Nano hetero nuclear fuel structure

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ABSTRACT

The direct energy conversion of nuclear energy requires nano-structured nuclear fuel The principle of the radiation energy direct conversion is the usage of the knock-on electrons produced by the moving particle interaction with the lattice. These electrons transfer their energy to other electrons creating a shower of low energy and high current. A structure created of independent nanowires of two different materials insulated in a thin dielectric coating may use as electron showers energy harvesting device. The dimensions of the conductors are in the range of few tens of nm while the insulators are of several nm, offering a breakdown voltage of few milivolts. When the mowing particles interacts with them it generates consistent e-showers when riches the high electron density conductor which are passing through insulators and stops in the low electron density conductor polarizing it negatively. These two types of conductors are connected to an external load transferring the accumulated charge. To obtain a higher voltage, in a uniform radiation field bimetal nanobeads insulated together and self-organizing have to be created around the radiation source. The advantages consist in transforming the actual nuclear reactors into high power solid-state batteries with no heat exchangers and turbines.

Keywords: nano structure, self-organized, nuclear fuel,

1 INTRODUCTION

The direct energy conversion attempts started by 1940th [1, 2] when nuclear power civil applications started. They were followed by the fast development of the semiconductor devices and the research oriented to establish their behavior in various radiation fields. The 1950th up to 1970th period is dominated by the attempt of using various semiconductor structures to harvest electric power from the radiation field energy [3-8], marking the beginning of the beta-voltaic as a technical domain. The development of electronic devices, and ion beam applications inspired the devices developed afte the capacitor model [9, 10]. Other researches were looking in the potential applications of the MEMS devices as instruments to harvest nuclear power [11, 12], or in various effects possible to occur in special semiconductors and junctions [13, 14], which seems promising for the nuclear power conversion. Most of these previous attempts of nuclear energy harvesting were exhibiting low overall energy efficiency or incompatibilities with the nuclear structures.

2 THE HETERO-NANO STRUCTURE CONCEPT

The concept development starts in early 1980th when during ion beam based experiments various manifestations of direct energy conversion occurred as annoying and in few cases jeopardizing the experiments [15]. Later during the recoil implantation and IBA experiments [16] these phenomenon have been understood and special care have been taken to prevent its unwanted manifestations.

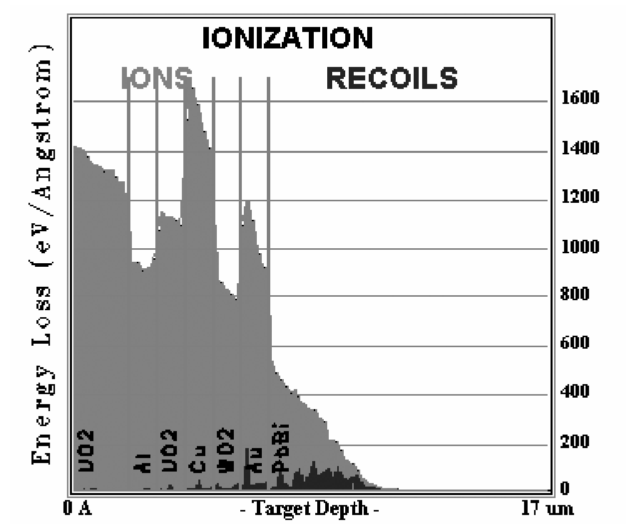

Fig. 1 – SRIM 2006 simulations for a multiplayer target

The final developments are explained by using the Monte Carlo simulation [17] for a multi-layered material

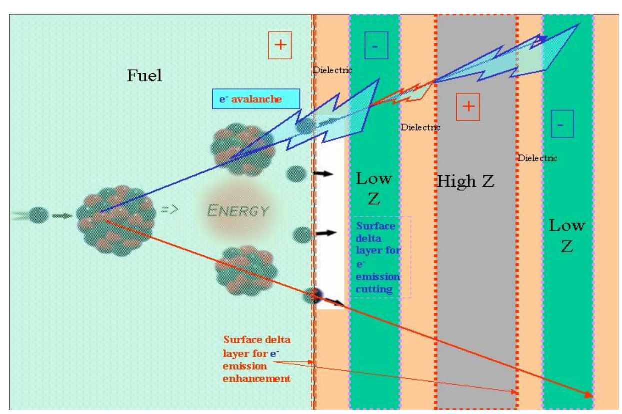

Fig.2 – Energy harvesting schematic diagram

shown in Fig. 1. The sandwich material structure is made of various layers with different electron densities. The nuclear particles stopping in these strata are mainly ionizing the

