

**LITHIUM DOPED DOUBLE WALLED CARBON NANO-TUBE
ELECTRICITY STORAGE CELL**

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ABSTRACT

The described lithium doped double walled carbon nano-tube electricity storage cell would store electric power in a high capacity electricity storage cell for the purpose, among others, to power vehicles with the same energy storage capacity and the same energy/weight ratio as a tank of petroleum fuel.

The proposed cell is based on the hexagonal carbon structure of a carbon tube or nano-tube. However, lithium atoms are intercalated into the hexagonal carbon structure, replacing a layer of carbon atoms, so that the chemical formula for the molecule is Li_2C_2 . As the chemical bonds are weak there is capacity around the Lithium atoms for surplus electrons to congregate. This increases the electrical storage capacity of the carbon hexagonal structure.

As the lithium doped carbon hexagonal structure is physically weak, and its electrical conductance is reduced, these problems are removed by using a double walled nano-tube. Carbon tubes are physically strong and have high electrical conductance. It is proposed that the outer wall of the double-walled tube is the lithium doped and intercalated carbon hexagonal structure, providing the electrical storage and capacitance, while the inner wall of the double-walled tube is the un-doped carbon hexagonal structure providing the physical strength and the electrical conductance.

The purpose of this invention is to provide a high electrical capacity storage cell with a very high-power storage/volume ratio (at least approaching that of a tank of petroleum fuel), the ability to charge the device in a matter of minutes with no adverse consequences, safe long term storage of electric power, and the ability to slowly release this power under controlled circumstances. Such a device would be ideal to provide power for electricity powered vehicles, for instance.

The possible structure of this carbon/lithium double-walled nano-tube electric storage cell is very flexible. A wide variety of different electricity storage cells can be constructed using this basic structure of carbon/lithium double-walled nano-tubes.

LITHIUM DOPED DOUBLE WALLED CARBON NANO-TUBE ELECTRICITY STORAGE CELL

It is proposed to use double walled nano-tubes made of carbon and carbon-lithium to form an electricity storage cell .

The molecule carbon can be made to form layers, fibers or tubes, including nano-tubes, based on a hexagonal structure of carbon atoms one layer deep. This structure is essentially two dimensional, with each carbon atom connected to these others in a hexagonal pattern. This hexagonal structure of carbon atoms forms naturally as one carbon atom can attach to six others as its valance is six. A diagram showing such a structure is shown in **Figure 1**.

The hexagonal structure of carbon graphene layers, tubes, and fibers is well known and established and needs no further explanation here. Indeed, carbon fiber is manufactured in the hundreds of tons, and even carbon nano-tubes are now sold in ton lots. Graphene is a newer technology, but even that is becoming available in commercial lots. The technology for producing these products is well established.¹

It has been noted² that carbon tubes and graphene are excellent conductors of electricity with very low electrical resistance verging on superconducting levels. This is because it has been theorized that the extra electrons 'flow over' the surface of the carbon atoms, and do not have to dislodge electrons as they do when they flow through normal conductors such as copper.³

However little work appears to have been done to date on the capacitance characteristics of the hexagonal carbon layer.

Currently a major search is being conducted for devices which can store large quantities of electric power. The ideal is a very high-power storage/volume ratio (at least approaching the power storage/volume ratio of a tank of petroleum fuel), the ability to charge the device in a matter of minutes with no adverse consequences, safe long-term storage of electric power, and the ability to slowly release this power under controlled circumstances. Such a device would be ideal to provide power for electricity powered vehicles, for instance.

The best contenders for this storage device at the moment are the various lithium cells and capacitors. However, they are expensive, and suffer from defects such as gradual decline in storage ability and the generation of heat on charging and discharging.⁴

The proposed device also makes use of lithium, for the same reason it is used in other storage cells. This is because in a normal lithium storage cell, charged lithium ions move easily into or out of the carbon anode or cathode. This is called intercalation (insertion). This movement of the charged ions into and out of the cathodes is the reason why these cells store electricity.⁵

The advantage of holding lithium atoms in solid carbon, where they cannot move, is that the lithium atoms are already intercalated. All that moves are the electrons. Thus, this cell is much more efficient than the cell which depends on the movement of lithium ions.

