COLD FUSION ACTIVITIES IN RUSSIA

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Abstract
A review of Cold Fusion researches in Russia during last two years is presented.

1. Introduction

Four years ago at the Nagoya ICCF4 one of us (V.T.) described the decay of the USSR and a new geography of CF studies in the ex-Soviet Union [1].

Unfortunately all "final state products" of the decay, the new independent countries, are still in the "excited state". There is no stabilization of the economy, and as a result nowadays our society does not want or is unable to support our science properly. Since 1991 the number of scientists in our country reduced 3.5 times. Nevertheless our CF community is still alive and active. In the period of 1993-1996 four Conferences on CF have been organized in Russia with participation of scientists from other former Soviet republics and France, Italy, Japan, Spain and USA (see Table 1).

Table 1

Title of Conf.	1st (and last) All-Union CF Conf.	1st Russian CF Conf.	2nd Russian CF Conf.	3rd Russian CF Conf.	4th Russian CF Conf.
Place	Dubna JINR	Abrau-Durso Novorossiisk	Burevestnik Sochi	Dagomys Sochi	Dagomys Sochi
Date	March 1991	September 1993	September 1994	October 1995	May 1996
Number of participants	117	42	44	39	30

The modest number of participants last years is due to the poor financial support and a scanty salaries of Russian scientists, which is often even not payed at all. In 1990 at Como ICCF2 the results of more than 80 papers from about 45 Russian Institutes and laboratories have been presented [1]. In 1992 at Nagoya ICCF3 these numbers were about four times less. Almost the same situation is at present. There are now about 15 Institutes where enthusiasts of CF carry out their researches usually without any financial support. The total number of Russian papers submitted to the ICCF6 or published just before the Conference is about 25. It is impossible to discuss all of them in this report in detail. Luckily many of them are presented at this Conference. Thus the main aim of this review is to show a landscape of Russian CF activity and to mention some of the recent results, which have not been submitted to the ICCF6.

2. **Experimental results**

2.1. **CF in gas discharge.**

The most ambitious results are presented by two research groups from "LUCH" (Podolsk, Moscow District), which are continuing their studies of CF with gas discharge.

Romodanov et al. [2] carry out mainly tritium measurements. During the last few years they accumulated the following evidences from experiments with metallic cathodes: (a) the rate of nuclear reactions in condensed matter for deuterium ion energy range $10\text{-}10^4$ eV exceeds the calculated rate of the ordinary thermonuclear fusion reactions by several orders of magnitude, (b) the neutron-to-tritium branching ratio is less than 10^{-7}, (c) the rate of nuclear reactions is increasing with increasing the atomic number of target and with concentration of hydrogen in deuterium, (d) the energy dependence of tritium yield has a threshold at about 100 eV of deuteron energy, (e) the linear dependence of the tritium production rate R upon ion current density j is observed (see Fig. 1), (f) the "nuclear interaction coefficient" Q (the number of tritium atoms produced per one deuterium ion) as a function of plasma gas pressure has a maximum in the range of 1000-3000 Pa.

In experiment with ceramic targets (TiC, VC, ZrC, ZrN, ZrB_2, LaB_6) this group measured both tritium production and gamma ray radiation. They reported rather large tritium production rate of (3.6-3.9) 10^7 T/s for ZrB_2 cathode in the temperature interval 1650-2240 K. The rate of gamma emission was very low: less than 10-1000 1/s, so the ratio gamma/T was less than 10^{-4} - 10^{-6}.

This group also studied tritium generation at transfusion of hydrogen isotopes through the target during plasma glow discharge. For V, Nb, Ta cathodes deuterium transfusion did not produce any detectable effect on the tritium production rate R. For Mo cathode it led to about 2 times increase in R. For the same cathode the hydrogen transfusion resulted in decrease of R.

The other group (Karabut, Savvatimova et al.) measured both transmutation phenomenon and excess heat generation in gas discharge [3]. In Pd cathode after irradiation by D, H, Ar, Xe ions in glow discharge they observed many new elements: Na, Mg, Ti, Fe, Ni, Cu, Rb, Zr, Nb, Ag, etc. with relative concentration 10^{-6} - 10^{-8} of the matrix element (Fig. 2). The amount of new elements was shown depending upon the kind of gas used: it was the largest for D and the smallest for Ar and Xe.

