Electrical & Computer Engineering

D E F E N S E

Louisiana State University

Inverse Design of Reconfigurable and Nonreciprocal Nanophotonic Devices

a dissertation to be defended by

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Abstract—In this dissertation, we use a memetic optimization algorithm to inverse design planar aperiodic multilayer structures which provide reconfigurable and nonreciprocal control of light and thermal radiation in the visible and infrared wavelength ranges.

We first introduce multilayer structures with the phase-change material $Ge_2Sb_2Te_5$ (GST) for use as broadband switchable absorbers in the infrared wavelength range. We optimize both the material composition and the layer thicknesses of the multilayer structures, in order to maximize the difference between the absorption for GST in its crystalline phase and the absorption for GST in its amorphous phase in the wavelength range of interest. We show that in the optimized structures near perfect absorption can be switched to very low absorption in a broad wavelength range by switching GST from its crystalline to its amorphous phase. Our optimized lithography-free structures have better performance than harder-to-fabricate three-dimensional structures. Our results could pave the way to a new class of broadband switchable absorbers and thermal sources in the infrared wavelength range.

We next apply the same design approach in the visible wavelength range. We introduce multilayer structures based on phase-change materials for reconfigurable structural color generation. These structures can produce multiple distinct colors within a single pixel. Specifically, we design structures that generate either two or four maximally distinct structural colors. We employ a memetic optimization algorithm coupled with the impedance method to identify the optimal combination of materials and layer thicknesses that maximizes the distinctiveness of the generated colors. We demonstrate that our design approach achieves strong color contrast between the generated colors. To elucidate the physical mechanism underlying the observed strong color contrast, we analyze the optimized design using a Fabry–Pérot cavity model. The proposed multilayer design eliminates the need for subwavelength lithography, making it highly suitable for large-scale applications. Our results could lead to a new class of single-cell multicolor pixels which retain each color without power consumption, making them particularly appealing for low refresh rate displays.

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