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PROTON TRANSPORT MEMBRANES - SIEVING HYDROGEN ISOTOPES THROUGH 2D CRYSTALS

A novel approach in which hydrogen isotopes may be selectively isolated by filtration

BACKGROUND

Hydrogen, the most abundant element in the universe, has a variety of potential applications including its use in fuel cells, rocket fuel and numerous chemical reactions. The heavier isotopes of hydrogen, deuterium and tritium, have other applications which include nuclear fusion and fission reactions. However, the methods that are currently used to selectively isolate the isotopes of hydrogen are extremely energy intensive. As a result, novel approaches of isolating hydrogen and its isotopes could be of significant interest to a number of industries.

Typically, defect free single layer graphene is impermeable to all gases and liquids. However, it was recently discovered that 2D monolayers made from materials such as graphene are capable of allowing thermal protons, i.e hydrogen ions, to permeate their crystalline surface. The ability to exploit this characteristic of 2D materials could therefore represent a novel approach in which hydrogen isotopes may be selectively isolated by filtration.

THE TECHNOLOGY

This technology builds upon the discovery that 2D materials are capable of filtering hydrogen ions. The technology utilises graphene and other 2D materials such as hexagonal boron nitride (hBN), molybdenum disulfide (MoS_2) and tungsten disulfide (WS_2) that are coated as monolayers onto a proton conducting polymer such as Nafion. At room temperature, the technology facilitates a separation factor of ~10 for deuterium and ~30 for tritium, which represents an effective sieving capacity. It has also been demonstrated that this technology is compatible with CVD grown graphene, which is a reasonably cheap and scalable graphene production method.

Therefore, this technology represents an effective, scalable and commercially viable alternative to traditional hydrogen isotope separation processes.

KEY BENEFITS

- The membranes described in this technology can be made significantly thinner than traditional membranes, reducing electrical resistance and improving efficiency
- These membranes retain the exceptional mechanical qualities of graphene, making it suitable for use in applications in which mechanical strength is important
- Protons and deuterons can permeate the membrane under ambient conditions, eliminating the need to add additional thermal energy
- Protons and deuterons are able to permeate the membrane whilst water (or any other species) is unable to
- The compatibility of this technology with reasonably cheap CVD-grown graphene reduces manufacturing costs and facilitates improved scalability

APPLICATIONS

Potential applications of this technology include:

- Its incorporation into hydrogen fuel cell technologies as a thermally stable proton membrane that prevents fuel crossover and fuel poisoning
- The development of devices that harvest or separate hydrogen from shale gas, natural gas, waste gas mixtures or the atmosphere
- Its incorporation into processes that require the enrichment of protons, deuterons and tritons e.g. the production of heavy or light water. Such an application would be of significant interest to companies in the energy and nuclear sectors
- Its incorporation into other technologies requiring atomically thin proton conductors
- The development of drinking water filtration devices that facilitate the removal of the heavier isotopes of hydrogen from water, which has been linked to healing benefits in cancer patients
- Its inclusion in novel sensing, detection or measurement applications

INTELLECTUAL PROPERTY

Patent applications have been filed to protect this technology, and worldwide protection is being pursued.

RELEVANT PUBLICATIONS

Proton transport through one-atom-thick crystals.
S. Hu, M. Lozada-Hidalgo, F. C. Wang, A. Mishchenko, F. Schedin, R. R. Nair, E. W. Hill, D. W. Boukhvalov, M. I. Katsnelson, R. A. W. Dryfe, I. V. Grigorieva, H. A. Wu & A. K. Geim
doi:10.1038/nature14015

Sieving hydrogen isotopes through two-dimensional crystals.
M. Lozada-Hidalgo, S. Hu, O. Marshall, A. Mishchenko, A. N. Grigorenko, R. A. W. Dryfe, B. Radha, I. V. Grigorieva, A. K. Geim.
doi:10.1126/science.aac9726

Scalable and efficient separation of hydrogen isotopes using graphene-based electrochemical pumping.
M. Lozada-Hidalgo, S. Zhang, S. Hu, A. Esfandiar, I. V. Grigorieva, A. K. Geim.
doi:10.1038/ncomms15215

OPPORTUNITY

There are opportunities for partnership and collaboration to further develop and commercialise this technology.

UMIP REFERENCES

20140342, 20150295.

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