Super-capacitor-like Structure for Fission-Fusion Direct Nuclear Energy Conversion

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ABSTRACT

Direct nuclear energy conversion system uses nano-hetero-structures that harvest the nuclear particles energy, charging a structure resembling a super-capacitor, that discharges releasing it as electric energy.

The nano-structure design uses heterogeneity, in order to create a super-capacitor like structure, generically called "CIci", where "C" is a conductive layer, made of a material with high electron availability, typically, but not limited to a high Z material, and "c" is a low electron availability material, simply a low Z material, or a combination of such. Specific insulators, also present as nano-layers, separate these two conductive layers.

Constructive variants use nano-layers, nano-beads or nano-structures like nano-tubes or nano-wires, each having their particularities. The theoretical energy conversion is very high, but there are various constructive issues that limit the total conversion efficiency. This process determines the maximum power density a structure may provide.

The use of the fission, fusion or mixed structures (hybrid rectors), provides energy on demand that is much better than the isotopic batteries, where these "CIci" structures might be successfully applied, but the energy depends on the natural decay of the isotopes combination used.

The system is in a conceptual stage, but shows obvious advantages, making it a strategic importance device.

Keywords: Nano-hetero-structure, fusion-fission, hybrid-reactors, direct-energy-conversion, knock-on-electrons

1 INTRODUCTION

Novel nuclear energy sources are based on new nano-hetero-structures, where special emphasis is given to direct energy conversion processes, i.e., the direct conversion of moving nuclear particle kinetic energy into elecricity.

Nuclear energy as we know it today is a technology that barely reached its late-infancy stage, and recently developed micro-nano-hetero-structures are giving a novel perspective to nuclear power, making possible the development of compact, solid state nuclear power systems.

There have been identified six major direction in nano-materials for nuclear energy, that might be applied jointly, resulting in complex systems with outstanding capabilities and performances.

The novel type of meta-material based on nano-hetero-structures may harvest the kinetic energy of the moving nuclear particles and efficiently convert in electricity.

2 NOVEL NUCLEAR POWER SOURCES

One of the solution for future nuclear power sources rests in developments in nano-materials technology, that may facilitate direct nuclear energy conversion into electric energy, in compact supercapacitor-like solid-state devices, which rely on fission, fusion, or nuclear decay, being generically called nuclear batteries.

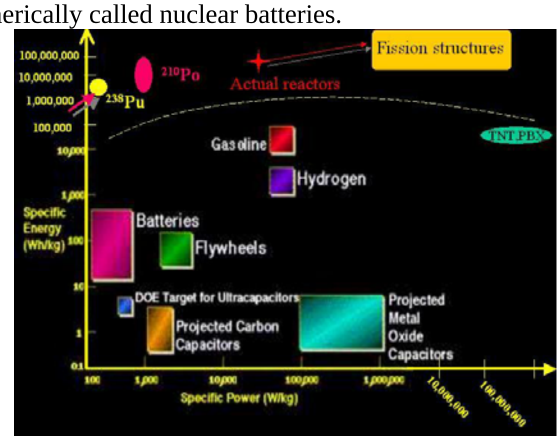

Fig. 1 – The specific performances of prezent power sources

The interest for the nuclear power sources is due to their high energy/mass ratio, that is by three orders of magnitude higher than the best chemical sources, as one can see from Fig. 1, being possible to have the same specific power or higher, rendering them as the most compact power sources.

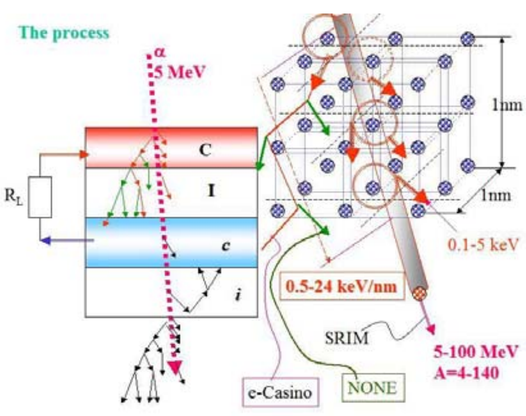

Fig. 2 – The physical principle of direct energy conversion is depicted.

The operation principle of such a solid-state battery is shown in Fig. 2, resembling a capacitor that is charged from the kinetic energy of moving particles and is discharged directly as electricity. The process relies on the interaction between a moving nuclear particle and the electrons on atomic orbitals, that are knocked-on and interacts with other electrons sharing the energy, and creating an electron shower. In a supercapacitor structure, with an enginered meta-material, it is possible to maximize the polarization effect due to selective collection of the electron on the negative foil-electrode, and create a usable voltage.

