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Artificial intelligence designs metamaterials used in the invisibility cloak

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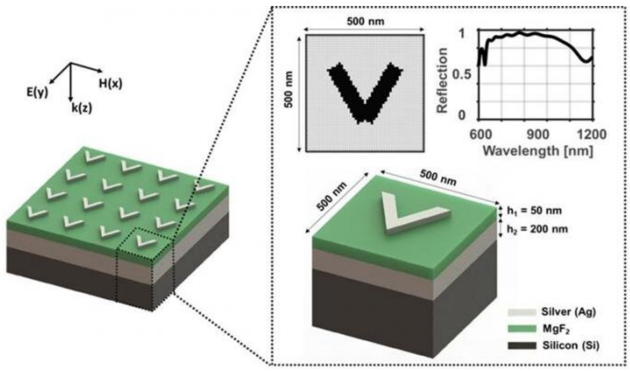
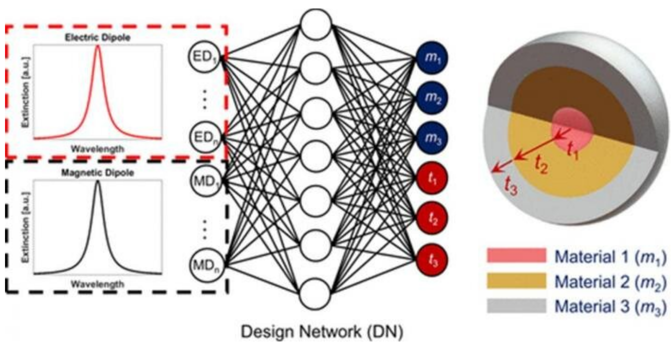


Schematic diagram of an artificial neural network that can design arbitrary photonic structures. Cross section of structures is mapped as two-dimensional cross-sectional bitmap so that artificial neural network can design structures of metasurface antenna which cannot be designed with structural parameters. Credit: POSTECH

Metamaterials are artificial materials engineered to have properties not found in naturally occurring materials, and they are best known as materials for invisibility cloaks often featured in sci-fi novels or games. By precisely designing artificial atoms smaller than the wavelength of light, and by controlling the polarization and spin of light, researchers achieve new optical properties that are not found in nature. However, the current process requires much trial and error to find the right material. Such efforts are time-consuming and inefficient; artificial intelligence (AI) could provide a solution for this problem.

The research group of Prof. Junsuk Rho, Sunae So and Jungho Mun of Department of Mechanical Engineering and Department of Chemical Engineering at POSTECH have developed a design with a higher degree of freedom that allows researchers to choose materials and design photonic structures arbitrarily by using deep learning. Their findings are published in several journals including *Applied Materials and Interfaces, Nanophotonics, Microsystems & Nanoengineering*, *Optics Express*, and *Scientific Reports*.

AI can be trained with a vast amount of data, and it can learn designs of various metamaterials and the correlation between photonic structures and their optical properties. Using this training process, it can provide a design method that makes a photonic structure with desired optical properties. Once trained, it can provide a desired design promptly and efficiently. This has already been researched at various institutions in the U.S. such as MIT, Stanford University and Georgia Institute of Technology. However, the previous studies require inputs of materials and structural parameters beforehand, and adjusting photonic structures afterwards.



Schematics of and artificial neural network that can design structural parameters and material simultaneously. When desired optical properties (electric/magnetic dipole spectrum) is inputted, each thickness and types of materials of the three-layer core-shell nanoparticle are provided as output. Credit: POSTECH

Prof. Rho and his group taught an AI system to design arbitrary photonic structures and gave additional level of freedom of the design by categorizing types of materials and adding them as a design factor, which made it possible to design appropriate materials for relevant optical properties. Analysis of metamaterials obtained through this design method revealed that they had identical optical properties predicted by the artificial neural network.

The research team, who have published various research findings on the design of metamaterials and optics theory, used the programming language Python. Their design method is revolutionary in many ways. First of all, it significantly reduced the time needed to design photonic structures. It allows various designs of new metamaterials because scientists are no longer limited to conducting empirical designs to obtain results.

The resulting metamaterials can be utilized in display, security, and military technologies. In this regard, introduction of AI to the design method is expected to make important contributions to the technological development of metamaterials.

Lead researcher Prof. Junsuk Rho said, "Our research was successful in bringing a higher degree of freedom to design, but the new system still requires users to input certain problem settings at the beginning. It sometimes produced untenable designs, and therefore made it impossible to produce desired metamaterials. So I'd like to take our findings a step further by developing a complete design method of metamaterials using AI. Also, I'd like to make innovative and practical metamaterials by training AI with reviews of the design constructed in consideration of final products."

More information: Sunae So et al, Simultaneous Inverse Design of Materials and Structures via Deep Learning: Demonstration of Dipole Resonance Engineering Using Core–Shell Nanoparticles, *ACS Applied Materials & Interfaces* (2019). DOI: 10.1021/acsami.9b05857

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