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material along its path. The ionization energy transferred from the nuclear particle (photon, X or gamma, electron, ion, or neutral nucleus) is further used to create knock-on electrons and resonant X lines.

Fig. 2 shows a potential energy harvesting structure looking like Young's [10] and Ritter's [9] patents but applied from the fission products generated in the near by layer. The fission product carries 80% of the energy as kinetic energy shared between the two fission products. According to the simulation in Fig. 1 the range of the fission products in near by matter is less than 20 microns while the stopping time is less than 100 ps. During this time the knock-on electrons generating by the Couloumbian collisions are generating showers, which are interacting further with the atoms in lattice, until all the energy is degraded into heat. During the electron showers generation

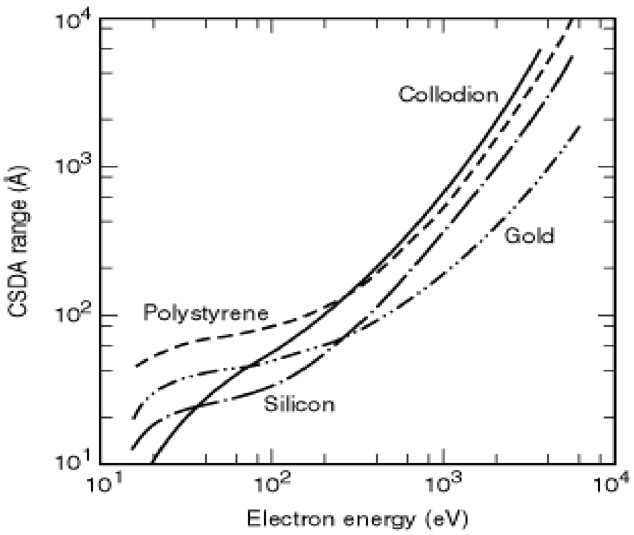

Fig.3 – The Range of electrons in materials

and displacement the polarization of the material occurs and the electrons are coming back after a path similar to the Brownian displacement further exciting the phonon modes. To prevent the material heating, there is possible to alternate the layers and offer electrons conductive paths. As shown in Fig. 3 the free electron path in materials [18] is about 1 to 10 nm, comparable with the equivalent Debye length for the free electrons in conduction bands. It shows that for a insulator material thickness the electron may have a ballistic behavior for a thickness up to 10 nm which may offer a breakdown voltage of few mV. If we connect in parallel the nano-layers made from various materials as in Fig. 2 is possible to obtained a capacitor like structure loaded by the nuclear particles induced current and discharged electrically. The concept represents an enhancement from the Young's patents [10, 19], being applied to all the kind of nuclear particles from photons to fission products. In divergence to the previous art, the low "Z" concept is good for educational purposes only, in reality what matters is the real electron density, and the Fermi level concept is not directly applicable to the structure because the high heterogeneity in the energy discharge, all the process taking in average 20 ps. As a synthesis, for each fission act delivering about 25 pJ, about 2.5nA at 10mV electric energy is obtained.

3 THE NANO-STRUCTURE

The previously presented intuitive structures looking similar to super-mirrors or super-capacitors do not withstand the time and radiation fields, layers diffusing into each-other. The new development is improving this feature by using a nano-grain structure or nano-wires connected by polarity and immersed into insulator, creating a structure