The solid-state battery consists of layered materials whose electronic shells are crossed by fast moving nuclear or atomic particles. Such a particle could be a neutral atom or molecule, a fission product, an alpha particle obtained from fusion or nuclear decay, a beta particle (electron, positron), a (gamma) photon, or a neutron. As soon as the particle interacts with the battery material, it gets into a dynamic ionization state [1], shown by the cylindrical gray tube. The particle interacts with the electronic shells by knocking-off electrons, shown by the red arrows that are directed in the direction of motion of the particle. These ejected electrons further interact with other electrons, ejecting them from their orbits, as indicated by the green arrows. The final result is a bulk electron current that has less energy than the initial knock-off electron energy.

If this process takes place inside a repetitive multi-layered capacitor, as shown in Fig. 1, left side, it might amplify the polarizing process thus enhancing the conversion of electron kinetic energy into electricity. Such a ”super capacitor” can be formed from nano-material layers containing a conductor C of high electron density with a thickess of several 10 nm. Intense electron currents will be generated during the sudden deceleration process from the deposited kinetic energy of the moving particle. The knock-on electrons may tunnel up to 100 nm inside the conductor material, followed by a thin layer I, of insulator material. Electrons tunnelthrough this layer with little interaction, and are eventually stopped into a layer of conductive material, c, of low electron density. This layer generates only a very small electron shower and is coated by another insulator layer I. This quadruple structure is repeated, and the number of these layers is large enough to ultimately bring the particle to rest within this lattice. The plot in the left of Fig. 1 shows the novel type of capacitor with its two conductive semi-conductor layers, C and c that are connected to the (external) load resistor RL, where layer c plot is negatively charged with respect to C. When this kind of novel energy conversion is applied to fission, e.g. a nuclear reactor, it may be possible to eliminate the complete thermo- electric energy conversion system, and thus reduce the size of the power station to the nuclear reactor itself together with only an interface needed for electrical output. The chart (right of Fig. 1) shows the performance of various power sources both in terms of power and energy density. It is obvious that nuclear power sources are delivering an energy output three orders of magnitude higher than any other known energy source.

Fig. 3 shows the voltage and current distribution inside the super-capacitor. The red layers, possibly made of gold, have a thickness of several tens nanometers and are the high electron conductor nano-layers. It is these layers that are generating the electron shower. These electrons, then, tunnel through the dielectric material and are stopped at the blue layers, which are made of low electron density material, like aluminum. Their thickness has to be large enough to reduce the tunneled electron curent, Id, (close) to zero, and thus this layer gets negatively charged. Furthermore, the insulator layers need to be thick enough to withstand the breakdown voltage Vbk that is higher than the operational voltage Vop.

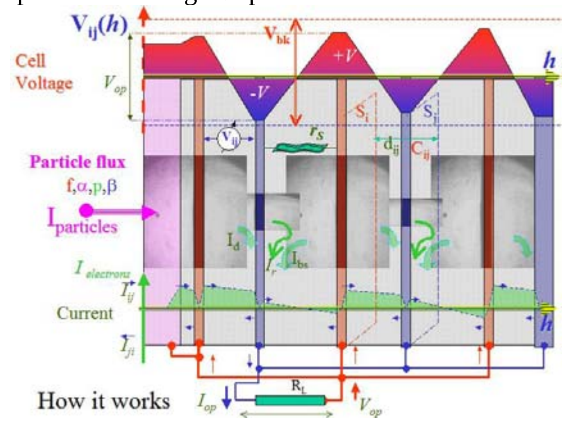

Fig. 3 shows the detailed structural assembly inside the prpoposed super-capacitor.

The capacitor foils are connected in parallel to the external load resistor RL (Fig. 1, upper right), extracting the current Iop at a voltage Vop. The power density depends on the power deposition of each particle in the respective layer as well as the number of particles stopped in that layer and, naturally, the efficiency of the energy conversion.

The energy conversion efficiency of these new materials will be larger than the efficieny obtainable from any of the current nuclear power plants, also including thermo-electric convertors with a conversion efficiency lower than 10%.

The direct energy conversion structure has several constructive variations, as shown in Fig. 4. It can be built from planar depositions (Fig. 2), but there is a disadvantage in that most of the heterogeneous structures deposited in such nano-layers possess the tendency to separate and precipitate, forming nano-beads at higher temperatures. This kind of structure modification limits the operation temperature of planar nano-structures, but there exist other structures (see below) were conceived that might successfully operate at higher temperatures.

