Microstructural improvements enhance material properties

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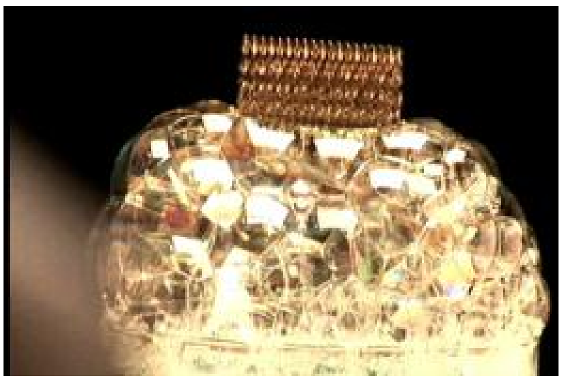

DARPA's Materials with Controlled Microstructural Architecture program combines engineering principles developed for large structures with emerging fabrication techniques to engineer and control the architecture of a material's microstructure and develop materials with tailored properties.

Exquisite buildings like the Eiffel Tower were made possible because of advances in structural engineering design methods. Truss structures, like the Eiffel Tower, are highly efficient; they can carry the same loads as solid structures, but at approximately one tenth of the weight. This weight and strength advantage is also what enabled the dramatic increase in building heights between 1885 and 1930, when buildings went from an average of ten stories to more than 100 stories, as epitomized by the Empire State Building. With its novel structural engineering, construction of the Eiffel Tower ushered in the age of the skyscraper.

Structural engineering is only part of the story, however. Drilling down a level to the materials that make up a structure, there is room again for dramatic improvements in strength, weight and other properties. With current technologies, materials are generally made using bulk processing methods. Bulk processing limits material properties because it provides insufficient control of the morphology, or form, within a material's microstructure. The microstructure refers to the arrangement of the constituents that make up a material at the microscopic (material grain) level. The lack of full control in the microstructure allows for flaws in materials. However, if the limitations of bulk processing can be overcome, the range of material properties available might be greatly increased.

DARPA's Materials with Controlled Microstructural Architecture (MCMA) program seeks these kinds of breakthroughs. In an attempt to overcome the limitations of bulk processing and achieve its goals, MCMA is combining engineering principles developed for large structures with emerging fabrication techniques to engineer and control the architecture of a material's microstructure down to the micron level. This control allows researchers to develop materials with greatly enhanced properties. For instance, as demonstrated in the video below, DARPA was able to construct a material so light that it can rest atop a bubble. MCMA researchers are working toward the goal of developing a material that is as strong as steel, but as light as a plastic. To do so, they are exploring the full range of properties that can be manifested as functions of truss design and weight in a material's microstructure.

DARPA has also developed lightweight materials that can absorb energy without failing, or breaking. As shown in the following video—previously released in conjunction with a journal article on ultralight metallic microlattices—the nickel microtruss structure can achieve a 40% strain level without collapsing; in fact, it fully recovers its form. DARPA is exploring how much strength and energy absorption can be combined in the same material without damaging it. The ultimate objective of the MCMA program is to be able to develop materials in the future with properties tailored to meet specific mission requirements.

More information: Ultralight Metallic Microlattices. Schaedler, et al. *Science* 18 November 2011: 962-965. DOI:10.1126/science.1211649

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