Graphene Filter To Reduce The Cost Of Nuclear Power

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Abstract-Nuclear Energy is one of the resources used to generate electricity. The production of electricity from Nuclear Energy is a very energy intensive and tedious job as every nick and corner of the plant there has to people/engineers responsible for every part of the plant to work correctly and safely according to the requirement. The nuclear fission and fusion reactions are responsible for the nuclear energy and also the nuclear waste which is hazardous to the surrounding environment if not dealt properly. Hard water plays a major role in this aspect as it behaves as a coolant and also a moderator to the nuclear reactors. The people of the University of Manchester have made experiments to demonstrate us a new method to sieve out the isotopes of Hydrogen using Graphene as a filter which is easy and convenient. This method if implemented can save huge amount of investments and also space.

Index Terms- Nuclear fission, Girdler Sulphide process, Graphene filter.

1. INTRODUCTION

Electricity is a need to everyone and everything in the present, past and the future. It's been about a century of human civilization living with electricity and evolving together. Now and for the future generation electricity poses a greater demand and also an aid to human society across the world. Generation of the same is done by various fuels and most of them may or may not be present in the future.One way of production of electricity is by nuclear energy. Nuclear energy is a thermal energy produced by either fission or fusion reaction of atomic materials. In 2011 nuclear power provided 10% of the world's electricity. In 2007, the International Atomic Energy Agency (IAEA) reported there were 439 nuclear power reactors in operation in the world, operating in 31 countries. The alpha of production of electricity may not be the nuclear power but, the near future generations may have to depend on them as they are not as fast depleting as the fossil fuels are. The fusion and fission reaction happens between a radioactive element and the waves are dangerous if left unchecked, hence the plant itself becomes isolated from the world and also it needs high quality of treatment. In nuclear power plant one has many units to concentrate about. The nuclear waste and the production of heavy water is an issue in the current generating stations where the idea of Graphene filter comes about.

Nuclear power is the use of nuclear reactions that release nuclear energy to generate heat, which most frequently is then used in steam turbines to produce electricity in a nuclear power plant. The term includes nuclear fission, nuclear decay and nuclear fusion. Presently, the nuclear fission of elements in the actinide series of the periodic table produce the vast majority of nuclear energy in the direct service of humankind, with nuclear decay processes, primarily in the form of geothermal energy, and radioisotope thermoelectric generators, in niche uses making up the rest.

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Nuclear fission is either a nuclear reaction or a radioactive decay process in which the nucleus of an atom splits into smaller parts (lighter nuclei).Nuclear fission of heavy elements was discovered on December 17, 1938 by German Otto Hahn and his assistant Fritz Strassmann, and explained theoretically in January 1939 by Lise Meitner and her nephew Otto Robert Frisch. Frisch named the process by analogy with biological fission of living cells.

Fission is a form of nuclear transmutation because the resulting fragments are not the same element as the original atom. The two nuclei produced are most often of comparable but slightly different sizes, typically with a mass ratio of products of about 3 to 2, for common fissile isotopes. Most fissions are binary fissions (producing two charged fragments), but occasionally (2 to 4 times per 1000 events),three positively charged fragments are produced, in a ternary fission. The smallest of these fragments in ternary processes ranges in size from a proton to an argon nucleus.

The conversion to electrical energy takes place indirectly, as in conventional thermal power stations. The fission in a nuclear reactor heats the reactor coolant. The coolant may be water or gas or even liquid metal depending on the type of reactor. The reactor coolant then goes to a steam generator and heats water to produce steam. The pressurized steam is then usually fed to a multi-stage steam turbine. After the steam turbine has expanded and partially condensed the steam, the remaining vapor is condensed in a condenser. The condenser is a heat exchanger which is connected to a secondary side such as a river or a cooling tower. The water is then pumped back into the steam generator and the cycle begins again. The water-steam cycle corresponds to the Rankine cycle.

Heavy water is used in certain types of nuclear reactors, where it acts as a neutron moderator to slow down neutrons so that they are more likely to react with the fissile uranium-235 than with uranium-238, which captures neutrons without fissioning. The CANDU reactor uses this design. Light water also acts as a moderator but because light water absorbs more neutrons than heavy water, reactors using light water for a reactor moderator must use enriched uranium rather than natural uranium, otherwise criticality is impossible.

