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Tunable Nanophotonic Infrared Filter Based on Thermochromic Vanadium Dioxide

Background

Optical bandpass filters only allow incident light within one or more specified wavelength bands to be transmitted through or reflected from the device, while blocking others. The key parameters of these filters are the central or peak wavelength and the desired spectral range. Reflective filters using Fabry-Perot (FP) cavities reflect a specified visible wavelength of light in order to achieve microscale color printing. Transmissive filters have many applications in dense wavelength-division multiplexing network channel selection or in the spectral selectivity of lasers. Thermochromic materials can be added to optical filters to enable changes in the optical properties of the filter in response to their temperature.

Vanadium dioxide is a thermochromic insulator-to-metal material that changes its properties with changes in temperature. Vanadium dioxide has been observed to behave as a monoclinic insulator when it is under its transition temperature of $\sim 340\text{K}$, but as a rutile metal once that temperature is exceeded. Its optical properties can be experimentally modelled and fit into various optical models.

Invention Description

Researchers at Arizona State University have developed a novel tunable infrared filter with a nanophotonic structure based on thermochromic vanadium dioxide. This filter achieves a narrow-band transmittance peak in the mid-infrared spectrum at $4\mu\text{m}$ wavelength when the filter is cold, which becomes broadly opaque when the filter is heated beyond its phase transition temperature. This filter is designed by placing a silicon spacer layer between two nanometric vanadium dioxide films on a thick infrared-transparent substrate. The structure of the filter can be optimized for certain applications by altering the thicknesses of the thin-film layers to achieve maximum performance.

Potential Applications

- Energy dissipation (radiative cooling)
- Thermal camouflage (apparent temperature can be reduced)
- Smart windows
- Spacecraft thermal management

Benefits & Advantages

- Reduces transmitted power by $\sim 75\%$ between semitransparent and opaque states
- Eliminates need for external energy source to maintain thermal camouflage
- Ability to switch between semitransparent and opaque states

- Tunability in spectral location of transmittance peak

Related Publication: ["Design and Energy Analysis of Tunable Nanophotonic Infrared Filter based on Thermochemical Vanadium Dioxide" | International Journal of Heat and Mass Transfer \(2022\)](#)