



Low Cost, Small Form Factor, and Pb-free Solder Reflow Compatible Wafer Level Camera Module for Mobile Devices

Hongtao Han, Keith Main

Tessera, 9815 David Taylor Drive, Charlotte, NC 28262, hhan@tessera.com

Abstract *Small form factor, low manufacturing cost and Pb-free solder reflow compatible digital camera modules have been developed using wafer scale micro-optics, wafer scale integration, and wafer level packaging technologies.*

Introduction

Mobile devices such as cell phone, PDA, laptop, etc. have penetrated into our daily life globally. A significant percentage of cell phones and other mobile devices contain digital cameras with different resolutions [1]. Figure 1 illustrates the mobile phone market trends. The increasing demand for more features and functions for the mobile devices from consumers drive for high level integration and manufacturing paradigm shifts from serial manufacturing to parallel manufacturing where thousands of optical devices are fabricated simultaneously on wafer scale. Wafer scale manufacturing of micro optics has attracted a lot of attention from the OEMs and optics component suppliers in recent years. Wafer scale micro optics and wafer scale integration offer small form factor, low manufacturing cost [1-5].

In this paper, we will present Tessera's OptiML™ wafer level camera (WLC) technology for low cost cell phone camera application. WLC technology is based on wafer level optics and wafer level packaging technologies. These technologies are scalable with imaging sensor resolutions.

OptiML™ Wafer Level Camera

Figure 2 is a schematic drawing of the cross sectional view of OptiML™ WLC module with SHELLCASE® RT package. This design is a VGA camera with two-lens element (4 optical lens surfaces) and two-spacer configuration. The multi-element optics in Figure 2 are fabricated and integrated on wafer scale.

In addition to the cost effective advantages,

WLC technology also enables small form factor and Pb-free solder reflow compatible (depending upon material selection). The latter feature can further save assembly cost for the camera phone manufacturers.

Figure 3 is the size comparison of a conventional camera module with flex leads and a WLC module with BGA interface.

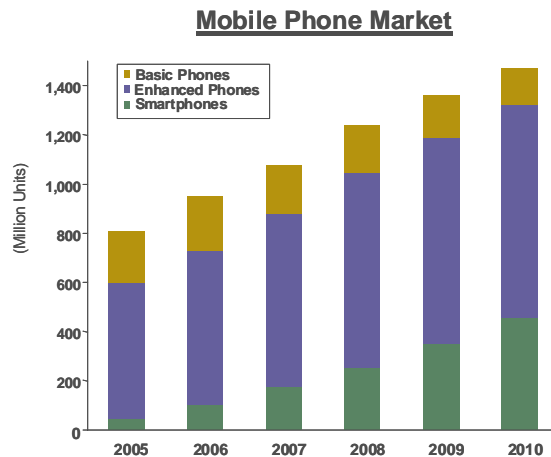


Figure 1. Mobile Phone Market Trends (Source: Gartner Dataquest)

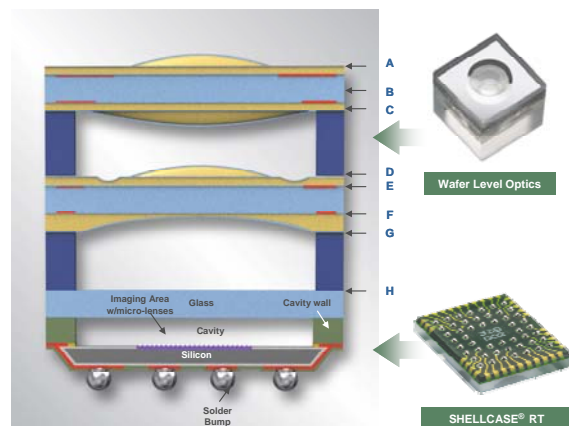


Figure 2. Cross sectional view of OptiML™ WLC



Figure 3 Comparison of conventional cell Phone camera with OptiML™ WLC module

OptiML™ WLC Fabrication & Assembly Flow

As Figure 4 illustrates, OptiML™ WLC includes three major segments: 1. Fabrication and singulation of wafer level optics (WLO); 2. Wafer level chip scale packaging (WLCSP) and singulation of image sensors; 3. Integration of WLO with packaged image sensors.

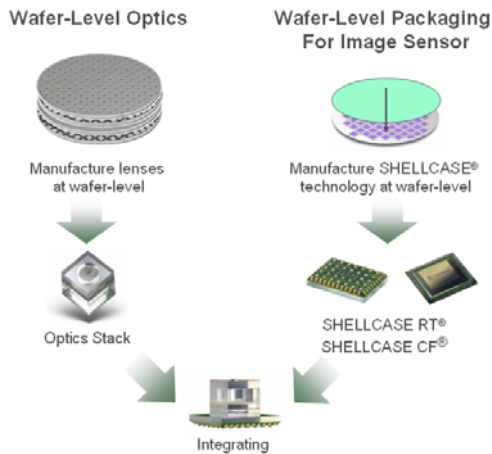


Figure 4. Fabrication & Assembly Flow

1. Fabrication of wafer-level micro optics contains following steps:
 - a. UV replication of micro-optics on wafer scale. Depending upon the optical design, micro-optics can be fabricated on both sides of glass wafers;

