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Research Article

Energy Release and Transmutation of Chemical Elements in Cold Heterogeneous Plasmoids

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Abstract

Our main experimental results from excess energy release (COP >1) in cold heterogeneous (nano-cluster) plasmoid are considered and analyzed in this work. These experimental results were obtained by our team during the last 20 years. The main results may be divided into four groups.

(1) Excess energy release behind shock wave in a non-equilibrium heterogeneous plasma and plasma precursor creation before its front was revealed in our experiment. This measured energy is much higher than the electric energy consumed by the plasma, COP$\sim$ 4–10. This excess energy is estimated by measured gas density and pressure behind shock wave, its propagation velocity in plasma, and by using gas dynamics conservation laws.
(2) A systematic study of new chemical element creation in water by cold heterogeneous plasmoids was performed. The plasmoids are created by RF discharge over water surface. The plasmoid's chemical composition is determined by optical spectroscopy. The chemical compositions of water and its sediment are studied by independent diagnostic methods: IR spectroscopy, atomic absorption spectroscopy, ion mass spectroscopy, chemical analysis and micro-X-ray spectroscopy. We observed optical lines of the H, Li, K, Ca, OH-molecular bands, CaO-molecular bands and *unknown molecular bands* inside red plasmoids. The Li concentration and the Ca concentration are increased in a water sample by factor $10^2 - 10^3$. It is very important that the isotopic composition of the lithium is dramatically changed in this experiment. To be precise, it is possible these new elements are created by RF plasmoid in water.
(3) The energy release inside heterogeneous plasmoid in swirl gas flow was measured. The measured COP is about 2–4 in this experiment.

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1. Plasma Aerodynamics and Additional Energy Release in Weakly Ionized Non-equilibrium Plasma

A new branch of science called plasma aerodynamics (PA) was created 30 years ago thanks to a scientific discovery made by Russian scientists [1]. Flow control around flying vehicles and aerodynamic force control by weakly ionized non-equilibrium plasma formations (WINP) are now possible Scientists also observed shock wave dispersion and dissipation in WINP.

A dramatic change of a bow shock wave near spherical projectile in WINP is shown in the shadow picture, Fig. 1. One can see a considerable increase in the shock wave stand off and its dissipation in this picture. It is possible to create a regime of total shock wave dissipation at specific parameters of plasma formation and a specific Mach number. This is important because cold plasma formation with a gas temperature less than $T_{\rm g} < 1500$ K is used in these plasma aerodynamic (PA) experiments. Note that plasma with a gas temperature $T_{\rm g} > 8000$ K should be used in this experiment to explain of the experimental results obtained.

Excess energy release q behind a shock wave in pulse discharge plasma was measured in PA experiments and shock wave-plasma experiments many years ago [1,2]. A typical shadow picture of shock wave structure in WINP is shown in Fig. 2. One can see that there is shock wave splitting (a twofront structure) in this picture. There is considerable acceleration of shock waves in WINP also. Pulse discharge plasma created by preliminary charged capacity is used in this PA experiment. So, it is very simple to measure of maximum energy consumption in plasma by measuring of electric energy of a charged capacity. Specific energy consumption q in plasma is small in this experiment and determined by the following equation:

$$q = \int_0^{t_{\rm rop}} j_{\rm p} E_{\rm p} {\rm d}t \le 0, \quad 3c_{\rm p} T_{\rm g} \equiv 0.3 h_0, \tag{1}$$

where $j_{\rm p}$ is the current density, $E_{\rm p}$ the electric field strength, $t_{\rm rop}$ the pulse time duration, $C_{\rm p}$ the heat capacity, $T_{\rm g}$ the gas temperature, and h_0 is the initial gas enthalpy. The value $E_{\rm p} = U_{\rm d} * /L$ is mean electric field in pulsed glow discharge, where $U_{\rm d}^* = U_{\rm d} - \delta U_{\rm c}$ is mean voltage in discharge gap ($\delta U_{\rm c}$ is the cathode voltage gap), L is the discharge gap length. These values are measures by electric probes and voltage probes in this experiment. Formula (**??**) is simplified in a pulsed discharge. Charged capacity C is used for the glow discharge creation in this experiment. One can estimate the electric energy of this charged capacity $W = {\rm CU}^2/2$ accurately. The plasma volume V is estimated by high-speed frame very simple. So, maximum value q is estimated by the following formula $q = W/V$. The value W is so small that the value q is less than $0.3h_0$ in our experiment.

