Optimization of Dielectric-Metal Freeform Metasurfaces for highly saturated transmissive colors

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Transmissive color filters are essential for next-generation display technologies, requiring high color purity, optical efficiency, and stability across diverse operational conditions. However, conventional metasurface designs have been fundamentally constrained by fabrication-imposed height uniformity, limiting both structural freedom and achievable optical performance. In this study, we propose a hybrid dielectric-metal freeform metasurface structure, and employ particle swarm optimization (PSO) to simultaneously maximize color saturation, transmission efficiency, and angular stability. The absence of height restrictions allows independent tuning of resonant modes across different spectral regions, leading to sharper spectral selectivity and broader color gamut coverage. Experimental realization of the optimized structures demonstrates robust color performance over a wide range of incident angles and polarization states, surpassing conventional height-restricted metasurfaces. These findings underscore the critical importance of structural freedom in metasurface engineering and offer a versatile foundation for next-generation AR/VR displays, dynamic holography, and optical computing applications.

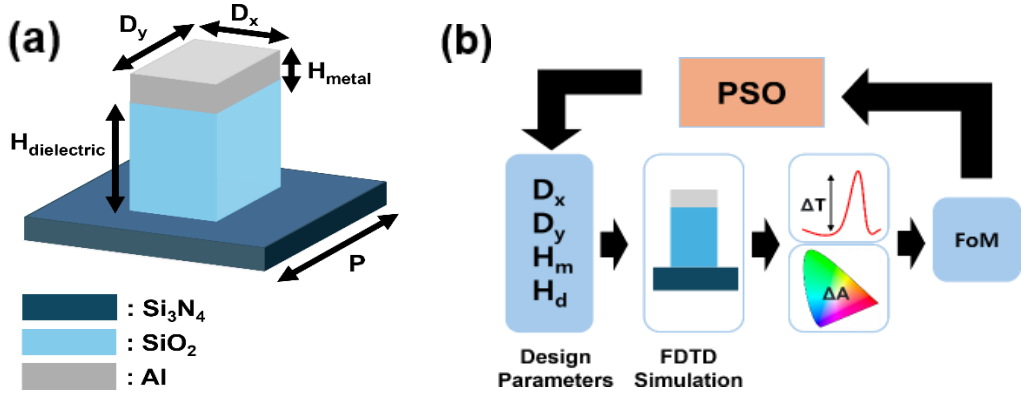

Fig. 1. (a) Schematic of the metasurface structure and (b) inverse design process using PSO

References

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