Developing an Efficient Low-Temperature Nuclear Fusion Reactor

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Abstract

There is an increasing empirical data supporting the evidence of different types of low temperature nuclear fusion reactions in condensed matter, mainly in metals. The mechanism of this phenomenon is similar to **μ**-catalysis. The rate of this reaction depends on the type of material and its environmental conditions. The rate can be increased enormously by having hybrid nanostructured material with high screening energy capability. The correlation between electron screening and low temperature nuclear fusion constitutes the most important notion in modern physics. Understanding this phenomenon would revolutionize physics and open up new frontiers in science and technology.

Contemporary nuclear physics theory conceives of a nuclear reaction as an isolated process between two bare nuclei, neglecting the environment where the nuclear process takes place, e.g. the electron clouds surrounding the target nucleus. In the so called LENR, however, the effects of the surroundings of a nucleus on the nuclear phenomena were surprisingly very strong.

However, for fusion reaction to occur with a high probability, the nuclei must be brought close to distances of the order of (10^{-11}- 10^{-10}cm). Attempts have been made since the beginning of the 1950s to obtain fusion energy based on the principle of thermonuclear reaction (heating dt- or dd- mixtures up to temperatures 10^{8} -$10^{9^{\circ}}$). There is another potential way of initiating fusion reactions, viz. by using the **μ**-catalysis effect. The process of **μ**-catalysis was first discussed as early as 1947.

L.Alvarez in 1957 was the first to detect the **μ**-catalysis in a hydrogen bubble chamber containing a natural impurity of deuterium. Muon has a remarkable resemblance of electron. Indeed, both have identical spin (S=1/2), baryon charge (B=0) and electric charge (Z= ± 1). Both participate in weak interactions and reveal all the characteristics of such an interaction (small cross section, parity violation). Both participate in electromagnetic interactions in an identical manner. For example, just like electrons, negative muons can form an atom (called the **μ**-atom) and the energy transitions of negative muons in a **μ**-atom are accompanied by the emissions of electromagnetic radiation.

It is well known that the electron obeys Dirac's equation from which it follows in particular that the electron magnetic moment is the following:

$$\mu_e = e\hbar/2m_e C = M_B \quad (1)$$

Where, M_B is the Bohr magneton.

This value was found to be in good agreement with the experimental value which had been already known at the time when Dirac obtained his results. Later on, the interaction of the electron with its intrinsic electromagnetic field was taken into account, and this introduces a small correction to formula (1).

The appropriateness of the radiation corrections was also confirmed experimentally. If the muon completely resembles the electron, it must satisfy Dirac's equation like the electron, i.e its magnetic moment must coincide, to a first approximation, with formula (1) in which the electron mass is replaced by the muon mass:

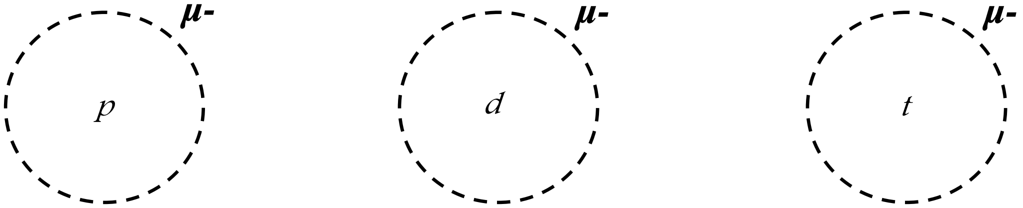
$$\mu_\mu = e\hbar/2m_\mu C = m_e/m_\mu M_B \quad (2)$$

If, however, the muon is not a Dirac particle, its magnetic moment must differ from (2). This difference must reflect some special features of its interaction (in the same way as the anomalous magnetic moment of the nucleons indicates that they participate in electromagnetic as well as strong interactions). Measurements of the muon magnetic moment made by using the resonance Method fully confirmed the validity of formula (2), which once again reflects the amazing resemblance between the electron and the muon. Therefore, it was found that the muon resembles the electron in all respects, including the fine effects like the radiation corrections to the value of the magnetic moment. Only the mass of the muon was found ≈ 207 times larger than that of the electron. The muon has another feature, different from the electron, as it has a very short life time.

It was assumed, that the difference between the masses of electron and muon was related to the difference in the electron and muon neutrinos. However, it is difficult to understand this assumption since the difference in the properties of the neutrinos is a property of the weak interaction, which should not significantly affect the mass of the particles. The situation became more complicated after the discovery of the heavy τ-lepton with a mass of 1.78 BeV. The problem of the mass of charged leptons is now considered being solved by the unified theory of weak and electromagnetic interactions.

