2-D MATERIALS

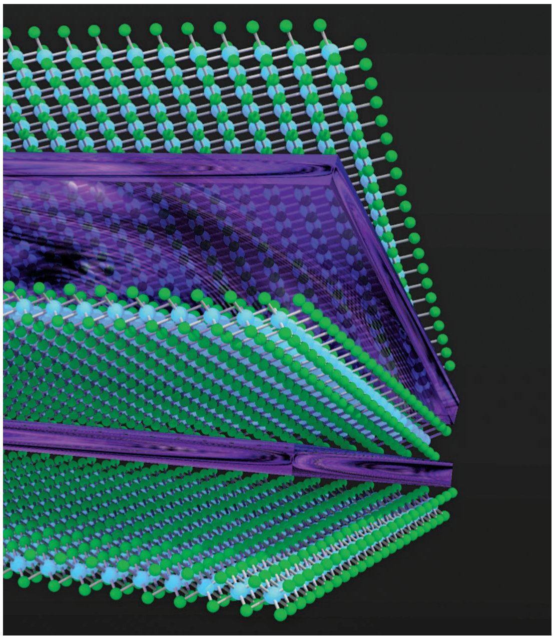
Electrides join the 2-D materials club

Exfoliating nanosheets from the layered ionic solids may open door to electronics applications

Thanks to a simple exfoliation process, an unusual class of ionic solids known as electrides has joined the growing ranks of two-dimensional materials (*J. Am. Chem. Soc.* 2016, DOI: 10.1021/jacs.6b10114). The availability of the highly conductive material in nanosheet form may lead to applications in electronics and chemical synthesis.

Electrides are exotic materials that include layered ionic solids in which planes of atoms are separated by sheets of delocalized electrons. Also known as a "2-D electron gas," the charged sheets endow electrides with high electrical conductivity—higher than graphene. The electrons could also make the materials strong reducing agents and useful in other ways.

One way to put those properties to use would be to expose the electron layers by forming ultrathin electride sheets in which the electrons reside at or near the surface. Theoretical studies indicate that nanometer-thin sheets of electrides should be stable. But researchers have been unable to prepare electrides in that form.



Ca_2N, an electride, consists of layers of calcium and nitrogen atoms (green and blue) separated by layers of electrons (purple).

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Until now, that is.

Daniel L. Druffel, Scott C. Warren, and coworkers at the University of North Carolina, Chapel Hill, synthesized bulk crystals of the electride Ca_2N by reacting Ca_3N_2 with calcium metal. Then the team searched for ways to exfoliate the crystal layers, including sonicating the material in solvents.

The researchers evaluated 30 solvents, but most were unusable for liquid exfoliation. For example, the team found that alcohols and other protic solvents reacted vigorously with Ca_2N, forming $Ca(OH)_2$. Ketones, aldehydes, and nitriles decomposed the electride. And although benzene and other nonpolar solvents didn't react with Ca_2N, they didn't form stable suspensions of nanosheets.

But a handful of solvents, including 1,3-dioxolane, dimethyl carbonate, and dimethoxyethane did the trick. The team finds, for example, that 1,3-dioxolane exfoliates Ca_2N thoroughly, yielding nanosheets that remain stable in the solvent and in a nitrogen atmosphere for at least one month. Microscopy and spectroscopy analyses indicate that the exfoliated flakes are crystalline and metallic, suggesting that the electron sheets are preserved in the 2-D form of the material.

Ca_2N is easily oxidized, and its sensitivity to water and oxygen has made it difficult to exfoliate for applications, says Hideo Hosono, an electride specialist at Tokyo Institute of Technology.

By examining a large number of solvents, the UNC team succeeded in coming up with a simple exfoliation method, Hosono adds. "This is a surprising finding that demonstrates the power of chemistry. Various opportunities for application can be expected from this finding," he says. The researchers note that they are now working with the Honda Research Institute to test the feasibility of Ca_2N in next-generation batteries.—MITCH JACOBY