Also, the proposed hexagonal carbon cell makes use of the excellent electrical conducting characteristics of a carbon hexagonal layer. It utilizes the fact that this layer, whether a flat layer or a tube has a 'cloud' of free electrons which move over the surface of the hexagonal layer. (See above).

The essential characteristic of this invention is that one carbon layer (of two carbon layers) is 'doped' with lithium. Lithium is inserted in the carbon hexagonal structure as shown in Figure 2. This process is called 'intercalation'.

As can be seen from **Figure 2**, the chemical formula of this product is Li_2C_2 . There is one lithium atom for every carbon atom. Each lithium atom is connected to and held by three carbon atoms. These connecting carbon atoms are connected to another carbon atom, thus forming a hexagonal structure. Effectively a row of carbon atoms in the hexagonal structure is replaced (intercalated) by a row of lithium atoms. Otherwise the hexagonal structure of the carbon atoms remains unchanged.

As a result of placing a row of lithium atoms into the hexagonal carbon structure there are free electron spaces in the molecular structure surrounding the lithium atoms. Free electrons, instead of flowing loosely over the surface of the hexagonal structure tend to congregate around the lithium atoms. These electrons are not tightly held and easily move in and out of the area around the lithium atom.

Thus, the insertion of lithium atoms increases the electrical storage capacity of the carbon hexagonal structure. The carbon-lithium structure is no longer a good conductor of electricity, but has been turned into a capacitor. There is a second pure carbon hexagonal layer that provides the conductance.

The degree of capacitance depends on the design of the electric storage cell, and the input voltage applied.

While lithium doped graphene layers can be produced and inserted into electrical storage devices, there is some concern regarding their structural integrity. Lithium will reduce the strength of the hexagonal structure compared to carbon. There is therefore a greatly increased probability of breaks in the hexagonal structure. If breaks occur, there will be breaks in the conduction of electrons, and past a certain point the ability of the device to charge or discharge will be severely curtailed. Given normal rough treatment, the life of a graphene device would be very limited.

There are also concerns regarding the low electrical conductance of a lithium-carbon hexagonal structure. The insertion of lithium into the structure significantly reduces the conductivity of the structure, reducing its usefulness as an electrical storage device. While a cell of lithium doped carbon layers will have a high capacitance, it will have low conductance, reducing the capability of the cell to let electricity enter and leave the cell.

As mentioned above, an additional layer of pure carbon graphene laid upon the lithium-carbon layer will improve conductance, but these two layers of graphene would be extremely fragile, and would not make a useful electricity storage cell.

However, carbon tubes, as apart from carbon layers, are extremely strong. It is very difficult to break or even bend them. This structural characteristic is used to make carbon-reinforced products very strong, and increase the strength/weight ratio.

Lithium atoms can also be inserted into the same positions on the surface layer of a carbon tube as a graphene layer. It would thus have the same characteristics of high electrical storage of electrons around the lithium atoms. Indeed, as it has been noted⁶ that the tubes themselves have a high capacity to store electric charge on the surface, the carbon tube is likely to have much higher electric storage capacity than a graphene layer.

However, as with the graphene layer, the insertion of lithium atoms in the hexagonal carbon structure of the carbon tube reduces the tube's structural integrity, thus increases the chance of breakages, and this reduces electrical conduction in the electrical storage device.

However, carbon tubes can be manufactured with two layers. See **Figure 3**. This is the so-called 'Double Walled Tube'. One wall of hexagonal carbon atoms lies on top of an inner wall hexagonal carbon atoms.

