Novel Dielectric Structures for Optical Performance Enhancement in Deep Sub-micron CMOS Image Sensor

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Novel dielectric structures, light guide and air gap guard ring, have been successfully developed to improve pixel sensitivity and crosstalk in 0.18um technology. As the light transmission path surrounded by low RI (refraction index) dielectric films, the incident light will be confined to the selected pixels. This paper focuses on the optical performances of CIS with pixel pitch 2.8um~4.0um fabricated by modifying 0.18um CMOS logic technology.

The fabrication flow of proposed dielectric structures is compatible with typical CMOS logic process. After IMD (Inter-Metal-Dielectric) CMP (Chemical Mechanical Polishing), the extra steps of light guide are listed as follows: (I) Define light guide pattern and remove IMD films (FSG-oxide) upon sensor area; (II) Fill high RI dielectric film (PE-oxide) then CMP. The process differences of air-gap guard ring include (I) Define narrow and deep dielectric trench around sensor area; (II) Deposit non-conformal dielectric film to seal the opening of the trench.

The critical angles θ_c of light guide [PE-oxide(RI~1.46)/FSG-oxide(RI~1.43)] and air-gap guard ring [FSG-oxide(RI~1.43)/air-gap(RI~1)] are 79° and 44°, respectively. With the incident angle β at PE-oxide/FSG-oxide and FSG-oxide/air-gap interface larger than θ_c, the incident light is total internal reflected and confined to the high RI regions upon sensor area. Even as β is smaller than θ_c, the refracted light is more closed to the selected pixels after pass through two or more interfaces of different dielectric films. Therefore, with these novel dielectric structures, the incident light will be easily confined to the selected pixels thus reducing the crosstalk issues. Air-gap guard ring with larger RI difference shows better confinement. (Fig.1, 2)

Dramatic reduction of optical crosstalk thus facilitating higher pixel sensitivity has been demonstrated in small pixel pitch 2.8um~4.0um. Air-gap guard ring with larger RI difference shows the best optical enhancement. The reduction of optical crosstalk reaches 90% for 3.0um pixel at a 20° incident angle (Fig.3), which shows significant improvement in suppression of color mixing caused by oblique illumination (Fig.4, 5). Therefore, these novel dielectric structures can offer better optical performance to realize system-on-chip for small pixel size, multi-layer metal application in deep sub-micron CIS technology and are suitable for zooming lens system.

1. D. N. Yaung, S. G. Wuu, H. C. Chien, T. H. Hsu, C. H Tseng, J. S. Lin, J. J. Chen, C. H. Lo, C. Y. Yu, C. S. Tsai and C.S. Wang, in *IEDM*, p. 401, (2003).
2. T. H. Hsu, Y. K. Fang, C. Y. Lin, S. F. Chen, D. N. Yaung, S. G. Wuu, H. C. Chien, C. H. Tseng, J. S. Lin and C. S. Wang, *IEEE Electron Device Letters*, **25**, 22 (2003).

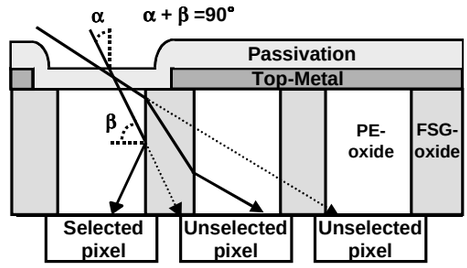

Fig.1 The illustration of refraction for light guide.

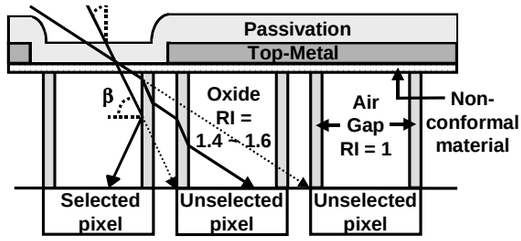

Fig.2 The illustration of refraction for air-gap guard ring.

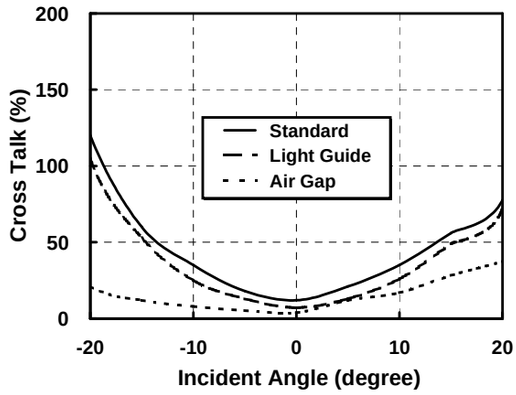

Fig.3 Crosstalk versus incident angle for 3.0um pixel.

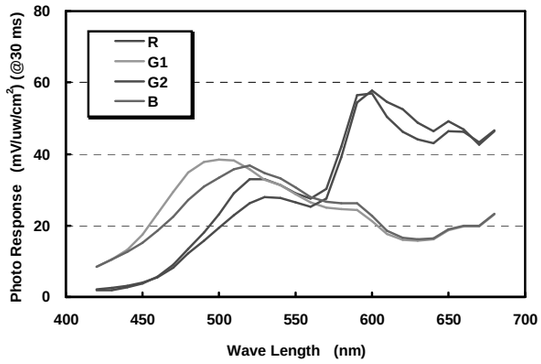

Fig.4 Spectrum response of standard samples illuminated by 15° collimated light.

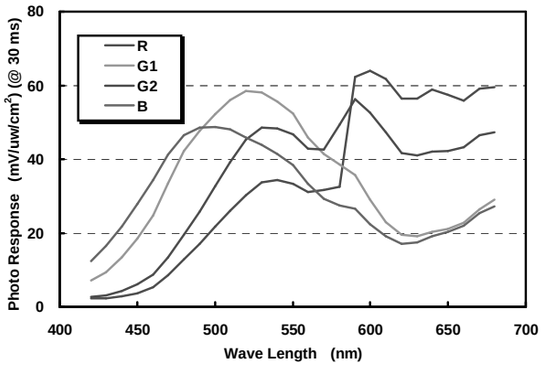

Fig.5 Spectrum response of standard air-gap guard ring illuminated by 15° collimated light.