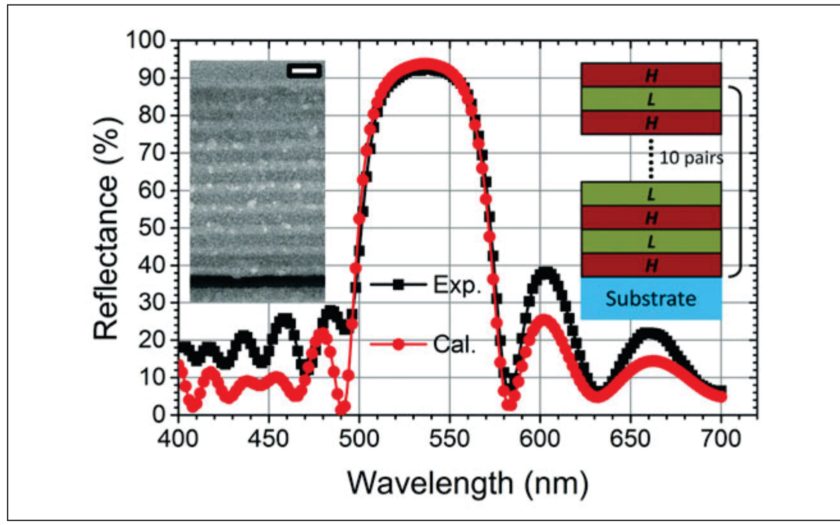
Inorganic–organic hybrid distributed Bragg reflectors heighten electrical conductance

Research in optoelectronics is moving toward combining traditional inorganic materials with cheaper, more versatile organic semiconductors. A recent example comes from a research group at Soochow University, demonstrating hybrid inorganic–organic distributed Bragg reflectors (DBRs), which show high performance and relatively easy fabrication compared with traditional all-inorganic DBRs.

DBRs are one-dimensional photonic crystals that are used in resonator cavities for electrically pumped vertical cavity surface-emitting lasers. They are composed of alternating layers of high- and low-refractive-index materials, making them highly reflective (close to 99%) and weakly absorbing. Ideal DBRs also show high electrical conductivities, which have limited the field so far to inorganic materials such as AlGaAs/GaAs layers and metal oxides. Unfortunately DBRs made of these inorganic materials also require either high temperature or highly pervasive fabrication techniques. Organic materials offer the advantage of low cost and easier fabrication but suffer from lower electrical conductivities, and have been difficult to combine with inorganic materials due to incompatible fabrication conditions.

In a recent issue of *Advanced Materials* (DOI: 10.1002/adma.201503003), X.-B. Shi, Z.-K. Wang, L.-S. Liao, and their colleagues present a solution for a hybrid DBR that shows high reflectivity (92.2%) over a wide spectral range (>70 nm) with high electrical conductivity and vastly improved current density compared to all-organic based DBRs, fabricated under low-intensity conditions. The materials used in their study included molybdenum trioxide (MoO_3) and 1,4,5,8,9,11-hexa-azatriphenylene-hexacarbonitrile (HAT-CN), hole injection materials, and a series of hole-transporting organic materials 4,4′4″-tris[3-methylphenyl(phenyl)-amino]triphenylamine, α-napthylphenylbiphenyl diamine, and 1,1-bis[(di-4-tolylamino)phenyl]cyclohexane. Critically, the refractive-index contrast that is essential for high reflectivity in a DBR was determined by the difference in refractive index between the MoO_3 layer and the low refractive indices of the organic materials. A relatively larger refractive index difference of 0.4 was achieved.



Experimental and calculated reflectance of the hybrid semiconductor distributed Bragg reflectors (DBRs) with quartz/(*HL*) 10 *H* structure at 8°. (Left inset): The cross section of the hybrid DBRs characterized by SEM. The scale bar is 200 nm. (Right inset): Schematic of the hybrid DBRs. *H* represents MoO_3 and *L* represents m-MTDATA. Credit: *Advanced Materials.*

The electrical and optical properties of hybrid films and devices show high reflectance but lower conductivity than pure MoO_3. The researchers say this is due to the high conductivity and charge mobility in the inorganic material, compared to the organic layers. The researchers also show that the charge-carrier properties can be improved by using a multi-alternating structure of organic semiconducting films, rather than a single organic material. The conductivity of a device for five units of HAT-CN interlayers was shown to be two orders of magnitude higher than a device with a single HAT-CN layer. In addition, the current densities showed a seven orders of magnitude improvement compared to an equally thick all-organic device at the same voltage. However, the reflectance suffered a small loss (~ 86%) in the multi-alternating film.

With these hybrid DBRs, the research team showed that a combination of more than one organic semiconductor can improve electrical conductance beyond single organic devices and pave the way for more hybrid organic–inorganic DBRs.

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