Now, the double walled structure is very useful as it adds strength to a lithium doped carbon tube. If the lithium doped tube is the outer wall, and it lies on an inner wall of un-doped hexagonal carbon, the inner wall will provide strength to the structure, and also the necessary the electrical conductance, while the outer wall provides the electrical capacitance. Alternatively, it might be found that if the lithium doped tube is the inner wall, the structure of the double tube might be slightly stronger. Aside from slight differences in capacitance, there is very little difference in using either method.

It is proposed that these carbon tubes be inserted into an insulated box, so that the tubes lie parallel along this length, lying side by side and on top of each other. Both ends of the box are made of conducting material, onto which the ends of the carbon tubes touch on the inside. See **Figure 4**. The tubes are charged by simply charging the conducting ends of the box, along the same lines as a normal electric storage cell. The amount of electricity stored in the cell depends on the voltage of charge applied. Gradual discharge is also from the conducting ends of this box, and the electricity is led through a device which controls this discharge.

This concept of a double walled nano-tube electric storage cell has been rejected as a patent, as it was deemed by the patent examiner that the concept was not novel. Rather than fight this decision, I have decided to submit this concept to an open forum for the purpose of public benefit.

SUMMARY

The invention can be described as follows:

- 1 The aim of the device is to provide an electrical storage device with a very high-power storage/volume ratio (at least approaching that of a tank of petroleum fuel), with the ability to charge the device in a matter of minutes with no adverse consequences, with the ability to maintain safe long-term storage of electric power, and with the ability to slowly release this power under controlled circumstances. Such a device would be ideal to provide power for an electricity powered vehicles, for instance.
- 2 The device is based on the hexagonal carbon structure which forms itself into a two dimensional layer, one layer thick. Such a hexagonal carbon structure can be formed into tubes or tubes of a very small diameter, nano-tubes. These tubes can be currently manufactured to indefinite length.
- 3 These carbon tubes have a very high electrical conductance, much higher than that of copper. In this hexagonal structure a row of carbon atoms can be replaced or intercalated with a row of lithium atoms. The chemical structure of this carbon-lithium hexagonal layer is Li_2C_2 .
- 4 As a consequence of inserting the Lithium atoms into the carbon hexagonal structure the electrical storage capacitance is greatly increased, as electrons tend to congregate around the lithium. Electrical storage cells made from lithium intercalated hexagonal carbon would make excellent electrical storage cells, with a very high electrical capacitance.
- 5 Such cells would be a vast improvement on lithium ion cells which depend on the movement of the lithium ion into and out of the carbon cathodes and anodes. The proposed lithium intercalated electrical storage cell would depend solely on the movement of electrons flowing to and from the area around the fixed lithium atoms.
- 6 However, a lithium intercalated hexagonal carbon structure would be physically weaker than a pure carbon hexagonal structure, as the lithium-carbon bonds are weaker than carbon-carbon bonds.
- 7 Also, the electrical conductance of the lithium intercalated hexagonal structure is reduced compared to the pure carbon hexagonal structure.
- 8 To remedy this, it is proposed to use double walled carbon nano-tubes. The outer wall of the nano-tube is made of the lithium intercalated carbon hexagonal structure, while the inner tube is a pure carbon hexagonal structure. This arrangement can be reversed with little difference in the outcome.
- 9 The outer wall of lithium intercalated carbon hexagons is the electrical storage part of the double walled structure, while the inner wall of pure carbon hexagons provides both strength and electrical conductance.
- 10 It is proposed that these carbon tubes be inserted into an insulated box, so that the tubes lie parallel along this length, side by side. Both ends of the box is made of conducting material, onto which the ends of the carbon nano-tubes touch or are attached on the inside. The tubes are charged by simply charging the conducting ends of the box. The amount of electricity stored depends on the voltage of charge applied. Gradual discharge is also from the conducting ends of this box, and the electricity is led through a device which controls this discharge.

