Active metasurface and metamaterial platforms enabled by DNA-assembled plasmonic nanoparticles

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Templated nanopatterning has great potential in various fields including plasmonics, metasurfaces and metamaterials. The ability to predictably, rapidly, and precisely place individual NPs into desired arrangements over large areas on a surface in both two- and three-dimensions would represent a significant advance in structural control, dramatically expanding the range of nanomaterials that can be synthesized and enabling new properties, many of which have likely never even been contemplated because a lack of access to such structures.

In this talk, I will describe passive and active metasurface and metamaterial platforms enabled by programmable DNA-assembly of plasmonic gold nanoparticles both on substrates as well as in solutions. First, I will describe large-area epsilon-near-zero metasurfaces [1] formed from DNA-assembly of gold nanocubes. ENZ frequency can be tuned by controlling the DNA bonding length dynamically using a varying ethanol concentration solution, therefore enabling significant frequency tuning range covering between 1.5 – 2.5 µm (Fig. 1 – left). I will demonstrate a broadband metasurface absorber [2] in which metal nanoframes formed from Pt-core and Au-shell can be arranged on a surface over large-areas to enable broadband absorption at visible frequencies (Fig. 1 – center). Hollow nanoframes enable further increase in light-matter interactions by reducing the reflection from the metasurface yielding enhanced absorption. Lastly, I will introduce a 3D negative-index metamaterial [3] formed from Au-Pt hollow nanoparticle superlattices exhibiting ccp crystal symmetry (Fig. 1 – right). Due to electric and magnetic resonances that are supported simultaneously, our simulations predicted negative-refractive index behavior at near-IR frequencies.

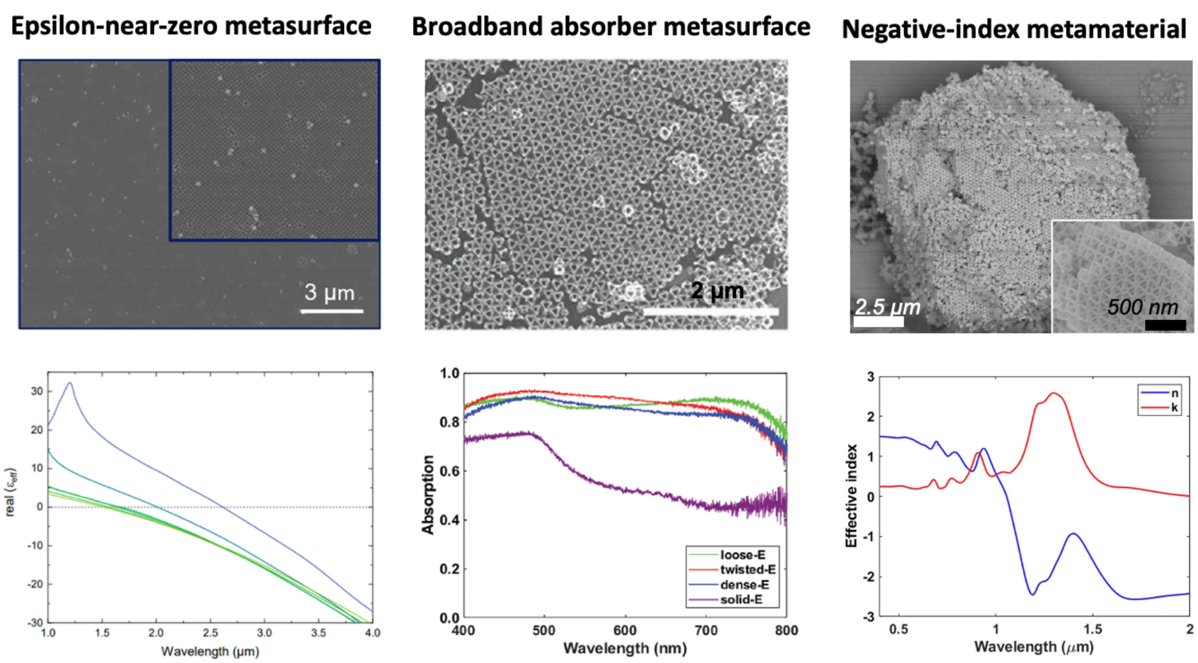

Fig. 1 (Left) Active, large-area, epsilon-near-zero monolayer metasurface enabled by DNA-assembly of gold nanocubes (Center) Monolayer Au-Pt nanoframe metasurface with broadband absorption in visible spectrum. (Right) 3D Open-channel, porous metamaterial formed of Au-Pt nanoframe ccp superlattice exhibiting negative refractive index at near-IR frequencies.

The synthesis of plasmonic NP architectures with structures and stimuli-responsive behavior that are not accessible in lithographically defined plasmonic nanostructures provides an opportunity to design materials with emergent optical properties that offer new fundamental insights and previously inaccessible functionalities.

References

[1] Zheng, C. Y., Hadibrata, W., Kim, S., Schatz, G. C., Aydin, K., and Mirkin, C. A., 2021, *ACS Nano*, 15, 18289.
[2] Li, Y., Tanriover, I., Zhou, W., Hadibrata, W., Abedini Dereshgi, S., Samanta, D., Aydin, K., and Mirkin, C. A., 2022 *Small,* 18, 2201171.
[3] Li, Y., Zhou, W., Tanriover, I., Hadibrata, W., Partridge, B. E., Lin, H., Hu, X., Lee, B., Liu, J., Dravid, V. P., Aydin, K., and Mirkin, C. A., 2022 *Nature,* 611, 695.