The measured energy release q behind the shock front was much higher than electric energy consumption q_0 (**??**) in the plasma. A typical COP of 4–10 was obtained in these experiments. Excess energy may be estimated reliably and carefully by measuring of gas density ratio ρ_2/ρ_1; pressure ratio P_2/P_1 behind the shock wave and its propagation velocity in plasma $V_{\rm p}$. Using gas dynamics conservation laws the value q may be estimated by the well-known formula [7]:

$$q = c_{\rm p} T \frac{\gamma - 1}{2\gamma} \left[\frac{p_2}{p_1} \left\{ \frac{\gamma + 1}{\gamma - 1} \frac{\rho_1}{\rho_2} - 1 \right\} - \frac{\gamma + 1}{\gamma - 1} \frac{\rho_2}{\rho_1} \right], \tag{2}$$

where the adiabatic index $\gamma = C_{\rm P}/C_{\rm V} = 1.4$ for air and WINP with ionization degree about $\alpha = N_{\rm e}/N_{\rm a} = 10^{-6}$. Note that air composition is not changed and chemical reactions are absent in this experiment. So, the adiabatic index γ_1 before shock front is equal adiabatic index γ_2 behind the shock front. Energy release q is connected with charge separation and Joule heating on the shock front only in this experiment.

The value $q = 4.2h_0 = 1.5$ kJ/g is estimated by this formula (2) and measured values (ρ_2/ρ_1 and P_2/P_1). So, this value q is higher than the initial value $q_0 = 0.3h_0$ by a factor of 10. So, there is additional energy release behind shock wave in WINP.

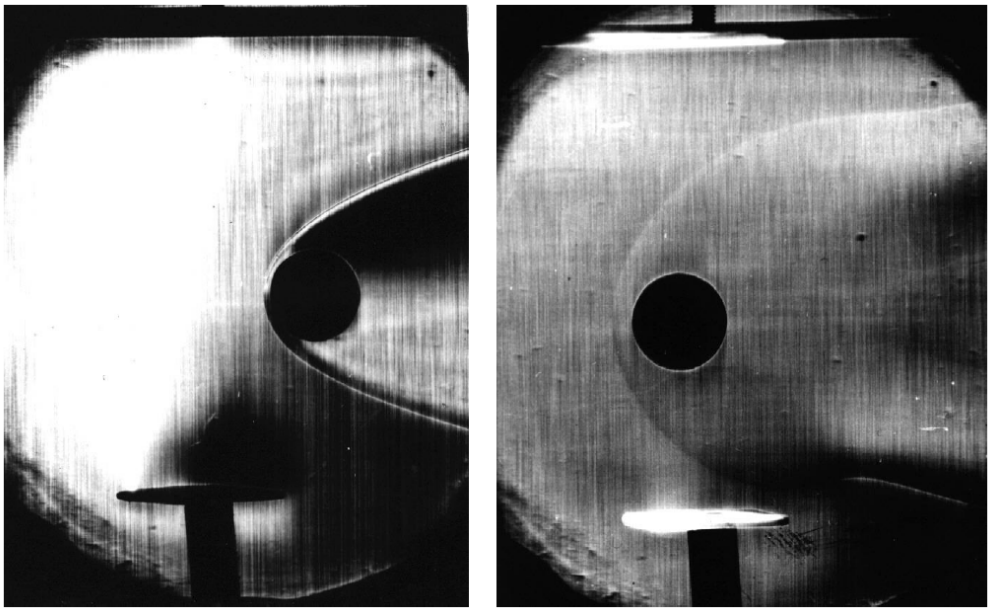

Figure 1. Shadow pictures flow around spherical projectile in WINP. Static pressure, $P_{st} \sim 40$ Torr, model's diameter, 20 mm, initial model's velocity, $V_0 \sim 2000$ m/s, and Pulse glow discharge, $j_d \sim 40$ mA/cm^2.

It is important to note that maximum change of shock wave parameters were obtained near the cathode region where *erosive nano-cluster creation takes place*, to be precise.

High value q (close to (2)) was obtained in plasma-ballistic experiment also, Fig. 1 [1].

