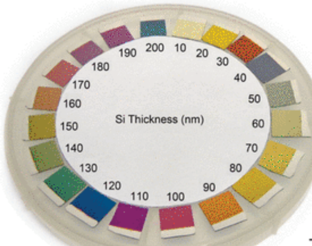
THIN-FILM FILTERS

# Silicon films on metal create perfectly absorbing optical color filters

Using two of the earth's most abundant and inexpensive materials—silicon and aluminum—wavelength-selective perfect absorption optical color filters have been developed by researchers at the University of Alabama in Huntsville.[1] Spectral-selective perfect absorption is caused by the critical coupling of incident light to the second order resonance mode of the asymmetric Fabry–Perot cavity formed by single-layer silicon films on the metal surface. The perfect absorption wavelength falls in the visible spectral range and changes with the silicon film thickness in the range from 20 to 150 nm. Silicon is chosen not only because it is inexpensive and widely used in the optoelectronics industry, but because it has a low optical extinction coefficient compared with other high-refractive-index semiconductor materials in the visible and near-infrared (NIR) range.

## Critical coupling to the 2nd order mode

Perfect absorption can only be achieved when the critical coupling condition is met; that is, when the optical power coupled from the air to the silicon film is equal to the optical loss per round trip in the nanooptical cavity. For these devices, the second-order resonance mode in the single-layer silicon films causes perfect absorption (> 99%) at the peak absorption wavelengths of 552, 605, 657, and 700 nm for silicon films with thickness values of 110, 120, 130, and 140 nm, respectively (see figure).




Single-layer silicon films with different thicknesses deposited on an aluminum layer surface.

Thermal annealing the devices blue-shifts the absorption wavelengths and correspondingly changes their colors. The reflectance spectra are measured at different angles of incidence up to 70°. As the angle of incidence is increased, the reflectance slightly increases, the peak absorption wavelengths become slightly shorter, but the peak reflection wavelengths do not shift.

Strong light absorption in nanometer-scale germanium thin films on metal surfaces was reported earlier by a group at Harvard University.[2] However, the absorption in the nanoscale germanium films was not complete because the group investigated the enhanced optical absorption of the first order optical cavity resonance mode. The researchers at the University of Alabama in Huntsville used the second-order optical cavity resonance mode to achieve perfect light absorption in single-layer silicon films at designated optical wavelengths using a technique called "selective mode critical coupling." For achieving perfect light absorption with critical coupling to the second-order cavity mode, the silicon film thickness is slightly increased, but still remains a small fraction of the peak absorption wavelength. —*Gail Overton*

REFERENCES

1. S. S. Mirshafieyan and J. Guo, *Opt. Express* 22, 25, 31545 (2014).
2. M. A. Kats et al., *Nat. Mat.* 12, 1, 20 (2012).