However, since the muon is similar to the electron in all its properties, with the exceptions of mass and life span: $m_\mu \approx 200\ m_e$ and $\tau_\mu = 2.2 \times 10^{-6}$ S

Therefore, a negative muon can replace an electron in a Bohr orbit and form a μ^--atom (fig. 1).



Fig

The radius of the μ-orbit in a μ-atom is about 200 times smaller than the radius of the e-orbit. Therefore, μ-atoms of the type μ^-P, μ^-d, and μ^-t are smaller than the corresponding hydrogen isotopes H^1, H^2, H^3 by a factor of 200. For this reason and due the fact that a μ-atom has a zero electric charge, this atom can come too close to a nucleus and form a μ-molecule of the type p μ d, d μ d, d μ t, which is of a very small size (10^{-11} -10^{-10} cm), thus allowing reactions of the type pd, dd and dt to take place (fig.2).

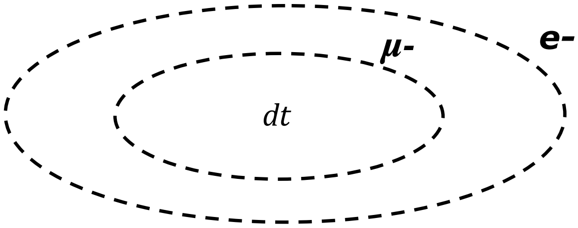


Fig.2

The process of μ-catalysis was soon found to be quite unsuitable from a practical point of view, due to a low rate of μ-catalysis at low temperature. Even though there were some theoretical predictions that raised the hope that μ-catalysis could be suitable, these hopes soon vanished. The short life span of the muon was, and still is, the basic problem that has not been overcome. Before a muon decays it should be able to interact about 100 times with nuclei, in order to release energy comparable with the energy devoted to the creation of the muon itself.

Thus, for this type of nuclear reaction to be suitable from a practical point of view, we need either muon with a longer life time or electron with a heavier mass. However, the electron does not have to be as massive as the muon in order to be captured by the proton. It is sufficient for the electron to be around 2.531 times as massive to be captured by the proton. In the free atom the mass of the electron is of course too small to screen the Coulomb barrier in an effective way, but in condensed matter the mass of the electron can be modified by local electromagnetic field fluctuations. Proper energy stimulation system on the right surface can dress an electron with additional mass. In many cases the mass addition can be very large. In this respect, it is beyond dispute that the surface states of certain metal hydrides and also other non-metallic materials with special properties (similar in a certain respect to metals) are very important.

In a deuterium/solid system, the electrons change their states before effective screening happens. The electron clouds surrounding the interacting nuclides acts as a screening potential. The projectile effectively sees a reduced Coulomb barrier, both in height and radial extension. That will lead to higher cross section for the screened nuclei σ_s (E), than would be the case for bare nuclei σ_b (E). Very large values of screening energy were found in some empirical data and the so-called Debye plasma model applied to quasi-free metallic electrons was useful for explaining some of these values. The electron Debye radius R_D around the deuterons in the lattice is smaller by about a factor 10 than the Bohr radius of hydrogen atom, thus, one finds the model suitable in explaining some of the experimental results. However, the values in some cases were 100 times higher than the commonly accepted maximum theoretical value, deduced by energy conservation: the so called adiabatic limit. In stars, it is believed that the cross section σ (E) of the fusion reaction decreases exponentially with decreasing energy E:

$$\Sigma\ (E) = S\ (E)\ E^{-1} \exp\left(-2\pi\eta\right) \quad (3)$$

Where S(E) is the astrophysical factor and $\eta = 2\pi Z_1 Z_2 e^2 / h\nu$ is the Sommerfeld parameter, where Z_1 , Z_2 are the integral charges of interacting particles, e is the unit of electric charges, h is Planck constant, ν is the relative velocity.

There is a discrepancy between values of electron screening in stellar plasma predicted by theoretical studies and electron screening found in laboratory. Therefore, these puzzling results cannot be explained by the screening mechanism found in astrophysics theory. Consequently, a deeper understanding of the enhancement factor of laboratory electron screening can definitely contribute to a deeper understanding of electron screening in stars.

However, investigations have shown that hydrogen nuclei in metal are strongly screened due to electron screening in the metallic d-band and also hydrogen induced s-band can contribute to the screening effect. It has been found that the screening distance between two hydrogen nuclei in metal is much shorter than in the case of atomic hydrogen.

