Direct Energy Conversion
Radioisotopes Based Battery

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Direct Nuclear Energy Conversion into Electricity is a process that uses the kinetic energy of the nuclear particles, into a super-capacitor like hetero-nano structure, harvesting the energy of knock-on electrons produced in the interaction between the nuclear particle and the lattice, and discharges directly delivering electricity similar to a battery.

The structure may be morphed on the energy source that can be a nuclear fuel, delivering energetic fission products, or a radioactive isotope delivering alpha, beta or gamma radiation from its natural decay.

For the most practical uses in near vicinity of the biological systems, there are preferred those radioisotopes that emit mainly charged particles with minimum associated gamma rays. The most preferred radioisotopes are $^{238}$Pu, $^{241}$Am, and $^{90}$Sr, $^{210}$Po, but there are many others that might be used if their production costs might be lower.
The use of these gamma ray “free” alpha or beta emitters makes the nuclear battery very small, looking like a 50 microns thick foil, with the minimum dimensions down to 0.1 mm, and power versus halving time given by the type of radioisotope used.

The power for such a small battery element is of about few nW for 90 years for $^{238}\text{Po}$, by 4-5 times less for $^{241}\text{Am}$ with 431 years half-life, and few microWatt for ½ year for $^{210}\text{Po}$.

The battery may be morphed on the case surface, on the printed circuit or on the electronic parts, may be distributed along the electronic modules, making self-powered electronic modules or even parts, being customized to the needed parameters ($V, I, P, T_\frac{1}{2}$ etc.).

The use of such power sources, may drive to super-miniaturization of the circuits, increase in reliability, being fit for space applications due to their energy mass ratio, one battery being equivalent to more than 100,000 chemical batteries.
Brief history of direct nuclear energy conversion in electricity – my experience
30 years ago

Prof. Ionel Purica

Ursu-Purica fission cell

Transversal section in a fission cell

VVR-4 Research Reactor

Control Room

Emitter

Fissile coating

Grids

Anomal secondary emission

Semiconductor oxide coating

Collector

Support rings

Power supplies

Fission products

Multipactor electrons

Insulating support

Vacuum chamber

235U

Fission products

Power supplies

Multipactor electrons

Insulating support

Vacuum chamber

235U
Lesson learned:
gas insulation reduces the power density
Need to make solid or liquid insulation
Liquid Immersed structures gave better results but short-circuited frequently
The multi-layer stack of thermocouple gave significant results in an ion beam power deposition experiment, but the research failed to reach its target – measure the internal temperature distributions by thermocouples.
Ion beam power deposition Experiment

RBS optional
Thermocouple
Beam
Grid optional
RBS chamber
Insulator

Expected
Obtained

Reproduced at CIM-AAMURI/2010
Invention and consideration

1950

Aug. 1, 1950

E. G. LINDER

METHOD OF AND MEANS FOR COLLECTING ELECTRICAL ENERGY OF NUCLEAR REACTIONS

Filed June 25, 1946

2,517,120

DIRECT ENERGY CONVERSION FISSION REACTOR

(NERI) Program DE-FG03-99SF21893 for the U.S. Department of Energy.

ANNUAL REPORT TO THE U.S. DEPARTMENT OF ENERGY

August 15, 1999 through August 14, 2000

by

L.C. BROWN

50 y delay

No correlation

No reference

The new part

Magnetic insulation

Fig. 1. Schematic diagram of the MIQSFEC.
Schematic diagram of the direct conversion of radiation energy into electric power.

Radiation Energy

Loads a nuclear super-capacitor made of nano-hetero structures.

Discharged by DC/AC (MEMS/SQUID) cascade that forms.

The electric power delivered to grid or to load.

