Fabrication of Phase Grating Based Angle Sensitive Pixels by CMOS Post-Processing

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Abstract:
Typical imaging systems generate a two dimensional intensity map of the light incident on them. Light field image sensors capture, in addition to intensity, the direction of the impinging light rays. In previous work [1], we built CMOS sensors called angle sensitive pixels (ASPs) that output both the local intensity and angle of the incident light. This prior work, however, was limited in its imaging capabilities due to drastically reduced quantum efficiency as compared to a conventional active pixel CMOS image sensor. In the present work, we develop device structures for angle sensitive pixels that offer greatly improved quantum efficiency without compromising function. We fabricate these structures by simple post-processing on a standard CMOS die.

Summary:
Angle sensitive pixels rely on a near field diffraction effect, known as the Talbot effect, to extract the local angle of incidence. ASPs use a periodic transmission grating to generate a diffraction pattern. They then detect the incoming angle by detecting lateral shifts in this diffraction pattern. In earlier ASP designs, the diffraction gratings were manufactured using the interconnect metallization layers offered by a commercial digital or mixed mode IC fabrication process. Since these gratings were made of metal they reflected a substantial portion of the incident light, thereby degrading the captured signal.

The periodic diffraction patterns essential for ASP function can be generated without any reflection loss by using binary phase gratings [2]. Phase gratings are periodic structures made of two transparent materials of different refractive indices (e.g., air and glass).

We incorporated phase gratings into our angle sensitive pixels by post-processing foundry fabricated dies containing metal grating designs. The metal gratings serve as templates for the fabrication of the phase gratings. The post-processing involves three simple steps: i) a photoresist mask to protect bond pads and support circuits, ii) a plasma etch to define the phase grating in the interlayer dielectric, and iii) an aluminum etch to remove the metal gratings.

The plasma etch is performed using a CHF₃/O₂ plasma in order to etch away both the SiN passivation and the SiO₂ inter-metal dielectric. The duration of this etch sets the depth of the grating. The other design parameters — the grating period and position — are determined by the metal grating template which adheres to foundry tolerances.

Measurements show that phase grating based angle sensitive pixels show a sinusoidal response to angle that is similar to metal gratings with a quantum efficiency that is nearly four times greater.

References:
Figure 1: Process flow for the fabrication of phase grating from metal amplitude gratings.

Figure 2: SEM image of the fabricated phase gratings.