In the other experiment they used the continuous flow calorimeter to measure heat effect, and various detectors to record reaction products. The results are: (a) excess heat up to 20W with $\Delta Q/Q$=115-190%, (b) neutron emission, (c) gamma emission with energies 100-3000 keV up to 1000 sec after switching off the current, (d) beta emission from the samples with energy 1-1000 keV and intensity of (1-10)/s. These effects were found correlating with production of stable isotopes up to 10^{16} - 10^{17} atoms during 10^4sec run, and with atomic mass numbers from 4 to 140.

The new results with glow discharge have been also presented by the group from the Tomsk Polytechnical Institute [4]. In the series of their experiments samples of Ni, Nb, Pd, Ti and stainless steel were stimulated with D or H ions by glow discharge, HRF discharge or electrolysis of D_2O+LiOD. Neutron signals of up to 100 times the background level and acoustic signals were recorded intermittently. Specific feature of the experiment is "after switch-off" detection of signals of gamma and phonons 40 s to 10 min after the switch-off the discharge voltage with no neutrons at all.

2.2 **Nuclear phenomena in deuterated ferroelectrics.**

The idea of using strong electric field of ferroelectrics (FE) was proposed in [5], and later specified [6] in the form of polarization reversal. Last years FE became popular materials in CF studies in Russia.

In experiment performed at the Russian Peoples' Friendship University in collaboration with the

Theoretical Physics Department of the Russian Academy of Sciences [7] $LiTaO_3$ and DTGS crystals $(ND_2CD_2COOD)3D_2SO_4$ were used. After preparation by degassing at 450-500°C in a vacuum of 10^{-5} Torr, the samples were saturated with deuterium at a pressure of 0.6-1.2 atm. The deuterated samples were subjected to a.c. field at operated time of 10 min and total neutron yield was recorded. The control experiment consisted in the neutron background detection before, during and after operating cycles. The neutron emission activity of $LiTaO_3$ sample was found to be (0.30 ± 0.12)n/s for the thick (10x10x5mm) and (0.49 ± 0.17)n/s for the thin (5x5x1mm) samples (Fig.3). This corresponds to the fusion rate of $(6.0 \pm 2.4)10^{-22}$ and $(7.8 \pm 1.4)10^{-21}$ reactions per second for the thick and the thin samples respectively, the higher rate being seemingly due to higher electric field (70kV/cm) which is more favorable for polarization reversal.

The group of the Institute of Physical Chemistry presented results on the experimental study of the influence of thermal neutron background level, D-H substitution and crystal mass on a neutron emission intensity in ferroelectrics in the vicinity of the Curie temperature T_c [8]. About 40 thermal cycles were done with DKDP crystals (DTGS) near T_c, and a decrease and an increase of the neutron emission was measured at different phases of the cycle (Fig4). A remarkable phenomenon, the shift of T_c by 4°C under irradiation by a very weak neutron flux (0.1-$10 n/cm^2 s$) was reported.

2.3 **CF in tungsten-bronze structure and in protonic conductors.**

The group from the Institute of High-Temperature Electrochemistry (Ekaterinburg) submitted to the Conference the following results [9].

(a) Using X-ray measurements before and after the experiment they claimed the observation a correlation between neutron activity of the Na_xWO_3 samples and their structural changes. The neutron signals were detected only in those samples, where changes from perfect to mosaic structure have been found in the surface layer after the experiment.

(b) They also confirmed the earlier results of the Liaw's group on excess heat generation in the electrolysis of molten salt eutectics. The specific feature of this experiment was parallel electrolysis in two cells: one with LiD and another with LiH, which allows them to measure the temperature difference in D- and H-electrodes. The excess heat was found at elevation of current density from 4 mA to 290 or 420 mA.