11 The shape of this insulated box is very flexible, and can be shaped to be thin and flat, so that it can conform to the floor of a motor vehicle, for instance. Other electricity storage cells of this type can be manufactured in a wide variety of sizes and shapes. A major advantage of this double-walled carbon/lithium nano-tube electric cell is that its structure is very flexible.

12 This concept of a double walled nano tube electric storage cell has been rejected as a patent, as it was deemed by the patent examiner that the concept was not novel. Rather than fight this decision, I have decided to submit this concept to an open forum for the purpose of public benefit.

REFERENCES

- 1 <http://www.fltechnical.net/articles/B>
http://en.wikipedia.org/Carbon_fiber_reinforced_polymer
http://en.wikipadia.org/wicki/Carbon_nanotube
2. http://en.wikipedia.org/wiki/Carbon_nanotubes
- 3 Carbon tubes are excellent conductors of electricity due to 'de-localisation' of electrons.
<Http://en.wikipedia.org/wiki/Graphite>

For a given (n,m) carbon hexagonal matrix, if $n=m$, the nanotube behaves as if it is metallic. In theory, metallic behaving nano-tubes cab carry an electric current of 4×10^9 Amps/ Cm^2 , which is more than 1000 times greater than metals such as copper. Multiwalled nano tubes show superconductivity.
- 4 http://en.wikipedia.org/wiki/Lithium_ion_battery
The advantage of holding lithium atoms in solid carbon, where they cannot move, is that the lithium atoms are already intercalated. All that moves are the electrons. This is more efficient.
- 5 Lithium moves easily into the carbon anode or cathode. This is called intercalation (insertion). This allows movement of charged ions into the anode or cathode and and is the reason why these cells store electricity.
- 6 The MIT has shown that carbon nano tubes stores electric charge on its surface in its work on ultra-capacitors.