Care must be taken when the dimension of the structure is decreased down to the nanometer range (Fig. 3 upper-left), because quantum effects start to dominate and the local material properties strongly differ from those of the bulk, giving rise to spherical charge reflection on a grapheme foil creating quasiparticles that are collective excitation within a material that behaves like a fundamental particle, i.e. a plasmon or a dropleton which comprises a small number of electrons and holes that are bound together.

The upper-right of Fig.4 depicts the dimensions and properties of super-cpacitor material in order to be able to sustain the indicated power density (compare measurements in Fig. 4 upper right).

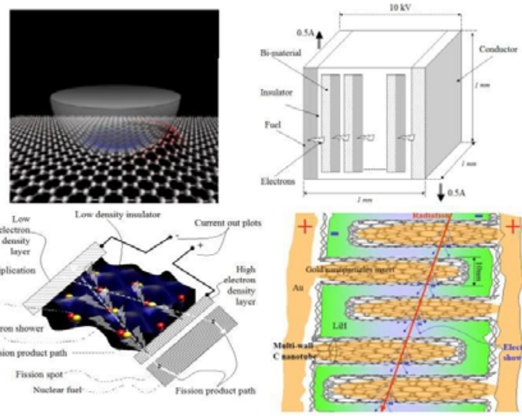

Fig. 4 – Various fabrication techniques for nano-hetero structures for direct nuclear energy conversion.

For example, consider a planar-layered structure of a volume of 1 mm3 , where edge effects are neglected. The structure is supposed to be made of silica and gold-aluminum (bi-layer), and thus should sustain a voltage of more than 10 kV. The admissible current is 0.5 A or higher. That is, a total power of 5 kW/mm^3 might be achieved, which is about three orders of magnitude higher than the largest power density achievable in nuclear reactors (maximum of about 1 kW/cm^3).

The lower-left picture of Fig. 4 shows a bi-material nano-beaded structure embedded into an amorphous silica insulator, where the beads are connected in series by knock-on electron discharge induced by the moving particle, representing another variant of metamaterial structure.

This structure presents the advantage of operating at higher temperatures of up to 1,000 K, where the power density of the heat flow may reach 0.5 kW/cm3, offering the possibility of higher electric power density, along with a supplementary thermo-mechano-electric conversion that may add up to 150W/ cm3, further improving the overall efficiency.

The lower right of Fig. 4 depicts a loaded-multi-wall nano-tube construction that operates for a large solid angle (moving particle geometry) being another constructive variant of direct energy conversion structure. Though operating at lower temperature, this structure may offer very good energy efficiency.

3 FISSION BATTERY

This is a new device that uses the same direct nuclear energy conversion for electricity generation. The fission products deliver about 170 MeV per fission act, equivalent to 25 pJ. The fission battery has the advantage of producing 20 times more energy (per moving particle) than a source powered by alpha decay. Fig.5 shows the functional diagram of a solid-state fission battery. This device, which is similar to an isotopic battery, has 235U or 239Pu based fuels embedded between the conversion structures.

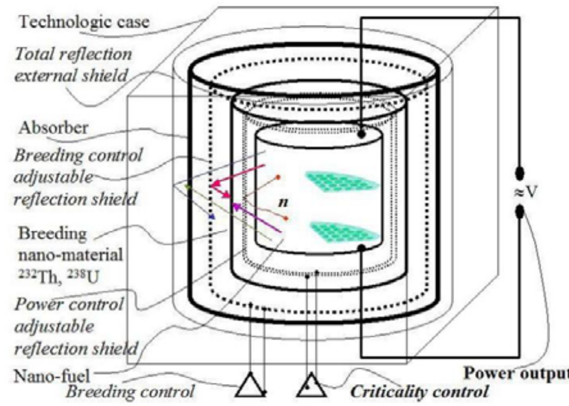

Fig. 5: Sketch of solid-state fission battery.

The necessary condition for such a structure to operate is to meet the criticality conditions and to have an adjustable system for the neutron flux. For any configuration, in order to meet the criticality conditions, structures with a diameter larger than 1 m are required, where all of them need to be comprised of nano-structures, which represents a substantial challenge for the manufacturer.

4 FUSION BATTERY

Recent advances in physics make it possible to use long-range nuclear reactions, triggered by low energy quantum changes, in order to induce high-energy quantum reactions. This effect was discovered experimentally in the 1920s, and since that period more than several hundred successful systems were fabricated. To understand the phenomena presented in Fig. 8, a more thorough understanding of quantum and higher-dimensional physics is necessary to properly account for entanglement, quantum – nuclear active environments, and higher multi-dimensional spaces.