(c) Electrolysis in D and H atmosphere at elevated temperature (200-800 C) was studied with SrCeO3 ceramic tablets. An excess heat $\Delta Q/Q_{in}$ = 10-1000% was measured in correlation with phase transition. However, the absolute value of the excess power was very small $\Delta P = 2 \cdot 10^{-3}$ W), which may rise some preoccupations.

Some new results on CF with Na_xWO_3 have been also reported recently at the RCCFNT4 [10]. In this experiment the single crystal multi-layers (1mkm thickness) of Na_xWO_3 (x=0.8 to 0.9) were deposited on the surface of tungsten wire of a diameter 200 mkm from Na_2WO_4+WO3 melt at a high temperature. For loading of these structured films with sufficient value of deuterium this wire was dragging out at a very small velocity through the electrolyte with a heavy water. Neutron bursts of 20-25 neutrons were measured.

2.4 **CF studies during electrolysis.**

The Lebedev Physical Institute group have investigated particle emission from PdO-Pd-PdO and PdO-Pd-Ag samples [11], prepared and electrolytically loaded with D or H in the Institute of Physical Chemistry.The main feature of this experiment was the study of charged particles emission by 3 different methods: a) by plastic scintillation detector, b) by CR-39 plastic track detector, and c) by Si-SSD. The proton and neutron emission were observed in the process of deuterium escaping from deuterized samples (see an example of the signal in Si-SSD in Fig.5).

The ratio of proton-like and neutron-like events was estimated as about 1. The charged particle emission was also observed in the experiments with light water, when hydrogen was escaping from hydrogenized samples. These particles may be interpreted as protons and/or alpha-particles. The influence of the weak thermal neutron flux (emitted by Cf-source throughout a moderator) on "CF" process in the samples loaded with D was also investigated, and the fast neutron flux emitted from deuterized samples exposed by thermal neutrons was found to be 300 times more of unexposed samples.

The emission of neutrons and gamma were observed by the "Erzion" Center group (Moscow) in solution H_2O+1.5M LiOD with Ti, Ni, and Zr cathodes, and Pt anode [12].

The other group [4] detected neutrons, gamma and acoustic signals during electrolysis of D_2O on Ni and stainless steel cathodes. In some cases the correlation between the signals was recorded.

The influence of tritium on hard emission generation during electrolysis of heavy water on Pd cathode was studied by the group from Semenov Institute of Chemical Physics [13]. The presence of tritium in the electrolyte was found resulting in sharp increase of hard emission (mainly neutrons) in comparison with the experiments without tritium, which is attributed by the authors to the CF reaction T + D --> He + n. The full reproducibility of the results is claimed.

2.5. **Miscellaneous.**

(a) Nuclear transmutation of isotopes in growing biological cultures was reported by the collaboration of Kiev Shevchenko University, Moscow State University and Gamaleya Institute of Epidemiology and Microbiology [14]. They claimed the CF transmutation Mn55--> Fe57 in nutrient medium based on a heavy water.

(b) The other amazing result reported by the Kiev group [15] is the "Discovery of the phenomenon of controlling and changing probability and time of spontaneous decay and gamma-transmutation of excited nuclear states". Both results are too puzzling to comment them.

(c) Transmutation of elements via nuclear mechanofusion. In an experiment of the Institute of Physical Chemistry group [16] graphite powder with and without 5% H_2O or 5% D_2O was rotated in a drum containing stainless steel balls. An increase of C^{14} concentration was recorded. The other group from the Russian Peoples' Friendship University failed to detect neutron emission in experiment with mechanical demolition of deuterated ferroelectrics [17].

(d) A large collaboration of 5 research groups ("Erzion", "Vizor", "Energiya", Institute of Physical Chemistry, Institute of Nuclear Physics of Moscow State University) has done a series of experiments with the hydro-aggregate "Yusmar" [18]. Electrolytic solutions H_2O+(LIOH,D_2O, H_2SO_4) and organic solutions were compressed cyclically with different periods of time. Tritium excess [(5.0 ± 0.7)Bq/ml], neutrons up to (304 ± 21)n/2.5h and radiocarbon excess [(3.0 ± 0.03)Bq/ml after 1.5h were registered during the aggregate running.