Recently, the electron screening in D(D, P)T has been studied for deuterated metals and insulators, i.e 58 samples in total (Raiola et al.2002, 2005). Compared to measurements performed with a gaseous D_2 target (U_e =25± 5 eV (Greife et aL.1995), U_{ad} =27.2eV), a large screening has been observed in all metals (of order U_e =300eV,i.e higher by one order of magnitude than U_{ad}), while a small (gaseous) screening has been detected in the case of insulators (C. Rolfs. Experimental Physi.III Ruhr-University Bochum, Germany). The data clearly demonstrates that the enhanced electron screening occurs across the periodic table and is not restricted to reactions among light nuclides. In general, these studies confirm that low energy D+D reactions are strongly enhanced when the reaction occurs in a metal environment. But more important is the fact that the environment which provides screening energy of more than 200eV is not apprehended at present.

Screening energy of the D+D reaction in metals obtained from the Lab. Of Nuclear Science, Tohoku University, Japan (Jirohta Kasagi), Surface & Coating Technology 201 (2007) 8574-8578

Material	Screening energy (eV)
PdO	600±30
Pd	310±30
Fe	200±20
Re	200±20
Cu	120±20
Yb	80±20
Ni	80±20
Au	70±20
Ti	65±30

In the past few years, a very large amount of screening energy was also obtained for Li+D reaction. This is an expansion of nuclear reactions other than D+D reactions. This large energy obtained for Li+D reaction for certain metals raises the important question whether these large values are due to electron screening alone, since bound electron screening, according to theoretical prediction, gives at most an energy of 20eV for the D+D reaction and 0.3 KeV for the Li+D reaction.

Therefore, one can see that there are variables for enhancing the screening energy. Those variables strongly depend on the physical and chemical properties and also on the enviroment of the host material such as surface dynamics, stimulation energy system, density, type and conditions of the working gas. Understanding the mechanism of the enhancement factors by extended comparative studies of certain materials can allow for the design of new nanostructured material. Studies must focus on finding composite material like complex metal hydrides. The best approach that can accelerate the possibilities for finding this ideal nanostructured material is through the combination of virtual high throughput screening (VHTS) and combinatorial synthesis and screening (CSS). This method can lead us to find the most promising material and understand its thermal and electronic properties, and as a result, develop models and simulations for improving our understanding of the enhancement factors and increasing the reaction rate of low temperature nuclear fusion.

Bring together ions of hydrogen isotops at distances of a few fermis, will allow a maximum increase in fusion rates. The investigation would aim to find the right lattice structures and understand their rearrangement when hydrogen, deturium or other gas mixtures is absorbed in them. The problem is how to trap the deuterium nuclei in the host lattice, and move them much closer together than they would otherwise be (in the gas phase), so that quantum effects take over and energy levels merge into broad bands rather than remaining discrete. The Coherent vibrations of the trapped nuclei, the electron cloud and the host lattice interact. That will greatly enhance quantum mechanical barrier penetration through the Coulombic field for fusion of adjacent deuterons held closely together in the lattice.

Experiments have already shown that when deuterium is absorbed or generated in a metal electrode, the deuterons become delocalized as waves with periods of the host lattice, this is known as Bloch state. Bloch states will cause the waves of different deuterons to overlap and when the kinetic energy of the vibration becomes greater than the potential energy of the Coulomb barrier, the result is that the deuteron waves would fuse into one another since the Coulomb barrier becomes essentially irrelevant. In this interaction the electrons are also delocalised as Bloch waves and serve to shield the relevant charges of the nuclei and enable them to come closer together.

Thus, having particles with very long wave lengths, in a lattice of confined deuterons leads to an extraordinarily high cross section, and therefore, if the charge distribution has dimensions of the order of de Broglie interaction length, the potential barrier due to Coulomb interaction can become very small and as a result, the internuclear distances and the height of the potential barrier are varied, both having an effect of increasing the fusion rate. When two deuterons fuse, the result is helium 4 and excess energy of 23,8 Mev. The excess energy is transferred to the host lattice as phonons and dissipated as heat. Depending on the precise experimental conditions, the excess heat can be produced in a predictable steady state or in unpredictable bursts of intense activity associated with the production of tritium.

