A Study on “On Chip Hybrid IRC Technology” to Provide a Thinner Solution for CIS

Li-Kai Lee\textsuperscript{1,4}, Chih-Chieh Chang\textsuperscript{1}, Yu-Kun Hsiao\textsuperscript{1}, J.C. Hsieh\textsuperscript{1}, Kazuaki Hashimoto\textsuperscript{2}, Chien-Hsien Tseng\textsuperscript{2}, Chun-Hao Chuang\textsuperscript{2}, Wei-Chieh Chiang\textsuperscript{2}

1: VisEra Technologies Company, No12, Dusing Rd.1, Hsinchu Science Park, Taiwan (30078)
2: Taiwan Semiconductor Manufacturing Company, No. 8, Li-Hsin Rd. 6, Hsinchu Science Park, Taiwan

(a)E-mail: LK_Lee@viseratech.com
Tel.: +886-3-6668788
Fax: +886-3-6662858

Abstract—
In this study, we developed a new type of OCMF (on-chip multi-film) technology applied on CMOS image sensor, by integrated Visera OCMF-IRC technology to provide huge benefit for the requirement of thin mobile phone camera.

We demonstrated our “On chip hybrid IRC” solution on TSMC 1.1 um 8M BSI CMOS sensor. Compared to traditional mobile camera module, we successfully reduced the total height of camera module by eliminating an extra glass for IRC and keep same blue shifting performance to large angle of incidence light. In our solution, the spectrum achieved a similar function as commercial IR cut on blue glass. The image quality and color error is comparable with commercial IR cut on blue glass. In addition, the quantum efficiency performance is comparable also based on our test results. However, the QE peak of green is lower but peak of red is higher to compare with the performance of commercial IR cut with blue glass.

The last, according to our demonstration results, we think Visera OCMF-IRC technology is a good and cost effective solution for the requirement of low Z-height camera module application.

Keywords— OCMF, CMOS sensor, OCMF-IRC, OCH-IRC.

I. INTRODUCTION

The vigorous development of the internet of things requires a variety of sensors for the special and professional applications to people's livelihood. The needs of the interference multi-film (MF) filter, such as the infrared-cutting (IR-cut), ultraviolet-cutting (UV-cut), IR-pass and etc, applied for the image sensor, the ambient light sensor and the proximity sensor will continue to increase and the relative application of the field will be more and more extensive [1,2]. Among those sensors, the CMOS sensor is one of the most widely used sensors, especially in the smartphone industry.

The camera module used for the smartphone is mainly composed of an image sensor, an optical lens module and a blue glass used as the IR cut filter [3]. The Z-height of this camera module becomes more and more critical. In this study, the IR-Cut filter is integrated directly onto the CMOS sensor chip to reduce the overall height of the camera lens module as well as the production cost by eliminating the blue glass. However, due to the blue shift property occurred at a large angle of incidence (AOI), there will be a color-shift phenomenon if only a MF IR-Cut being used. To overcome this color-shift phenomenon, an absorptive selective-near-IR (SNIR) photosresist is applied to form a hybrid IR-Cut filter. The result shows that VisEra’s On-Chip Multi-Film IR-Cut (OCMF-IRC) is a cost effective solution for the low Z-height camera module.

II. OCMF-IRC PROCESS INTEGRATION DESCRIPTION

The brief process flow of applying the hybrid IR-Cut filter to the 1.1um pixel BSI technology [4] is as followings: The R/G/B pixels and the etching back micro lens (ML), a material with a higher refractive index, were prepared by the standard color filter processes. A planar layer, a material with the lower refractive index, was spin-coated on the ML. Then SNIR was also spin-coated on the planar layer. The MF, which was prepared by the electron beam evaporation process, was placed on the patterned masking region, and then the non-defined area was stripped off by a lift-off process.

The scheme of the full structure is shown in Fig.1. The higher power ML (0.45um height with 0.65um ROC) was tuned to obtain the higher wafer level quantum efficiency (WLQE). The low refractive index planar was also tuned to obtain a flat surface on the ML. The process of the MF on the SNIR was integrated. Prior to deposit the MF on the SNIR, the patterned PR as a mask was used to define the deposited area. Then the Life-off process was performed to strip off in the periphery area.
The thickness of the SNIR layer was controlled and was combined with the different MF design in order to adjust the cut-off wavelength which resulted in the different blue shift level.

III. OPTICAL PERFORMANCE & QUANTUM EFFICIENCY

The hybrid IR-Cut spectrum for image color verification was first considered. As shown in Fig.2a, the color accuracy is not ideal at 2500K, especially in the green color, but it’s normal at 3200K. Fig.2b shows the comparison between the conventional blue glass IRC and VisEra’s OCMF-IRC, DP1-6, which’s cut-off wavelength was shifted from 700nm to 730nm. As it can be seen, The DP1-6 will cause more NIR light incident into the sensor and result in the color error.

In order to improve above problem, the DP2-5, DP2-8 and DP2-9 were designed by different SNIR thickness to adjust the cut-off wavelength. The result is shown as Fig.3. The DP2-8 has the lowest transmittance, 4.6%, at 700nm. The DP2-9, designed to have the same cutting slope as the conventional blue glass IRC, has the smallest blue shift. As it can be seen, when the AOI changes to 30 degrees, the major shift occurred in the region of the transmittance less than 35%. It indicates that there is less IR light into the sensor. The DP2-5 has a relative higher transmittance with a worse blue shift performance.