2. Transmutation of Chemical Elements in Water Cluster Plasmoid

In the present work, a systematic study of new chemical element creation in *water cluster plasmoid* was performed [5]. This plasmoid is created by capacity type RF discharge (torch RF discharge) over the water surface. The experimental set up used in this experiment is shown in Fig. 3. This setup consists of a reactor (**??**), Tesla's HF generator (4,5) and diagnostic instrumentation (high-speed camera, optical spectrometer and ion mass spectrometer). Reactor is manufactured from Quartz glass. Its inner diameter is varied from 20 up to 80 mm. The reactor height H is about of 50–200 mm. Quartz tube thickness is about of 3–5 mm. Distillated water fills this reactor. Maximum water depth equals to 1/3 H. Tungsten electrode (2) is arranged under the water surface (10–20 mm below the surface). Tested metal target (7) from different material (aluminum, copper, nickel and others) is arranged in top region of this reactor in some experiment. The compositions of the metal sample, water, Quartz glass, and the lower electrode are analyzed by different diagnostic methods, before and after the experiment. The reactor is installed in a cylindrical HF electrode (6) connected with a ball electrode (6).

The experimental conditions are as follows: HF frequency, 0.5 MHz, HF power, 0.5–5 kW, output voltage, 40–60 kV, operation regime:-continuous and modulated, operation time <10 min.

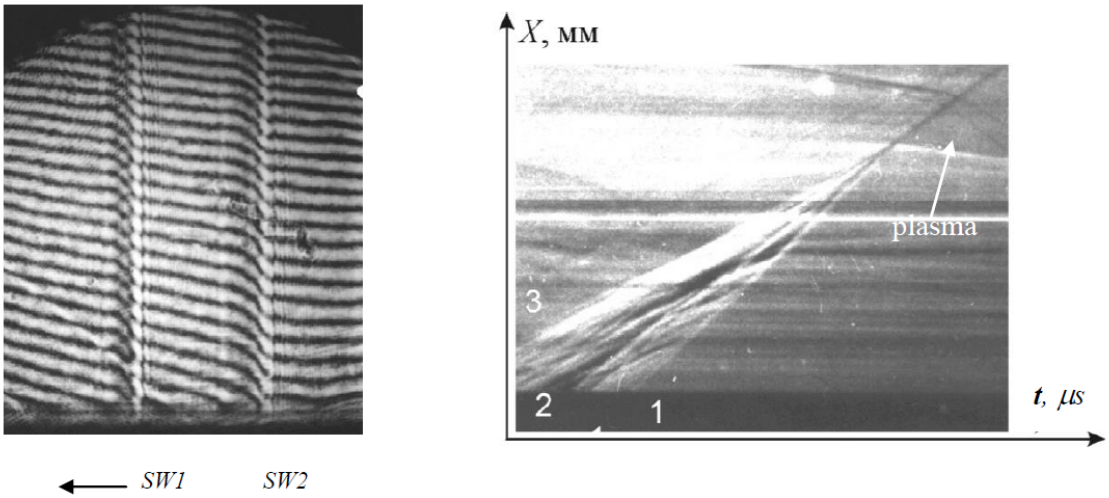

Figure 2. Shock wave structure in WINP (*left*, interferometer picture) and its scan shadow picture obtained by streak camera,$V_0 \sim 900$ m/s, static pressure, $P_{st,0} \sim 20$ Torr, Air, pulse glow discharge, $j_d \sim 30$ mA/cm^2.

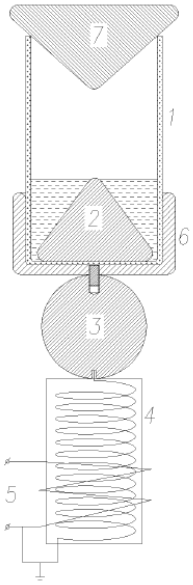

Figure 3. Schematic of experimental set up. 1- Quartz tube, 2- conical RF electrode, 3- ball RF electrode, 4, 5- HF Tesla's generator, 6- RF cylindrical electrode, and 7- metal tested sample.

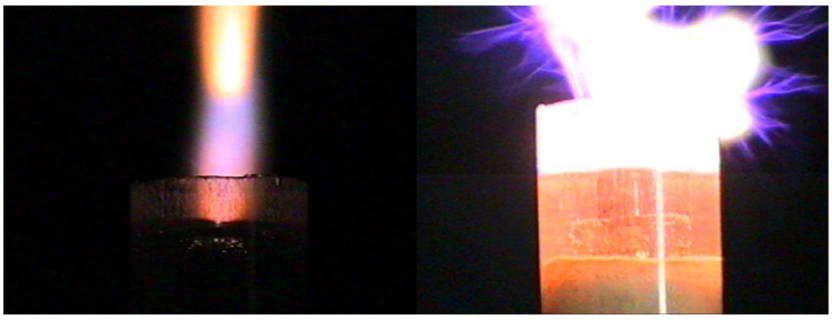

Figure 4. Water cluster plasmoid created by HF torch discharge. Non-stable regime (*left*). Stable regime of plasmoid's creation (*right*). Reactor diameter, 60 mm. .