- b. Wafer bonding, where multiple optics wafers and spacer wafers are bonded together with precision alignment to form optics stack;
- c. Wafer level optical testing on optics stack;
- d. Singulation of optics wafer stack

2. Wafer-level chip scale packaging (WLCSP) of image sensors has three popular configurations depending upon how electrical I/Os of image sensor are accessed [1]:

- a. SHELLCASE® CF package where sensor electrical I/Os are accessed through wire bonding from sensor to a substrate;
- b. SHELLCASE® RT package, where sensor electrical I/Os are accessed using edge connect and BGA;
- c. SHELLCASE® MVP package, where sensor electrical I/Os are formed by through Si via (TSV) and BGA.

Both SHELLCASE® RT and SHELLCASE® MVP enable surface mount technology (SMT) for post assembly, which will reduce assembly cost. In addition, one of the benefits of WLCSP is to protect image sensor pixels from damage and contamination.

After the wafer-level packaging of image sensors, the packaged sensor wafer is singulated into individual sensor units.

3. The integration of singulated WLO and WLCSP packaged image sensors are done using die attach equipment.

OptiML™ WLC Module Performance

To assess the quality of camera modules, we analyze the image quality based on the following parameters:

- a. Resolution (ISO12233 Resolution Chart)
- b. Color Error (Gretag-Macbeth Chart)
- c. Dynamic Range
- d. Distortion (SMIA TV distortion)
- e. Veiling Glare
- f. Relative Illumination

Figure 5 & 6 are the photo images of ISO 12233 Resolution Chart and Gretag-Macbeth Chart respectively taken by

OptiML™ WLC VGA camera in our lab. Figure 7 is an outdoor picture taken by OptiML™ WLC VGA camera.

Table 1 summarizes OptiML™ WLC VGA design parameters and provides a comparison of the average of eight commercially available cell phone cameras from leading OEMs with OptiML™ WLC VGA performance.

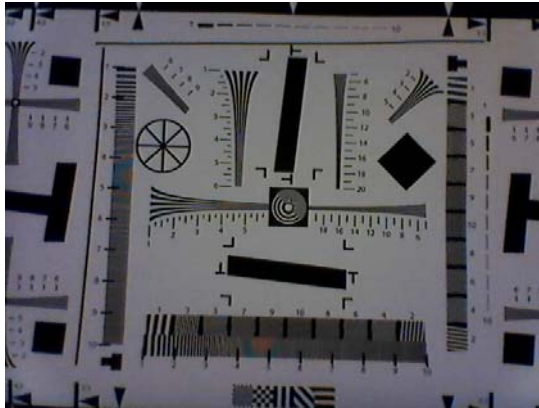


Figure 5. ISO 12233 Standard Resolution Chart taken by OptiML™ WLC VGA camera



Figure 6. Gretag-Macbeth Color Chart taken by OptiML™ WLC VGA camera



Figure 7. Outdoor Photo image taken by OptiML™ WLC VGA camera

Parameters	Market Average Performance	OptiML™ WLC Performance
F/#		2.8
Chief Ray Angle (max)		< 28°
Field of View		± 30°
Optical Track		2.2 mm
Pixel Size		2.25 μm
MTF @ Nyquist/2		
min MTF at 0% field	79%	78%
min MTF at 50% field	68%	68%
MTF @ Nyquist/4		
min MTF at 0% field	95%	98%
min MTF at 50% field	93%	93%
Color Error	15.2	13.5
Dynamic Range (f-stop)	6.5	7.65
SMIA TV Distortion	1.3%	0.48%
Relative Illumination	83%	75%
Veiling Glare	8.3%	7.00%

Table 1. Comparison of commercial VGA camera with OptiML™ WLC VGA

Conclusions

In summary, we developed a low cost, small form factor and Pb-free solder reflow compatible cell phone camera module using wafer-level micro-optics and wafer-level chip scale packaging of image sensors. The optical performance of OptiML™ WLC VGA camera is comparable with commercially available VGA cameras made by major OEMs. In some parameters, WLC camera performs even better.

References

- 1 Y Dagan, The future of cameras for Mobile Electronics, to be presented at 2008 SMTAI , August 17-21 (2008), Florida, USA
- 2 M Feldman, Wafer-level camera technologies Shrink Camera Phone Handsets, Photonics Spectra, pp.58-60, August 2007
- 3 D Shin, *et al*, Fabrication of phone-camera module using wafer scale UV embossing process, Proc. Of SPIE-IS&T Electronic Imaging, SPIE Vol. 6068 (2006)
- 4 M Rossi, *et al*, Wafer-scale micro-optics replication technology, Proc. SPIE, Volume 5183, pp.140-154 (2003)
- 5 H Rudmann, *et al*, Design and fabrication

technologies for ultraviolet replicated micro-optics, Optical Engineering, Vol. 43, No. 11,

pp. 2575-2582 (2004)