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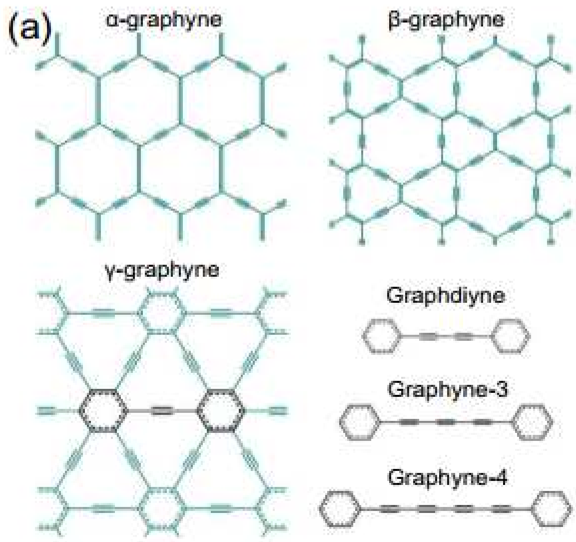
How Carbon Wonder-Materials Are Promising To Revolutionise Desalination

Graphyne sheets could filter salt from seawater at rates several orders of magnitude faster than conventional desalination techniques, say Chinese researchers



Rapid population growth as well as the agriculture, industry and pollution that goes with it has put huge pressure on our planet's freshwater resources. Fresh drinking water is a luxury in many parts of the world.

One of the most promising solutions to this problem is desalination–the removal of salts from seawater to produce fresh water. This has never been widely used because it is hugely energy intensive and inefficient.

Conventional desalination plants that rely on reverse osmosis require a massive 1.5 kiloWatt-hours of electricity to produce 1 tonne of freshwater. Clearly a better approach is needed.

Today, Wanlin Guo and friends at Nanjing University of Aeronautics and Astronautics in China say they have identified just such a better way. The new technique involves a material known as graphyne, a two-dimensional sheet of carbon atoms connected together much like graphene but with an altered structure because of double and triple bonds in certain places.

Graphyne is interesting because these double and triple bonds create holes between the carbon atoms that are large enough for water molecules to pass through. However, these holes are not big enough for sodium and chloride ions, which are larger because they attract a shell of water molecules since they are charged.

Graphyne can form in several configurations known as α-graphyne, β-graphyne, graphyne-3 and so on. Wanlin and co have created a computer simulation of the way that these membranes allow water molecules to pass through while sieving the various types of ions found in seawater.

Their conclusions are promising. They say that while water molecules can move freely back and forth through the holes in graphyne, none of the ions they simulated could pass through at all.

According to their calculations, a water molecule has to cross an energy barrier of less than 2 kcal/mol to pass through graphyne. By contrast, the energy barriers opposing the passage of sodium, potassium and chloride ions are in the region of 10 kcal/mol. And doubly charged ions such as magnesium and calcium face energy barriers as high as 60 kcal/mol.

“None of these ions can permeate through α-graphyne, β-graphyne and graphyne-3,” they say.

What’s more, Wanlin and co say that water passes through graphyne at a rate some two orders of magnitude faster than through the polymer membranes used in conventional reverse osmosis techniques.

There’s a caveat, of course. Nobody has ever been able to make graphyne of the type that these guys have simulated.

That may change in the near future. A couple of years ago, a team of Chinese chemists grew a different version of graphyne on a copper substrate, the first time that any type of graphyne had been synthesised.

So an important question is first whether this membrane material can actually be synthesised and whether it can be done on an industrial cost-effective scale. That’s no small challenge.

In the meantime, desalination is set to improve thanks to another carbon wonder material. Earlier this year, researchers from the aerospace giant Lockheed Martin announced that they had punched holes in sheets of graphene to produce a molecular sieve that removes sodium and chloride ions from seawater. This, they said, could desalinated seawater much more quickly and cheaply than existing methods.

Significantly, these guys had manufactured this stuff in the lab and were working on a way of producing it on an industrial scale. They have even patented the material and trademarked a name for it: Perforene.

While acknowledging the advantages of this approach, Wanlin and co say that one of the problems with creating nanopores in graphene sheets is ensuring that the holes are all of the same size and that the edges of the pores are properly treated to prevent them reacting spreading in unwanted ways.

By contrast, graphyne requires no modification once it has been synthesised since the required holes are a natural part of its structure.

What's clear is that these new materials will make desalination vastly more efficient. Lockheed Martin's new material has yet to appear on the market. When and if it does, it will be fascinating to see whether there is a graphyne competitor anywhere on the cards.

Ref: arxiv.org/abs/1309.0322: Exceptionally Fast Water Desalination at Complete Salt Rejection by Pristine Graphyne Monolayers