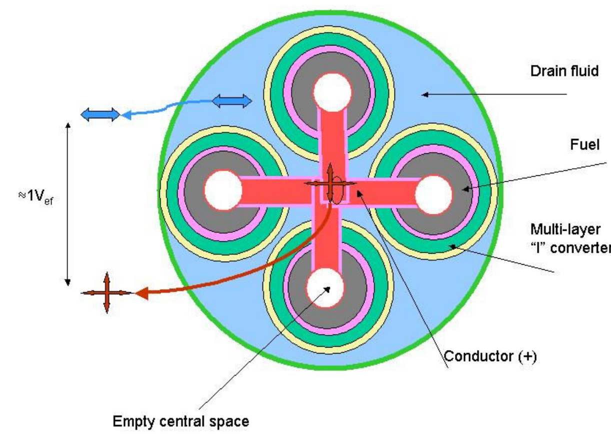

Fig. 4 – Spherical nano-hetero structure

similar to the MOS-FET, but generically called "Cici". The "C" conductor is a high yield generator of electron shower that passes ballistic through the "I" insulator and stops into the "c" conductor, which becomes negatively polarized. The "c" conductor is a low-yield electron shower generator, deflected back by the "i" insulator. Quantum interactions as those predicted by Klimov [14] may be stimulated in order to obtain the carrier multiplication.

Fig. 4 shows the structure in a energy harvesting voxel having a spherical symmetry. As shown in Fig. 1 towards the end of the range a lot of energy is given to recoil, inflicting high damage to the lattice. To avoid the radiation damage and fission products accumulation a micro-nano-hetero-structure may be designed. A liquid metal, with or without harvesting properties, surrounds the onion foil harvesting structure. Finally this structure generates about 50 microwatt per micro-bead.

3.1 Power extraction system

To carry out this power a local DC/AC converter is required. Fig. 5 shows the principal diagram of such a converter. The charge accumulated in the "Cici" structure is transferred to a buffer capacitor set that has its contacts switched by a MEMS device on an inductive load, representing the primary of a voltage multiplier transformer. The MEMS switch is controlled from a central unit, and is also providing status data, used for the reactor diagnosis and control.

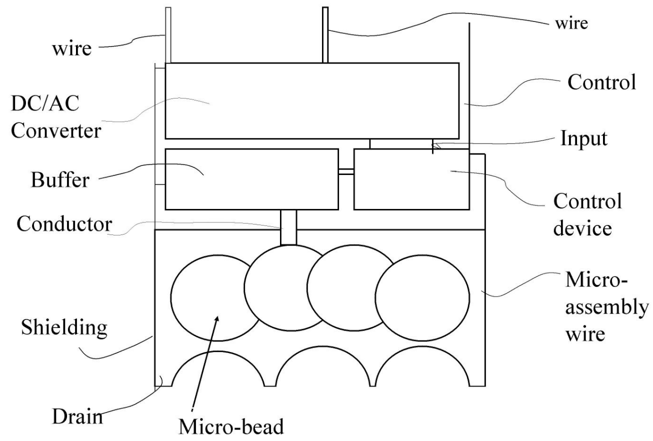

Fig 5 – DC/AC MEMS converter

The micro-assembly device spans over several cubic millimeters generating several watts alternate current.

3.2 The serial nano-hetero structure

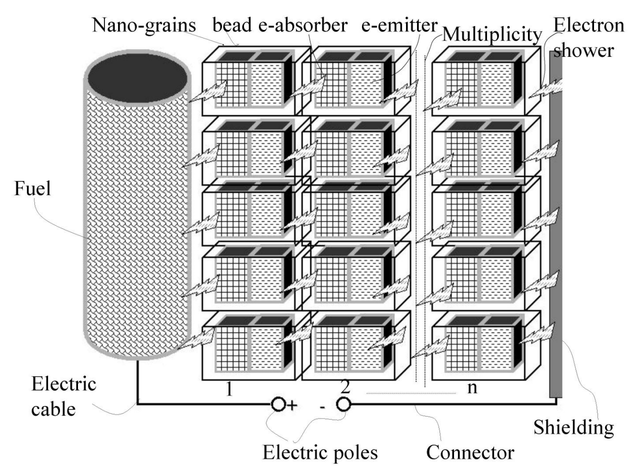

Fig. 6 – Bi-material, polarized nano-powder system

The system shown in Fig. 5 is starting the conversion from few mV that requires a smart MEMS switch to produce the voltage multiplication by D class wave simulation, or high efficiency autotransformer. Another option is presented in Fig. 6 where the voltage multiplication is achieved by using a new type of bi-material nano-grains, powder like, immersed into an insulator drainage liquid. This polarized powder acts like a serial connection, of several tens to hundreds of capacitors, allowing higher output voltages.