3. **Theory**

All published models aimed to understand the CF phenomena are based on some assumptions. Depending on how much radical these assumptions are we will divide (somehow arbitrary) theoretical papers on CF, published recently by Russian authors, into three categories.

Three papers published last year by the Lebedev Physical Institute group [19] fall into the first category being based on well known phenomena. In the first one the authors call attention to some physical phenomena related to nonlinear influence of electric field on current carrier mobility, which could manifest themselves in CF experiment. Similar phenomena are well known in gas and semiconductor plasma physics. In electrolytic or gas discharge experiments they could result both in heat effects and triggering off nuclear reactions in highly loaded hydrides. The arguments are presented that at high x>1 PdH_x can transform into a new phase with semimetallic (semiconducting) properties. It is shown that in this case the negative differential conductivity can arise leading to various current instabilities of the Gunn-effect type, current filamentation, pinch effect, etc. which could initiate nuclear reactions due to the ion acceleration or current compression, and also imitate excess heat effects.

In the second paper it is emphasized that all CF experiments with ferroelectrics have been carried out so far in far from being optimal conditions, and some possibilities to increase the reaction rate are suggested. The conditions are indicated under which strong electric field in ferroelectrics can exist over large distances (10^{-4} cm) producing very effective ion acceleration.

The third paper shows the possibility of nonequilibrium heating of electron and vibration degrees of freedom of crystals and heterogeneous solids during pulsed laser pumping. In this case the effective temperature for selected modes may exceed 10^9 K. Changing of some properties of solids is expected. Possible applications include: laser "cleaning" of crystals off defects produced during crystallization process, heterogeneous catalysis of solid state chemical reactions and diffusion processes, and possibly the initiation of nuclear reactions in solids.

The less orthodox claims are presented in the second group of papers.

An explicit non-relativistic analysis of the Barut-Vigier model is presented in [20]. The model is based on the assumption of existence of a new "tight" quantum orbit in the hydrogen atom with energy of few keV.This orbit is confirmed in [20] using the approximation which neglects the anomalous magnetic moment of particles.

In [21] the origin of CF is attributed to some hypothetical nuclear-chemical transformations involving electron capture by deuteron with formation of "bineutron", or three-particle electron capture with participation of D and H nuclei. The solid state matrix acts as a nonlinear active medium, and CF occurs presumably in "submicrocracks".

Yu.Bazhutov et al. continue to develop various aspects of their "erzion" model. (The "erzion" is a hypothetical heavy stable particle which could catalyze CF). In the new papers [22] they discuss transmutation of elements in radioactive wastes of nuclear reactors and conclude that nearly all radionuclides may be utilized. The other paper deals with the catalytic nuclear transmutation, ball-lighting and some other anomalous geophysical phenomena, which according to the authors, could be explained by "erzion".

And finally, the most radical approach to the CF explanation is presented by L.Sapogin [23]. It is based on his earlier research in the field of unitary quantum theory. A particle is described not as a point-like object as in conventional quantum mechanics, but as a wave packet. It periodically spreads out across the space (disappears) and assembles (appears), the envelope of the process coinciding with the conventional quantum mechanics wave function. On this basis the author is able to explain the tunnel effect, the suppression of the proton channel in CF, the excess energy and nuclear transmutation.

4. Conclusion

In spite of considerable efforts during 7 years after the first announcement, CF still remains to be rather illusive. This is especially relevant to the "on-line" registration of nuclear products (neutrons, protons, gamma). Neutron bursts are now doubtful. Other signals are reported typically at the level of less than 1.5-2 times the background. The experiments reported by two groups from "Luch" with accumulation of tritium and transmuted elements seem to be the most powerful, reproducible and clear (many standard deviation above the background level) proof of CF. However, the attempts to replicate these results by P.Hagelstein's group from MIT failed for 3 years.Well, one can say that both Russian groups have a 20-year experience in glow discharge experiments. But the consulting with an ex-Luch expert, Dr. Ya.Kucherov, did not helped to solve the problem. (P.Hagelstein, private communication). During the Conference the negotiations started on a possible collaboration between Hagelstein's and Romodanov's groups, which hopefully may bring a conclusive result. The situation in theory is also unclear. No theoretical formulation of CF has succeeded so far in quantitatively or even qualitatively description of reported experimental results. But some new claims have been presented and it remains to verify how justified they are. In any case this activity could clarify many problems related to CF and beyond and may initiate new experimental approaches.