Fig.4 shows the three kinds of hybrid IR-Cut that performed the good color accuracy. The color image and color bar were both compatible by 2500K and 3200K light source.

Fig.5 shows four schemes of the OCMF-IRC that prepared for the QE test. It refers to the ML only, the OCMF-IRC, the extra hybrid IR-Cut glass on ML, and conventional blue IR-Cut glass on ML correspondingly. The QE verification on OCMF-IRC is shown in Fig.6. The normalized QE shows that the conventional blue glass IR-Cut has the higher QE peak in green and blue (97.4% and 83.8%) than the OCMF-IRC (93.3% and 76.9%). But it’s QE peak in red (64.4%) is lower than the OCMF-IRC (76.3%). This QE gap in red is due to the spectrum slope which results in the decreasing transmittance from ~580nm, as showed previously in Fig.3. For the hybrid IR-Cut glass, the QE level of the R/G/B is normally lower than the OCMF-IRC. This is because there is only one surface processed which results in a reflection occurred on the 2nd surface of glass.

In addition, the low refractive index of the planar layer on the ML with a higher refractive index increase the QE level in green peak by 4~5%. It indicates that this planar played as an anti-reflection layer. But the low transmittance of the SNIR in visible area causes the QE drop 11~12% in green peak. This QE performance could be further improved by the optimum transmittance of the SNIR material. This will be VisEra’s future topic.

IV. CONCLUSION AND DISCUSSION.

The OCMF-IRC which integrates the conventional color filter process and multi-film deposition process has been studied. The result shows that this technology will be a cost effective solution for the requirement of low Z-height camera module by eliminating the conventional blue glass IRC. We believe this OCMF technology could also be well applied to other sensors such as the ambient light sensor, finger printing sensor and etc.

V. ACKNOWLEDGMENT

The authors would like to thank the leading IC foundry house- tsmc for test wafers. And we are appreciated very much to all members of the R&D group for their effort in design, test and process development.

REFERENCES

Different blue shift level. Adjust the cut-off wavelength which resulted in the was combined with the different MF design in order to in a reflection occurred on the 2nd surface of glass. Because there is only one surface processed which results R/G/B is normally lower than the OCMF-IRC. This is Fig.3. For the hybrid IR-Cut glass, the QE level of the transmittance from ~580nm, as showed previously in spectrum slope which results in the decreasing the OCMF-IRC (76.3%). This QE gap in red is due to the 76.9%). But it's QE peak in red (64.4%) is lower than (97.4% and 83.8%) than the OCMF_IRC (93.3% and glass IR-Cut has the higher QE peak in green and blue The normalized QE shows that the conventional blue IR-Cut glass on ML correspondingly. OCMF-IRC, the extra hybrid IR-Cut glass on ML, and verification was first considered. As shown in Fig.2a, color filter process and multi-film deposition process has changes to 30 degrees, the major shift occurred in the smallest blue shift. As it can be seen, when the AOI light source.

In addition, the low refractive index of the planar layer on the ML with a higher refractive index increase performance. The color image and color bar were both compatible by 2500K and 3200K performed the good color accuracy. The color image and there is less IR light into the sensor. The DP2-5 has a region of the transmittance less than 35%. It indicates changes to 30 degrees, the major shift occurred in the 4.6%, at 700nm. The DP2-9, designed to have the same thickness to adjust the cut-off wavelength. The result is shown as Fig.3. The DP2-8 has the lowest transmittance, Fig.5 shows four schemes of the OCMF-IRC that AOI30 shift @T72 8.8% T% @ 700nm AOI30 shift @T62 4.6% T% @ 700nm AOI30 shift @T35 11.2% T% @ 700nm Fig.2. (b) Spectrum between blue IRC glass and VisEra’s DP1-6 Fig.2. Comparison between conventional blue IRC and Visera’s OCMF-IRC (a) Color accuracy (b) Spectrum.

Fig.2. (a) Color bar. Fig.4. (a) Color bar Fig.4. (b) Color image Fig.4. Comparison between conventional blue IRC and Visera’s OCMF-IRC (a) Color bar (b) Color image.

Fig3. (C) DP2-9
Fig3. Different hybrid IR-Cut designed spectrum. (a) DP2-5 (b) DP2-8 (c) DP2-9.

Fig3. (a) DP2-5
Fig3. (b) DP2-8

Fig.3. (a) ML only
Fig.5. (a) ML only
Fig.5. (c) Extra hybrid IR-Cut glass on ML
Fig.5. (d) Conventional blue IR-Cut glass on ML.

Fig.5. (b) OCMF-IRC
Fig.5. (b) OCMF-IRC
Fig.5. (d) Conventional blue IR-Cut glass on ML

The authors would like to thank the leading IC AHS), Erlangen, 2012, pp. 70-76.

Micro lens
Iron glass
Micro lens
Micro lens
Fig. 6. Measurement of normalized quantum efficiency in different schemes.