MIT LEES on Batteries: MIT Press Release 2006

http://en.wikipedia.org/wiki/Carbon_nanotubes

Figure 1

Carbon only Hexagonal Structure

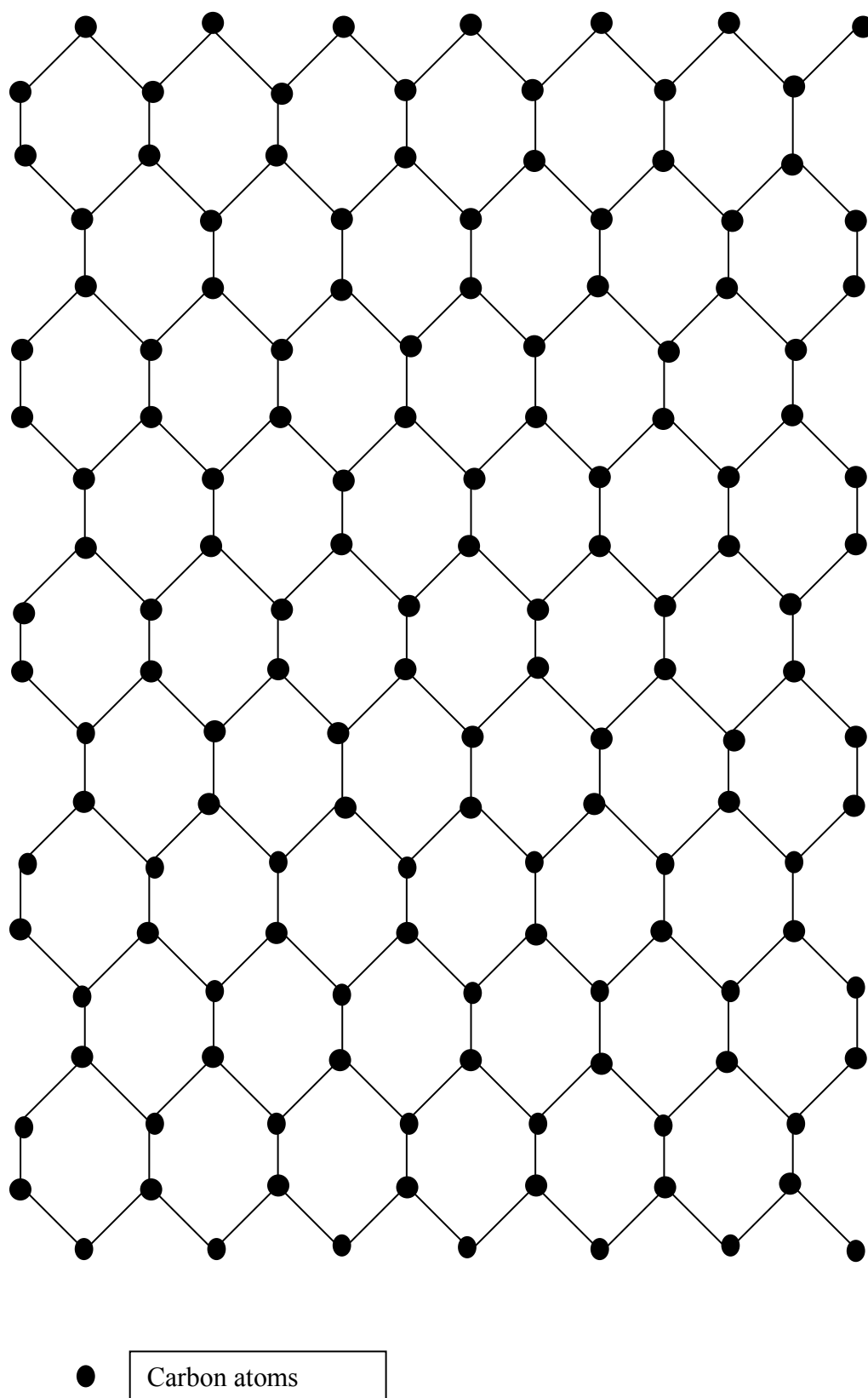


Figure 2

Carbon-Lithium Hexagonal Structure