This multi-layer powder may be contained in screening, metallic coatings, making intermediary capacitor systems in order to reduce the probability of breakdown or short-circuit which will produce the fuel heating. Several micro-beads may be connected in series or parallel in order to achieve the best power extraction combination.

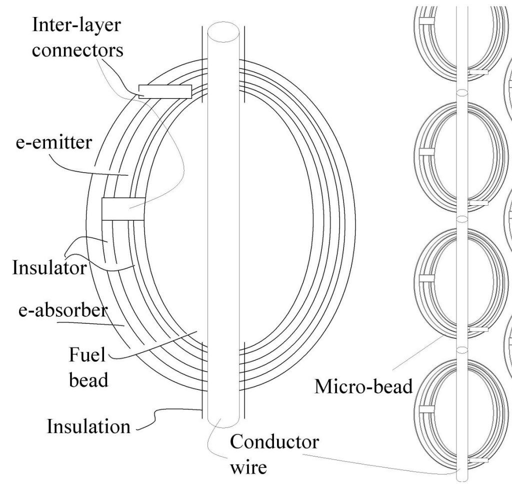

Fig. 7 Multi-bead connection system.

Fig. 7 shows an example of high voltage serial beads, placed in a variable geometry structure that allows higher burnup factors. The nano-structure extraction efficiency may be maximized, such as the residual heating energy to be at the limits of acceptable operating temperatures. This parameter dictates on the power density this structure may carry. Has to be understood that only the energy which was nor extracted as electricity is producing heat. The theoretical limits of a near 100% efficiency "Cici" mm^3 structure made by 10% carrier conductor and 90% capacitive structure is about 5 kw/mm^3, being several thousands higher than the actual power densities smaller than 1Kw/cm^3 based on thermal floe power extraction.

3.3 Electric system structure

To carry this power outside the reactor and to deliver into grid a pyramidal structure of impedance adapters and voltage multiplier system have to be build as in Fig.8.

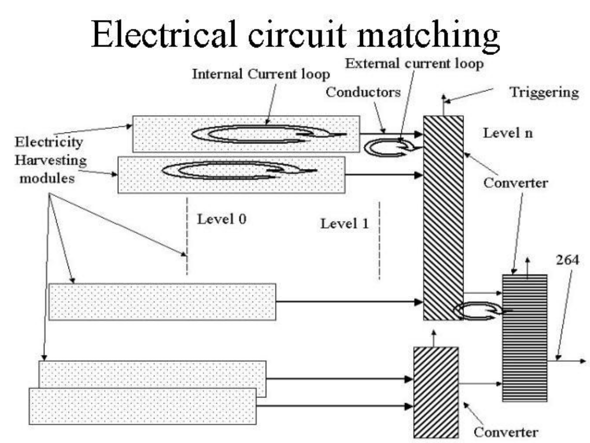

Fig. 8 – Pyramidal electric power extraction system

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This system has to mitigate between the direct conversion efficiency and the electricity conversion efficiencies. This new nuclear fuel represents a great challenge for the actual nuclear reactors concepts, representing a drastic volume reduction, finally reflected in costs.

4 THE HARVESTING STRUCTURE

The nano-micro-hetero structure may be build using actinides in its structure, and becoming an evaluated nuclear fuel, but may be also build without fissile materials in its structure. In this case, it may be used to harvest the energy of external radiations like that coming from radioactive materials, ion beams, fusion reactors.

