Excellent photon confinement for next-generation back-illuminated silicon photomultipliers

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Abstract:

Silicon photomultipliers have attracted increasing attention for detecting low-density light in both scientific research and practical applications in recent years. But the photon loss due to reflection on the light-sensitive planar front surface not only limits the photon detection efficiency, but also causes it to rapidly decrease from the peak value as the wavelength enters into the ultraviolet range. Here we demonstrate an excellent photon confinement by developing the comprehensive multi-layer antireflection coatings (ARC) and the textured silicon surface with micro-nano pyramids, which significantly reduces the reflection of faint light in a wide spectrum, from ultraviolet to infrared. The ARC materials are determined according to the theory of quarter-wave dielectric layers and the transfer matrix method, and grown via the E-beam & thermal evaporators. The upright pyramids are developed as the consequence of anisotropic etching of silicon (100) substrate due to the slowest etching rate of {111} crystallographic planes. Integrating this advanced photon confinement feature into next-generation back-illuminated silicon photomultipliers would increase the photon detection efficiency with higher quantum efficiency and fill factor. We discuss their potential implications to the emerging scenarios such as nuclear medical imaging, light detection and ranging for autonomous driving, and detection of scintillation light in ionizing radiation.