So far all microscopic investigations have shown that low temperature fusion reaction is taking place only on tiny, isolated areas of the surface of Pd and also other metals. In order to have a significantly higher reaction rate we have to modify the material's atomic configuration. This can be achieved by applying non-equilibrium materials synthesis methods, incorporating substitution and adding catalysts in a continuously modified reactive environment such modification will enhance the kinetics by increasing the diffusivity and reducing the diffusion distance. The desired material can allow the reaction to take place on a much larger area of the surface, rather than on a tiny, isolated area. This material can certainly be structured. There is considerable and compelling evidence about the feasibility of making it and creating the proper environmental conditions for inducing a very high reaction rates.

A scheme such as Monte Carlo Simulation has to be developed for understanding electrons phonon interaction and phonon transport to gain a fundamental understanding of the electronic and thermal properties at the material interface.

But the main hurdle in revealing the high energy reaction mechanism in condensed matter is the myth in the field of nuclear science that our knowledge about high energy reactions is nearly final and perfect and there is nothing else to add except for a few details. Furthermore, a researcher who does not follow these guidelines will be considered anti-establishment, a pseudoscientist pursuing a crackpot theory. Low temperature nuclear fusion is a demonstration of the above argument.

The limited research in this field has yielded a huge body of evidence by numerous experiments around the world. Some of those experiments generated heat for days at certain times. In May 2008 a demonstration of the phenomena was shown live to large academic and media gatherings in Japan. More important, however, is that these early endeavours at mapping the parameters of the domain can be improved by many orders of magnitude.

There is a real opportunity to develop entirely new and green nuclear power; nuclear power that does not create hazardous radiation or radioactive waste. This new power can improve the density and longevity of energy storage compared with existing technologies and can be cost effective, scalable, portable, so that it allows an airplane or spacecraft to travel for a very long journey without refuelling. We do not need millions of degrees and billions of Euros to fuse atomic nuclei and yield energy. We have been trying to achieve this goal for almost six decades and according to the most optimistic scenario we must wait at least another five decades before we can know for certain that hot fusion power can be practical. In the last few decades scientific communities started to behave like groups of high sheikhs or priests rather than seekers of genuine scientific understanding. We can no longer afford to protect either the financial interests of certain corporations or the selfish interests of certain individuals or scientific groups. Politicians must take action on climate change now or face long decades of war and social unrest and a planet that becomes totally unrecognisable. The first step and the wise action is to start investing in all types of fusion research.

The story of fusion energy research is the strangest untold story of 20th century science, but the enigma is now beginning to show signs of resolution. The most surprising part of this story may, in the end, well turn out to be that it is low temperature nuclear reaction and not thermonuclear reaction that is the only possible way for producing nuclear fusion on a large scale.

There can be no doubt that we have a serious deficiency in our present knowledge of the principles of electromagnetic theory. Nuclear fusion in metal crystal structures at low energy levels is real proof that electromagnetic interaction extends over the full range of dimensions, including the dimensions of nuclear force. Weak and strong interactions might be different manifestations of this most fundamental reaction in nature.

References:

1- Jirohta Kasagi. Surface and coatings Technology 201 (2007) 85 74 85 78

2- C.Rolf: A plasma of the poor man, Mem.S.A. It. (2006) Vol.77, 907

3-Raiola, F. et aL. 2005,Eur. Phys. J. , A31,1141

4- Cruz, J. et aL. 2005, phys. Lett., B6 24, 181

5-C.Rolfs, prog. Theor.phys. Suppl. 154 (2004) 373.

6-Kasagi, et aL., J.Phys. Soc.Jpn. 64 (1995) 3718

7- M.Fleischmann,S.Pons, J. Electro.Chem. 261 (1989) 301, S.E. Jones, et aL., Nature 338 (1989) 737.

8- C.M. Hurd, The Hall effect in Metals and Alloys, Plenum, New York, 1972

9- M. Lattuada, et aL., Astron. J. 562 (2001) 1076.

10- H. Yuki et aL., Proc. of ICCF7 (1998) p. 180.

11- H. S. Bosch and G.M. Hale, Nucl.Fusion 32, 611 (1994).

12- H.J.Assenbaum, K. Langanke and C.Rolf, Z. Phys. A237, 461 (1987).

13- S. Ichimaru, Rev. Mod. Phys. 65,255 (1993).

14- K. Czerski, A. Hulke, A. Biller, P. Heide, M. Hoeft, G. Ruprecht, Eur. Phys. Lett. 54 (2001) 449.

15- R. P. Feynman, Phys. Rev. 56, 585 (2003).

16-K. N. Mukhin, Exp. Nucl. Phys. Volume, I Phys. of Atomic nucleus, Mir publishers, 1983.

17--K. N. Mukhin, Exp. Nucl. Phys. Volume, II Elem. Particle Phys. , Mir publishers, 1983