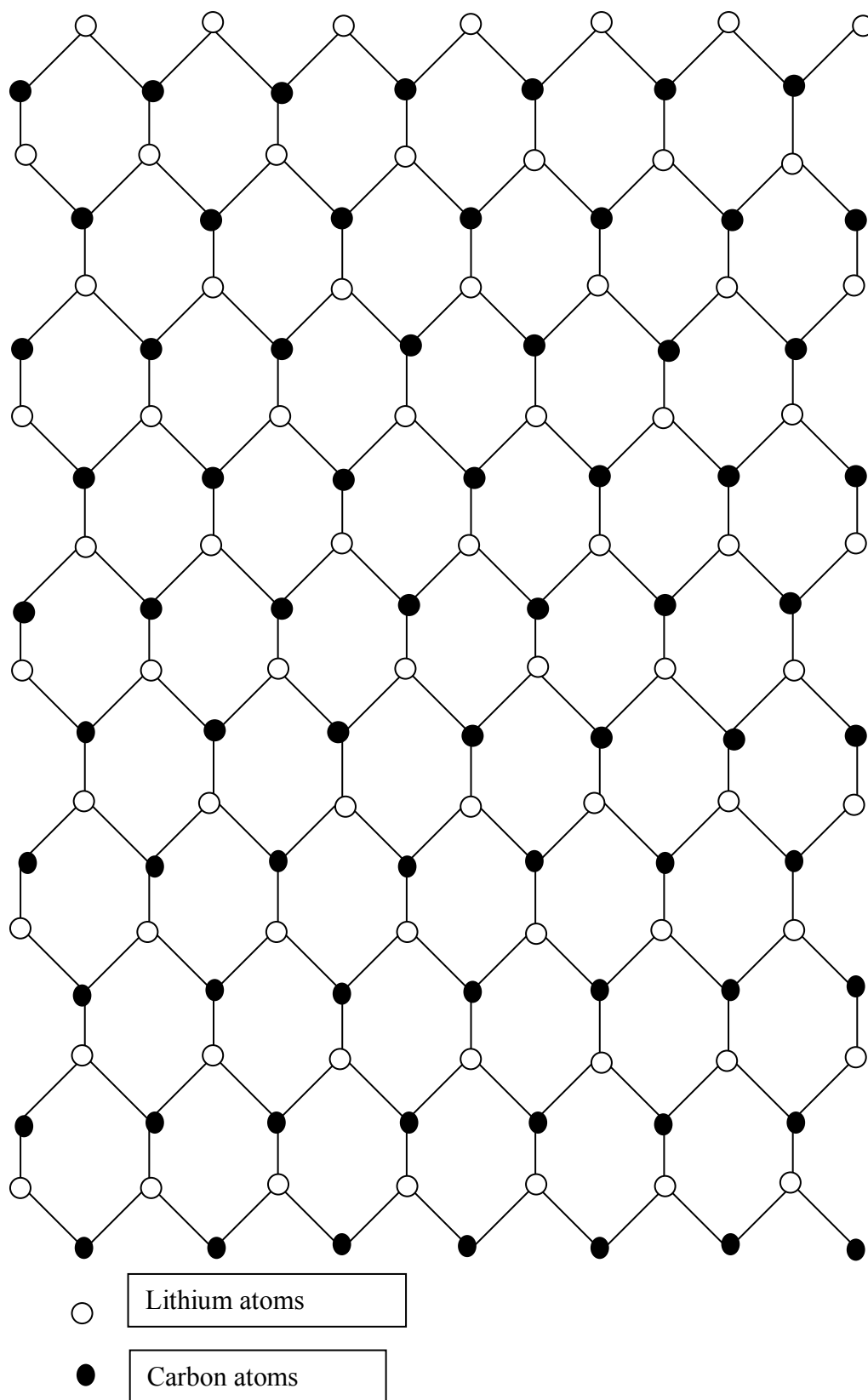


FIGURE 3

INNER AND OUTER TUBES OF HEXAGONALLY SPACED ATOMS – OUTER TUBE AN
HEXAGONAL MATRIX MADE OF ONLY CARBON ATOMS- INNER TUBE AN
HEXAGONAL MATRIX WITH AN EQUAL NUMBER OF CARBON AND LITHIUM ATOMS

