Selective Stray Light Suppression In Photodiode Modules Via Structured Black Photoresist

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Abstract

Stray light represents a significant challenge in a wide range of photodiode and photodiode array applications, as it elevates the background signal, reduces detector sensitivity, and degrades the signal-to-noise ratio. Traditional approaches to mitigate stray light, such as blackening of housing surfaces, inserting additional components or complex calibration routines, increase system complexity and cost; thus, there is strong market demand for innovative, wafer-level solutions that selectively suppress stray light at the detector surface while remaining compatible with standard manufacturing processes. The objective of this work is to address the challenge of suppressing false or stray light in an optical module featuring a light-emitting diode (LED) that emits light in a cone, directed toward a hole in an FR4 printed circuit board (PCB). The light passes through the PCB hole, continues through a corresponding hole in a silicon photodiode chip, and reaches the back surface of a daylight filter (Figure 1a). For realistic ray release from the LED, an Osram SFH 4855 model is used together with an imported ray file. This configuration induces problematic backward reflections, causing stray light that interferes with the intended signal. Additionally, light that successfully passes through the daylight filter can be further refracted and reflected at the air interface, leading to unwanted reflections that strike the active area of the photodiode and thereby generate an undesired background signal. To mitigate these sources of interference, we propose the application of a black photoresist ring selectively structured around the active area of the photodiode. This photoresist effectively absorbs stray light, diminishing the background signal. Using COMSOL Multiphysics®, we modeled the complete optical setup — incorporating the LED source, PCB, silicon photodiode, and daylight filter (Figure 1a) — and simulated the distribution of stray light on the photodiode surface. The simulations reveal that the majority of false light is concentrated in a ring-shaped region around the central opening (Figure 1b). By applying the photoresist as an open circular structure on the photodiode surface, we observe a significant reduction in stray light reaching the active area. Figure 2 summarizes the impact of varying the width of the photoresist ring. The results show a strong reduction in stray light detected on the sensor surface as the width of the resist ring increases. Specifically, the accumulated fraction of stray light is highest without resist, and decreases notably as the width of the black resist is increased from 1.2 mm to 1.5 mm (Figure 2a). Correspondingly, simulation demonstrate a drastic suppression of stray light on the photodiode surface when a sufficiently wide resist ring is used (Figure 2b). This black photoresist ring thus reduces the background signal by 94% compared to the uncovered photo diode. Our findings demonstrate the importance of targeted stray light suppression at the wafer and chip level as a highly effective, manufacturing-compatible solution for improving optical sensor performance across various applications.

Figures used in the abstract

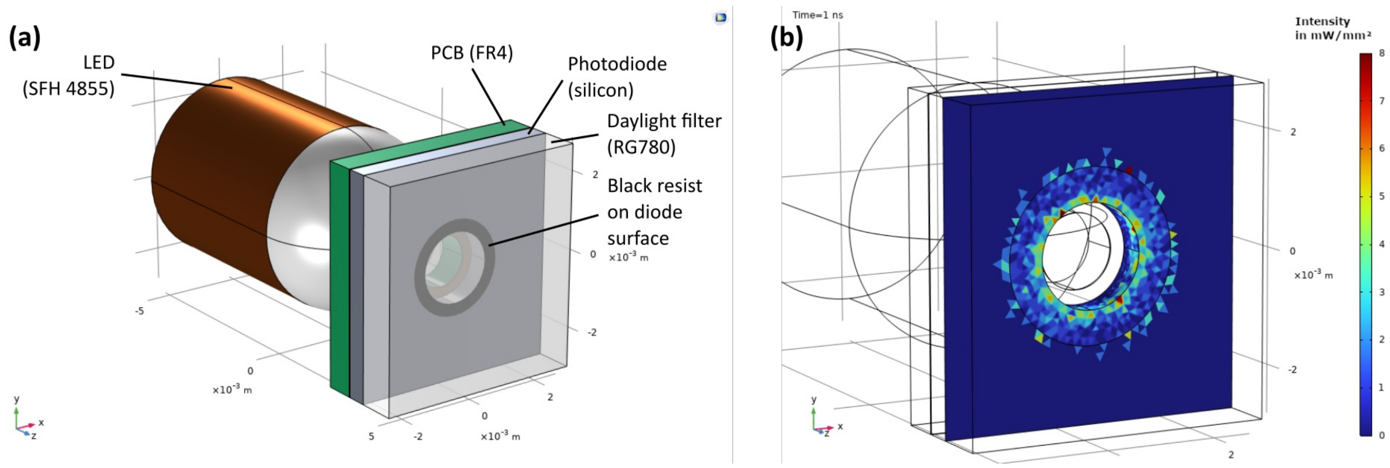

Figure 1 : (a) 3D model of the optical module assembly comprising LED (Osram SFH 4855), FR4 PCB, silicon photodiode, and daylight filter. (b) Simulation result showing the distribution of stray (false) light intensity on the photodiode surface, highlighting a ring

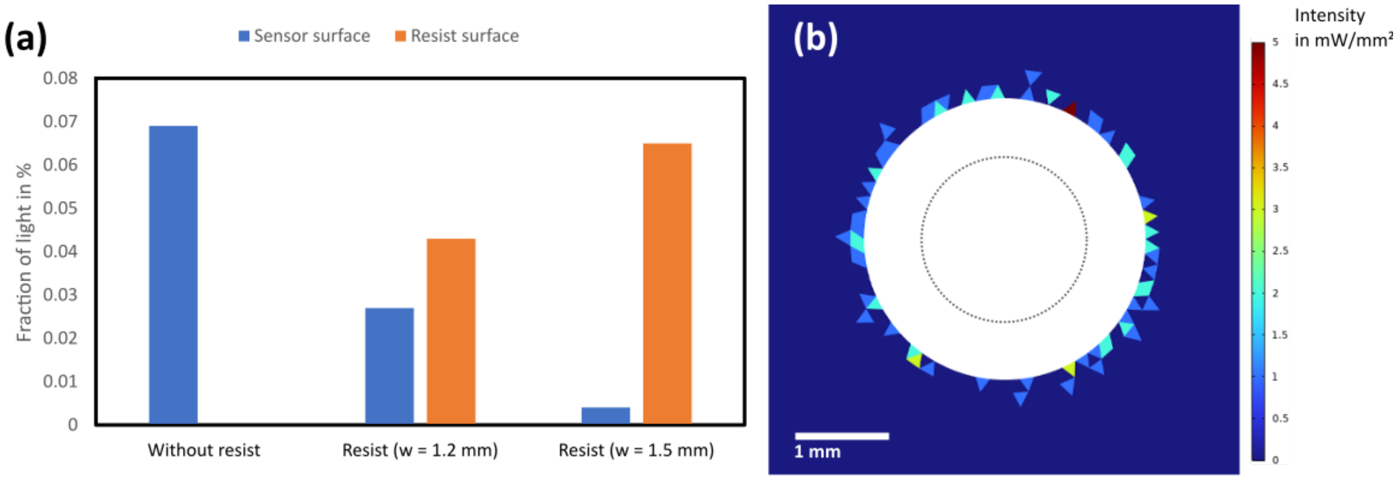

Figure 2 : (a) Accumulated fraction of stray light (in %) detected on the sensor (blue) and on the photoresist surface (orange) for different black resist ring widths on the photodiode, illustrating substantial reduction in stray light with increasing resist width.