

MIT Open Access Articles

Hybrid Optoplasmonic Structures and Materials: from New Physics to New Functionalities

The MIT Faculty has made this article openly available. **Please share** how this access benefits you. Your story matters.

Citation: Boriskina, Svetlana V., Jonathan Tong, Yi Huang, Lee Weinstein, Wei-Chun Hsu, Gang Chen, Wonmi Ahn, Yan Hong, and Björn Reinhard. "Hybrid Optoplasmonic Structures and Materials: From New Physics to New Functionalities." *Advanced Photonics* 2015 (2015).

As Published: <https://doi.org/10.1364/NOMA.2015.NM4C.2>

Publisher: Optical Society of America

Persistent URL: <http://hdl.handle.net/1721.1/109527>

Version: Author's final manuscript: final author's manuscript post peer review, without publisher's formatting or copy editing

Terms of use: Creative Commons Attribution-Noncommercial-Share Alike



Hybrid Optoplasmonic Structures and Materials: from New Physics to New Functionalities

Svetlana V. Boriskina*, Jonathan K. Tong, Yi Huang, Lee A. Weinstein, Wei-Chun Hsu, and Gang Chen

Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge Massachusetts 02139, United States
sborisk@mit.edu

Wonmi Ahn, Yan Hong, and Björn M. Reinhard

Department of Chemistry and The Photonics Center, Boston University, Boston, MA. 02215, United States

Abstract: We develop hybrid optoplasmonic architectures to tailor resonant energy transfer between trapped photons, plasmons, quantum emitters and elementary heat carriers for applications in near- and far-field emission manipulation, radiative cooling, imaging, and ultrasensitive detection.

OCIS codes: (240.6680) Surface plasmons; (230.4555) Coupled resonators; (160.3918) Metamaterials; (130.3060) Infrared.

Both, confined photon states in microcavities and localized surface plasmon resonances on metal nanoparticles have properties resembling those of confined electron states in atoms. This resemblance gives rise to the terms ‘photonic atoms’ and ‘plasmonic atoms’, and offers many interesting applications in optical energy generation and harvesting, signal processing, sensing and spectroscopy. Interaction between light and matter in photonic & plasmonic atoms can be further enhanced and manipulated via their mutual electromagnetic coupling when individual atoms are arranged into hybrid optoplasmonic molecules, supramolecular structures and nanostructured materials. We will show how this coupling can be tailored to trigger new physical effects, which add new functionalities to optoplasmonic materials not available in their purely photonic or purely plasmonic counterparts.

Among the emergent properties of optoplasmonic structures is their ability to simultaneously achieve extreme spectral and spatial localization of light. Ultrasensitive optical detection schemes, which benefit from high field concentration in plasmonics, also require high spectral resolution to reach single-molecule level of detection. High spectral resolution is typically unattainable in purely plasmonic sub-wavelength structures due to high dissipative losses of metals. We will show how this limitation can be overcome by combining plasmonic and high-Q photonic elements into hybrid optoplasmonic sensor platforms [1]. Furthermore, we reveal that the dramatic enhancement of localized electromagnetic fields in optoplasmonic structures stems from the energy recycling through nanoscale optical vortices. The obtained insight into the origin of the light enhancement enabled us to propose a new way of dynamical switching of the localized energy between multiple hot spots by re-routing the optical powerflow through the system via coupling and decoupling of individual vortices [2].

In state-of-the-art plasmonic architectures, the high plasmon-enhanced electric field in the visible or near-IR range that enables a wide range of useful applications also causes excessive heating of metal. We will show that counter-intuitively, the field intensity enhancement in hybrid optoplasmonic structures may be accompanied by the *reduced* absorption in their metal constituents. Furthermore, these hybrid systems can be designed to provide strong cooling of metal via the radiative heat extraction based on enhanced thermal emittance of the dielectric constituent. The radiative cooling may be achieved either via the far-field photon emission or via the near-field radiative heat transfer [3]. We will discuss how the infrared thermal emittance can be manipulated and increased via the proper choice of both material and morphology of the dielectric elements having dimensions on the scale at or below the thermal emission peak wavelength. Overall, a combination of the strong light localization and enhancement achievable under lower operating temperatures in optoplasmonic materials is expected to yield a wide range of applications in plasmon-enhanced spectroscopy, sensing and imaging.

Acknowledgements

This work was supported by the U.S. Department of Energy, Office of Basic Energy Sciences, Division of Materials Science and Engineering Award No. DE-FG02-02ER45977 (for the near-field heat transfer and far-field thermal emission manipulation) and Award No. DE-SC0010679 (for light focusing and resonant energy transfer).

References

- [1] S.V. Boriskina *et al*, PNAS **108**, 3147 (2011); M.A. Santiago-Cordoba *et al*, APL **99**, 073701 (2011); Y. Hong *et al*, Adv. Mat. **25**, 115 (2013)
- [2] S.V. Boriskina *et al*, OPEX **19** 22305 (2011); J. Tong *et al*, in Singular & Chiral Nanoplasmonics (Boriskina & Zheludev) Pan Stanford, 2014
- [3] S.V. Boriskina *et al*, Materials Today, **16**, 379 (2013)