Heavy water is extracted from Girdler sulfide process, also known as the Geib–Spevack (GS) process, is an industrial production method for filtering out of natural water the heavy water (deuterium oxide = D_2O) which is used in particle research in nuclear reactors (as a coolant and moderator) in which case they are termed 'heavy water reactors' and in deuterateddrugs.Karl-Hermann Geib and Jerome S. Spevack independently, and in parallel, invented the process in 1943 and its name derives from the Girdler company, which built the first American plant using the process. The method is an isotopic exchange process between H2S and H2O ("light" water), that produces heavy water over several steps. It is a highly energy intensive process. Seawater contains 180 parts per million of D_2O.

2. The Girdler Sulfide (GS) Process And Working

Each of a number of steps consists of two sieve tray columns. One column is maintained at 30 °C and is called the cold tower and the other at 130 °C and is called the hot tower. The enrichment process is based on the difference in separation between 30 °C and 130 °C.

The process of interest is the equilibrium reaction,

$$H2O + HDS \rightleftharpoons HDO + H2S$$

At 30 °C, the equilibrium constant K = 2.33, while at 130 °C, K = 1.82. This difference is exploited for enriching deuterium in heavy water.[6]

Hydrogen sulfide gas is circulated in a closed loop between the cold tower and the hot tower. Demineralised and deaerated water is fed to the cold tower where deuterium migration preferentially takes place from the hydrogen sulfide gas to the liquid water. Normal water is fed to the hot tower where deuterium transfer takes place from the liquid water to the hydrogen sulfide gas. An appropriate "cascade" setup accomplishes enrichment: "enriched" water is fed into the cold tower and is further "enriched". Using one tower instead of a cascade is possible, but in practice it never occurs, as the tower size and process inventory would be much larger.

Normally in this process, water is enriched to 15–20% D2O. Further enrichment to "reactor-grade" heavy water (> 99% D2O) is done in another process, i.e. distillation or electrolysis. As this process is highly energy intensive which requires huge gallons of water to be fed. The process requires 340,000 tonnes (370,000 short tons) of feed water to produce 1 tonne (1.1 short tons) of heavy water. Energy required to extract the same through graphene filter is easier and requires less energy.

"Graphene" is a combination of graphite and the suffix-ene, named by Hanns-Peter Boehm, who described single-layer carbon foils in 1962.Graphene is an allotrope of carbon in the form of a two-dimensional, atomic-scale, honey-comb lattice in which one atom forms each vertex. It is the basic structural element of other allotropes,

including graphite, charcoal, carbon nanotubes and fullerenes. It can also be considered as an indefinitely large aromatic molecule, the ultimate case of the family of flat polycyclic aromatic hydrocarbons. Graphene has a theoretical specific surface area (SSA) of 2630 m^2/g. This is much larger than that reported to date for carbon black (typically smaller than 900 m^2/g) or for carbon nanotubes (CNTs), from ≈100 to 1000 m^2/g and is similar to activated carbon.

Graphene is a crystalline allotrope of carbon with 2-dimensional properties. Its carbon atoms are densely packed in a regular atomic-scale chicken wire (hexagonal) pattern. Each atom has four bonds, one σ bond with each of its three neighbors and one π-bond that is oriented out of plane. The atoms are about 1.42 Å apart. Graphene's hexagonal lattice can be regarded as two interleaving riangular lattices. This perspective was successfully used to calculate the band structure for a single graphite layer using a tight-binding approximation.