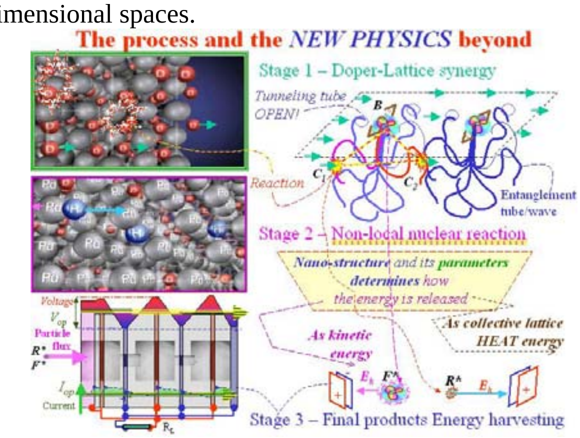

Fig. 8: Physical principles of long-range nuclear fusion and transmutation.

It was experimentally proved [4] that fusion reactions do occur in quantum-nuclear active environments under special conditions. The upper-left side of Fig. 8 shows a Pd–D lattice that is self-excited by random temperature effects. Alternatively, the lattice might be excited using electro-magnetic fields applying resonant frequencies in the THz range. In this environment, a He nucleus spontaneously emerges from the fusion of two deuterium nuclei, mediated by the palladium lattice. The process of fusing two deuterium nuclei into a single helium nucleus, as shown by the picture underneath, releases about 22.4 MeV per fusion reaction, where 22 MeV is due to the kinetic energy of the ejected helium nucleus, and about 300 keV is attributed to the recoil kinetic energy of the palladium nucleus.

A very simplistic explanation is expressed graphically in the upper right picture [5]. Self-excited nuclei have a special state of matter that develops along some fibers of space,[6] outside the force-field of the electric shell (a nucleus has an apparent radius of a few fm, e.g. 12C has a radius of about 2.8 fm), and extends far beyond. As demonstrated by special entanglement communication experiments, a state of quantum correlation may be maintained for hundreds of kilometers. It is also known that entanglement is continuously created and destroyed and that the kinematic equilibrium depends on amost all properties of the environment in which it takes place. Communication experiments also cope with teleportation of quantum states and non-locality. In our case, if these fibers of space with special properties, as entanglement or teleportation emitted by the palladium and deuterium nuclei, should be touching each other, as happens at points C1 and C2, as shown in Fig. 8, those nuclei are supposed to be in a special state of communion, similar to the one obtained in head-on collisions of accelerated particles breaking through the Coulomb barrier. In this case, they simply ignore the electric field by communicating and interchanging their quantum states, taking a new stand in accordance with the requirements of the quantum-nuclear active environment. As soon as the stand has been taken, the new manifestation takes effect and new nuclear particles and states appear, in the form of fusion, transmutation, and even fission [7].

Such a device is shown in Fig. 9, and it is called the fusion battery[8].

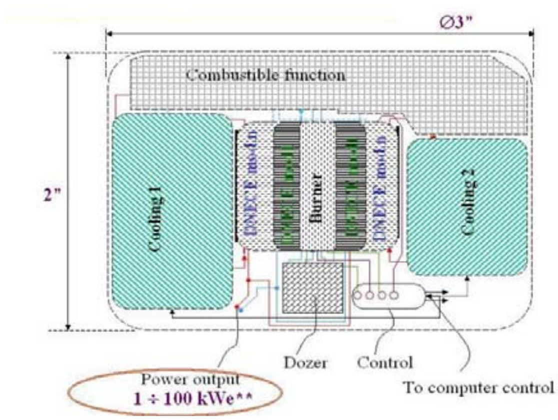

Fig. 9: Modular diagram of the proposed fusion battery for stage 4: building the functional device.

The fusion battery is made of a quantum-nuclear active microstructure, which is surrounded by direct nuclear energy conversion (DNECE) structures that harvest the kinetic energy and deliver it as electricity.

A fusion battery contains a deuterium tank from which the gas is loaded in a controlled manner into the structure, and together with the excitation control, the reaction rate and hence the power output is controlled. The system is surrounded by cooling equipment based on internal helium cooling for the active structure that is taking out the heat to the external heat exchanger, keeping the temperature within operating limits. For high temperature systems a thermo-mechano-electric system might be included in the cooling system, producing some extra energy. The structure is compact and, by computer control, delivery of energy is regulated.

5 CONCLUSIONS

Nuclear batteries – isotopic, fission, and fusion - are among the very few compact energy sources.

The new developments of quantum-nuclear active environments, based on long-range nuclear reactions via entanglement, may open the way for better understanding of advanced concepts and power production.

Fusion-based devices are the only ones that do not have energy storage limitations delivering the best solution of generating power when required and producing an almost unlimited amount of energy, have many military and strategic applications.

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