DIMENSIONS SHOWN RELATE TO ONLY ONE OF MANY POSSIBLE SIZES OF TUBES

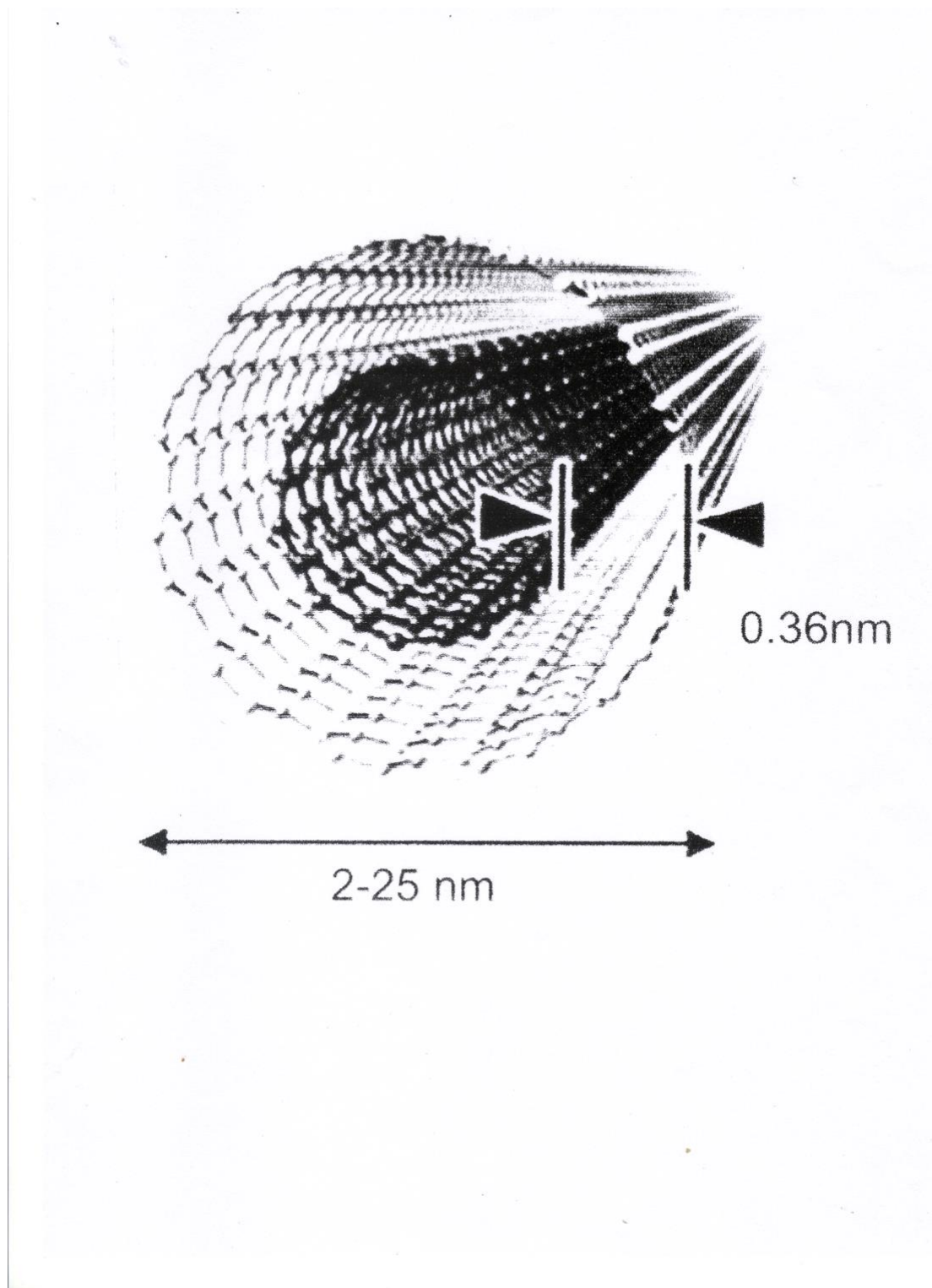


FIGURE 4

DIAGRAM OF AN INSULATED CONTAINER CONTAINING THE DOUBLE WALLED TUBES OF CARBON AND LITHIUM CARBIDE ARRANGED SIDE BY SIDE AND ON TOP OF EACH OTHER.

ALL THE SIDES OF THIS CONTAINER ARE INSULATED EXCEPT ONE SIDE THAT IS A CONDUCTOR.

ELECTRICAL
CONNECTION TO
GROUNDED
ELECTRICAL POWER
SOURCE DIRECT
CURRENT

ASIDE FROM THESE RESTRICTIONS THE CONTAINER CAN BE
ANY SHAPE SUITABLE TO
CONTAIN THE DOUBLE WALLED TUBES.

INSULATED SIDES OF A CONTAINER

CONDUCTING SIDE

DOUBLE WALLED TUBES – OUTER WALL CARBON,
INNER WALL LITHIUM CARBIDE. PLACED SIDE BY
SIDE AND ON TOP OF EACH OTHER, TOUCHING AND
ELECTRICALLY CONNECTED TO THE CONDUCTING
SIDE OF THE CONTAINER