Particles – fission/fusion
Photons – X, Gamma
Charges – electrons, muons

Cascade

LOAD
Direct energy conversion in nano-hetero structures meta-materials
The novel batteries

Fission structures

210Po

Actual reactors

238Pu

Gasoline

Hydrogen

The market place
The moving particle stopping in the lattice

\[ S = \frac{4\pi r_0^2 m c^2 Z_2 Z_1^2}{\beta^2} \left[ \ln \frac{2mc \beta^2}{1 - \beta^2} - \beta^2 \right] - \ln(I) - \left( \frac{C}{Z_2} - \frac{\delta}{2} - Z_1L_1(\beta) + Z_2^2L_2(\beta) \right) \]

Bethe-Bloch equation

Nuclear chain reactions

Lattice's atoms

Knock-on electron loops

Moving particle

Particle’s stopping path

Electric breakdown

The process

Heating the structure

\[ 0.5-24 \text{ keV/nm} \]

\[ 5-100 \text{ MeV} \]

\[ A=4-140 \]
Knock-on Electron showers

Material selection and structural dimensioning

Energy Loss (eV/Angstrom)

Layer 1  Teillon  Plus12  Teillon  Minus2  Teillen  Plus12

C I c i C I i

by ionization [eV/nm]

Alternate layers stopping

α-5 MeV

Normalized Range [%]
How it works

Particle flux $f, \alpha, p, \beta$

Particle flux diagram showing the movement of particles through a cell voltage $V_{op}$ and current $I_{op}$. The diagram includes symbols for $V_{ij}(h)$, $V_{bk}$, $+V$, $-V$, $d_{ij}$, $C_{ij}$, and $r_s$, representing voltage, current, and particle flux through the cell. The figure illustrates the interaction of particles with a cell voltage and current, explaining the flow and behavior of electrons and other particles through the system.
Power density of \(1 \text{ mm}^3\) direct conversion voxel

\[50 \text{ A}^{\text{superconductive}}\]

\[0.5\text{ A}\]

\[10 \text{kV}\]

\[50 \text{ kWs}^{\text{superconductive}}\]

\[5\left(\frac{kVA}{mm^3}\right)\]
The new idea
Structural diversity
Spherical shell immersed in drain liquid

From foil capacitor to nano-bead serial meta-material

Loaded nano-tube

Gold nanoparticles insert

Multi-wall C nanotube

Electron showers
The serial nano-structure

- e-shower
- e-absorber
- Bi-material bead
- e-generator
- Insulator
- Voxel
- Fuel
- Electrode
- Bi-material bead
- Fuel wire
- Converter
- Voxel
- Repetitive structure
- Plots

A
B
Pu Superconductive structures
isotopes on n absorption cross-section

When cooled at cryogenic temperatures <18 K becomes superconductor

<table>
<thead>
<tr>
<th></th>
<th>238Pu</th>
<th>239Pu</th>
<th>240Pu</th>
<th>242Pu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pu</td>
<td>558</td>
<td>1017.3</td>
<td>289.6</td>
<td>18.5</td>
</tr>
<tr>
<td>Co</td>
<td>37.18</td>
<td>37.18</td>
<td>37.18</td>
<td>37.18</td>
</tr>
<tr>
<td>Ga x 5</td>
<td>13.75</td>
<td>13.75</td>
<td>13.75</td>
<td>13.75</td>
</tr>
<tr>
<td>Amount</td>
<td>663.93</td>
<td>1123.23</td>
<td>395.53</td>
<td>124.43</td>
</tr>
<tr>
<td>visibility decrease</td>
<td>84%</td>
<td>91%</td>
<td>73%</td>
<td>15%</td>
</tr>
</tbody>
</table>
Maximum Allowable Power Density = 5 [kW/mm^3]

For superconductors this power density is 10-100 times higher, but the neutron flux is 10^-4 of an nuclear explosion.
Solid-state radiation batteries
A super-capacitor structure for electronic cooling with fission/spallation product extraction
Radio-Isotope decay powered batteries

Smallest size
0.1x0.1x0.05 mm

Intermediary voltage plots

P\(^{(238\text{Pu})}\)=0.1\(\mu\text{W}\); T\(\frac{1}{2}\)=90y

P\(^{(210\text{Po})}\)=10\(\mu\text{W}\); T\(\frac{1}{2}\)=0.5y

Equivalent of:
50-5,000 LiIon batteries in Power Density
50,000 same power, chemical batteries in Energy Density

Many applications
Self powered electronics

Battery morphed on object’s surface
Thank you!