled quite accurately to provide the best possible optical performance. Until today camera systems have been manufactured by manually assembling lenses into a barrel. This procedure is very costly, time consuming and doesn’t seem to be a reasonable approach for the manufacturing of multi level, miniaturized lens stacks that are supposed to be use in modern camera systems for mobile phones. Wafer-level bonding technologies seem to solve this issue. The industry started to use wafer bonding equipment platforms to bond lens wafers with spacer wafers or a second lens wafer with thermal curable adhesives. For this technology state of the art bond aligning and wafer bonding equipment can be used. However, the need for tighter post bond accuracy drives the industry to use a UV bonding process in mask aligner equipment. As lens wafers are transparent for UV light, the alternative to use UV curable adhesives is available as a cost effective and highly accurate wafer-level assembly. This option includes “in-situ” alignment in the mask aligner plus the final UV bonding process. Leading edge mask aligner technologies like SUSS’ Assisted Alignment Technology allows alignment accuracies well below 0.5µm.

The systems also offer high intensity UV illumination to decrease the UV curing process time. The sequence of a UV bond is very similar to common mask aligner photolithography. Two substrates have to be aligned in an accurately controlled alignment gap and UV exposure finalizes the process step. However, for UV bonding the mask aligner requires a specific substrate holder that includes a UV transparent chucking plate to hold the top lens wafer. Another hurdle to overcome is severe wafer warpage of several mm. Specific tooling is needed to ensure safe and efficient handling during the UV bond process.

In addition to the alignment and bond equipment, dispense technology plays a significant role in the manufacturing of WLC. The dispense volume and pattern of the adhesive need to be controlled to achieve a void free and reliable bond interface. Too much material results in contaminated optical elements while too less material results in leakages of the module itself. The adhesive itself also needs to be chosen carefully to fit to the general requirements to be a fast curing, highly reliable, dispensable and last but not least reflow compatible material. In addition suppliers like DELO offer material with integrated filler particles to achieve uniform and automatic residual thickness control by the material itself.

SUSS MicroTec: Solutions for the Wafer-Level Camera market

SUSS MicroTec is the only semiconductor and electronics equipment manufacturer who has in-house wafer-level optics expertise, prototyping and small-series manufacturing capabilities. Its core-scientists have more than 20 years of experience in micro-optics design, manufacturing and testing. SUSS MicroTec has established a Competence Center for customer demos and training, and provides lens master wafers, stamps, prototype lens wafers and wafer-level packaging capability on request.

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