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References

1. V.A.Tsarev, Proc. ICCF2, Como, 1991, 319; Proc. ICCF3, Nagoya, 1992.
2. V.A.Romodanov et al., papers P-045, P-070, P-071 submitted to this Conference.
3. A.B.Karabut et al., papers P-001, P-002, P-003, P-067 submitted to this Conference.
4. I.Chernov et al., reports at the RCCFNT3 and RCCFNT4, see Reviews H.Kozima, Cold Fusion 15, 18 (1995), Cold Fusion, 1996.
5. P.I.Golubnichii et al., Dokladi Akademii Nauk 307, 99 (1989).
6. A.A.Kouticov, G.V.Fedorovich, Proc. RCCFNT2 p.133 (1994).
7. N.V.Samsonenko et al., paper submitted to this Conference.
8. A.G.Lipson et al., paper P-011 submitted to this Conference.
9. A.L.Samgin, S.V.Vakarin et al., papers O-037, P-074 submitted to this Conference.
10. K.Kaliev, V.Filimonov et al., report at the RCCFNT4 (1996).
11. A.S.Roussetski, paper P-046 submitted to this Conference.
12. Yu.N.Bazhutov et al report at the RCCFNT3 (1995) .
13. R.A.Stukan et al., High Energy Chemistry, V.30 (5) p. 343 (1996).
14. V.I.Vysotskii et al., paper TS-007 submitted to this Conference.
15. V.I.Vysotskii et al., paper TS-006 submitted to this Conference.
16. A.G.Lipson et al., Proc. RCCFNT3, p.61 (1995).
17. N.V.Samsonenko et al., report at the RCCFNT4 (1996).
18. Yu.N.Bazhutov et al., paper P-057 submitted to this Conference.
19. Yu.M.Aliev et al., Kratkie Soobsheniya po Fizike 1995, 5/6,68, G.M.Guro, V.A.Tsarev, ibid. 1995, 5/6, 62. V.S.Gorelik et al., Proc. Italian Conf. on Cold Fusion, Siena, 1995, ed. B.Stella.
20. N.V.Samsonenko et al., Phys. Lett. A220 (1996) 297.
21. S.F.Timashev Russian Journal of Physical Chemistry, V.69(8), p.1259 (1995).
22. Yu. N.Bazhutov et al., papers P-058 and P-059 submitted to this Conference.
23. L.G.Sapogin, paper P-072 submitted to this Conference.