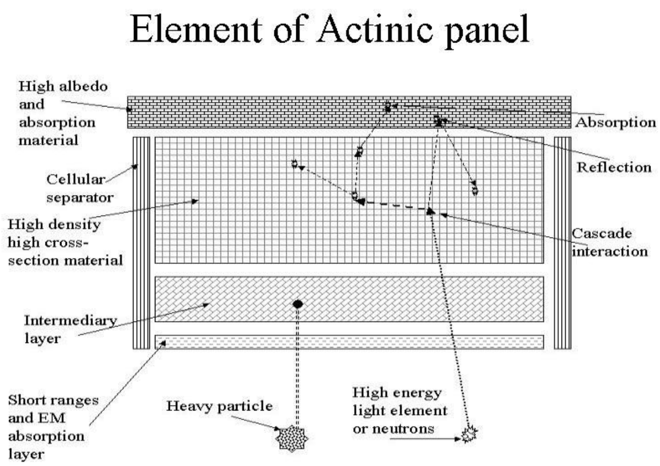

Fig. 9 – The energy harvesting tile structure

Fig. 9 shows the block diagram of a multi-radiation energy-harvesting device designed for fusion and space application. The first layer is very thin, being mainly an active coating collecting heavy nuclei and X ray, followed by a medium density layer, for medium energy radiation and a n energy harvesting and amplification layer, by using actinide based materials. A cryogenic version of this device is possible opening the way for high efficiency, high power density device.

5 CONCLUSIONS

The direct conversion nuclear fuels have the capability to reduce the size of the nuclear reactor down to a trailer, by cutting all the heat exchangers, turbine and associated equipments.

The nano-hetero-structures open the way for high power density, high conversion efficiency and portable nuclear power applications.

REFERENCES

1. Harmut Israel Kallmann, E.K., *Device for measuring the intensity of a radiation of slow neutrons by means of ionization chamber.* US 2288718, 1940.
2. Ernest G. Linder, *Method and means for collecting electric energy of the nuclear reactions.* US2517120, 1946.
3. Volney C Willson, *Generator of Power.* US2728867, 1955.
4. Eric Gustav Karl Schwarz, *Secondary emission type of nuclear battery.* US2858459, 1958.
5. Schuyler M. Christian, *Radiation responsive voltage sources.* US2847585, 1958.
6. WILLIAM E. PARKINS, *NUCLEAR BATTERY INCLUDING PHOTOCELL MEANS.* US3483040, 1969.
7. OLSEN K., *Semiconductor nuclear battery.* U.S. Pat. No. 3,706,893, 1972.
8. Adler Karl, D.G., *Miniaturized nuclear battery.* US3934162, 1976.
9. Ritter James C., *Radioisotope photoelectric generator.* US4178524, 1979.
10. YOUNG R.D., H.J.P., LIGHT G.M., SEALE S.W. Jr.,, *Charged-Particle Powered Battery.* WO9748105A1, 1997.
11. Amil Lal, L.L., Hang Guo,, *Tiny Atomic Battery Could Run For Decades Unattended.* TECH SPACE, 2002.
12. Anghaie S., S.B., Knight T.,, *Direct Energy Conversion Fission Reactor Gaseous Core Reactor with Magnetohydrodynamic (MHD) Generator.* DE-FG03-99SF21894, 2002. **Final Report**.
13. Nyevorov V., *The direct conversion of nuclear power into electric current for various applications.* Basic & Applied Research Bureau, 2006. **Proposals**(1): p. 5.
14. Klimov V.I., *Mechanisms for photogeneration and recombination of multiexcitons in semiconductor nanocrystals.* J. Phys. Chem., 2006. **B**(110): p. 16827.
15. POPA-SIMIL L., e.a., *Multi-thermocouple structure for measuring the target's temperature field during beam power deposition.* Internal Report, 1986. **NIPNE-HH, Accelerator division**(Special projects): p. 2.
16. POPA-SIMIL L., e.a., *Machining regime influence on rougness and carbon concentration in surfaces.* Vacuum, 1994. **99**(1).
17. Zigler James, *PARTICLE INTERACTIONS WITH MATTER, SRIM - The Stopping and Range of Ions in Matter.* IBA, 2006. **ibm**(web).
18. NIST, *Electrons interactions with matter.* web, 2005. **www.nist.gov**.
19. YOUNG Robert D., H.J.P., LIGHT Glenn M., SEALE Stephen W. Jr.,, *CHARGED-PARTICLE POWERED BATTERY.* US5861701, 1999.