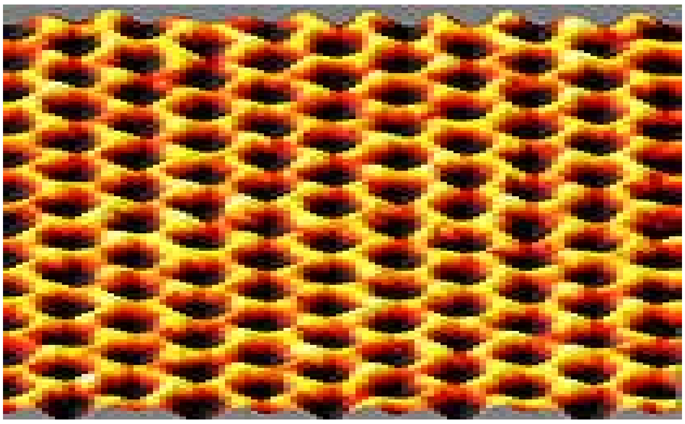

fig. Scanning probe microscopy image of grapheme

3. Sieving Hydrogen Isotopes Through Two-Dimensional Crystal (Graphene)

The **experiment** on the two dimensional crystal was demonstrated which has a greater and a much less energy intensive approach to sieve the hydrogen isotopes. Conducted by the fellow scientists of University of

Manchester, they clearly stated the tremendous approach towards the proposed system. The Manchester researchers experimented to see if the nuclei of deuterium, deuterons, could pass through the two-dimensional (2-D) materials graphene. The existing theories seemed to suggest that the deuterons would pass through easily. But to the surprise of the researchers, not only did the 2-D membranes sieve out the deuterons, but the separation was also accomplished with a high degree of efficiency. Unlike conventional membranes used for sieving atomic and molecular species, monolayers of graphene exhibit subatomic selectivity. Investigating whether deuterons— nuclei of the heavier hydrogen isotope, deuterium (D)—can pass through atomically thin crystals is of interest for elucidating the proton transport mechanism. If the 2D membranes can distinguish between the two nuclei (hydrons), this would also be of interest for applications, as hydrogen isotopes are important for various analytical and tracing technologies, and heavy water is used in huge quantities by nuclear fission plants.

4. Working

Grapheme was mechanically exfoliated and suspended over micrometer-sized holes etched in silicon wafers (fig. S1). To measure 2D crystal hydron conductivity, both sides of the resulting membranes were coated with a proton-conducting polymer - Nafion - and electrically contacted with Pd electrodes that converted electron into hydron flow. The measurements were performed in an atmosphere of either H2-Ar/H2O or D2-Ar/D2O in 100% humidity at room temperature. The different atmospheres turned Nafion into a proton (H-Nafion) or deuteron (D-Nafion) conductor with little presence of the other isotope

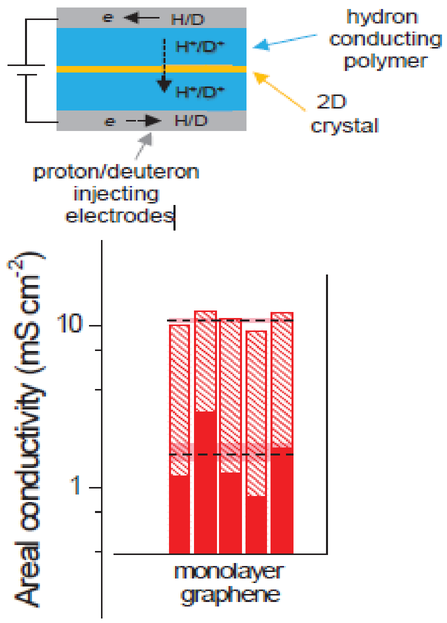

fig. Schematics of the experimental setup. Pd electrodes supply protons or deuterons into H- or D-Nafion.2D crystals serve as barriers for hydrons and Proton and deuteron conductivities (shaded and solid bars, respectively) for the most hydron-conductive 2Dcrystals.

5. Results

The observed large a compares favorably with sieving efficiencies of the existing methods for hydrogen isotope separation. The high proton conductivity exhibited by graphene monolayer, comparable to that of commercial Nafion films, makes it potentially interesting for such applications.

In this respect, the increasing availability of graphene grown by chemical vapor deposition provides a realistic prospect of scaling up the described devices from micrometer sizes to those required for industrial uses.

Furthermore, we estimate the energy costs associated with this isotope separation method as ≈0.3 kWh per kilogram of feed water, appreciably lower than costs of the existing enrichment processes. All this comes on top of the fundamentally simple and robust sieving mechanism, potentially straightforward setups, and the need for only water at the input without the use of chemical compounds.

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