Russian Activities

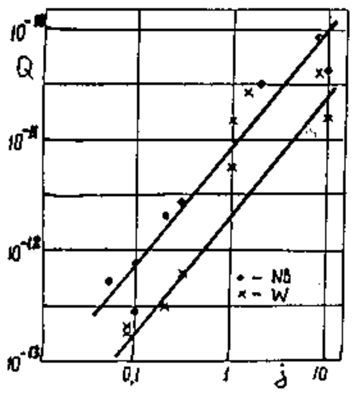

Fig.1

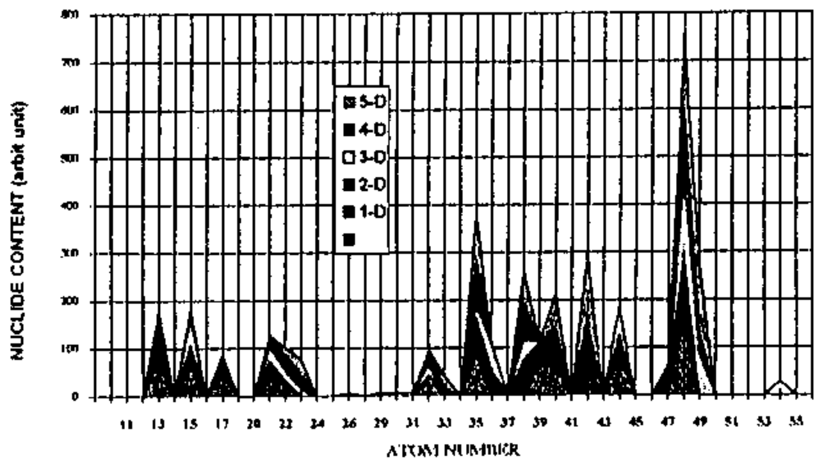

Fig.2

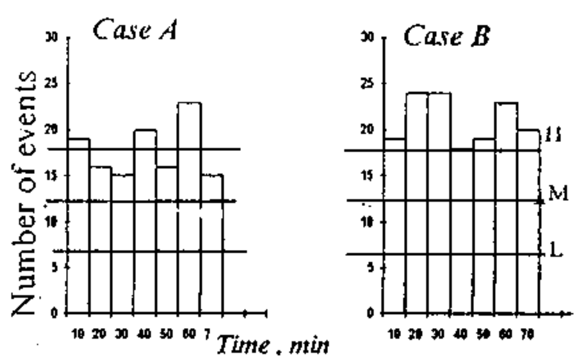

Fig.3

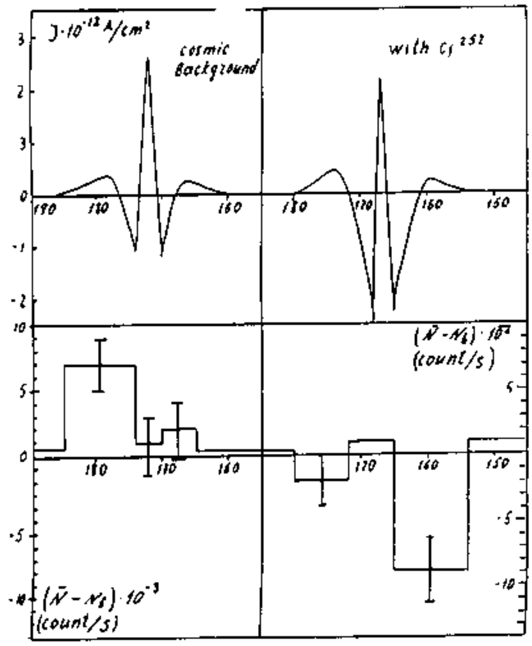

Fig.4

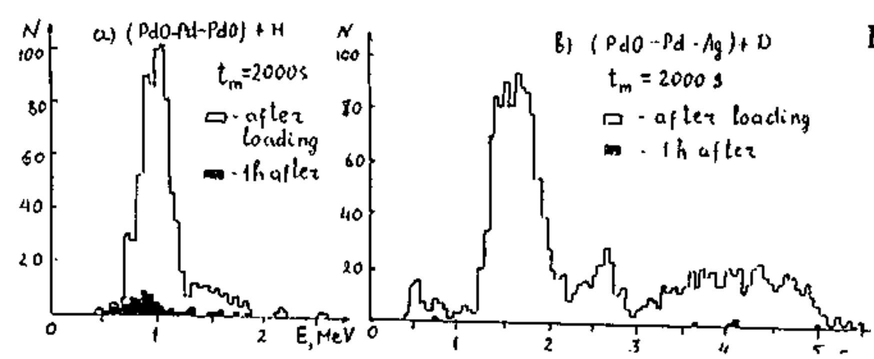

Fig.5

Fig.1 Nuclear interaction coefficient Q (atom/ion) vs j (A/cm^2) [2]
Fig.2 Concentration of new elements on Pd after irradiation by D-ions [3]
Fig.3 Number of events recorded by He^3 detector during 10 min-intervals (A-thick sample)
M - average background level, H and L - the limits of BG variation at 90% CF [7]
Fig.4 Transition the Curie temperature T_c during cooling in correlation with neutron measurements. Left - with cosmic background, right - under irradiation with Cf-source [8]
Fig.5 Signal in Si-SSD from hydrogenized (left) and deuterized (right) samples [11]