2.1. Experimental results

A red water cluster plasmoid created by HF torch discharge over water surface is shown in Fig. 4. The typical plasmoid's diameter is equal to 2–6 cm. This charged plasmoid has negative electric potential about – (4–8) kV. This potential is measured by electric probes. One can see that there is a streamer corona discharge around this charged plasmoid, Fig. 4 (*right*). It is shown that a red plasmoid is created inside blue torch HF discharge (the blue color is connected with OH-radical radiation).

2.2. Optical spectra in heterogeneous plasmoid

The plasmoid's chemical composition was studied by optical spectroscopy. The typical optical spectrum from cluster plasmoid is shown in Fig. 5. One can see the OH- radical molecular band, the Na-optical atomic lines, the Li -optical atomic lines and non-determined molecular bands X1 and X2. The optical lines of CaO-molecule, Ca I, Ca II, K, and H atoms are recorded in plasmoid also at different operation time $T_{\rm p}$ of HF generator. It is revealed that these optical lines appear and disappear at definite operation time intervals $\Delta T_{\rm p}$. The intensive H-lines and the OH-lines are recorded in the beginning of the experiment at $T_{\rm p} < 10$ s. Then the Na-lines and the K-lines are recorded at the time delay $T_{\rm p} > 3 - 5$ s after the discharge begins. The optical Li-line ($\lambda = 671$HM) and optical molecular bands X1, X2 appeared in the optical spectra at the time delay $T_{\rm p} > 5 - 10$ s. It is remarkable that the Na-line and the K-line disappeared at the same time period $T_{\rm p} > 5 - 10$ s simultaneously. Then the Li-line disappeared and bright Ca I-line and Ca II-line were recorded. The typical time evolution of the Li-line intensity is shown in Fig. 6. One can see that the Li-line dissipated finally at the time delay $T_{\rm p} > 60 - 100$ s. Vibration temperature $T_{\rm V} \sim 4000$ K and rotation temperature $T_{\rm R} \sim 2000 - 3000$ K are determined by processing of the recorded OH-optical spectrum. Electron concentration is about $N_{\rm e} \sim 10^{13} - 10^{14}\,{\rm cm}^{-3}$ estimated by processing of the H_β, H_α-lines. So, a hot charged cluster plasmoid is created in this experiment.

2.3. Chemical analysis of metal sample and water sample activated by plasmoid

The chemical compositions of the water and its sediment were studied by various independent diagnostic methods (IR spectroscopy, atomic absorption spectroscopy, ion mass spectroscopy, chemical analysis, and micro-X-ray spectroscopy). It was revealed that the Li-concentration and the Ca-concentration are increased *n* the water sample by factors of 10^2–10^3 (see Table 1). It is important to note that the Li-concentration of activated water is very high

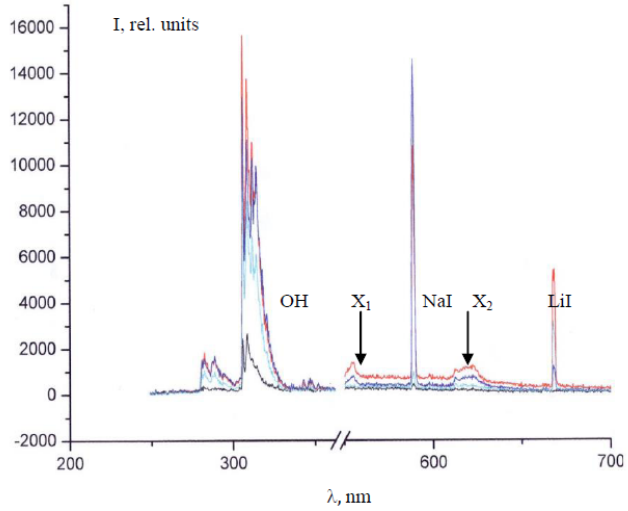

Figure 5. Optical spectrum of heterogeneous plasmoid. Operation time 10 s .

$\sim$ 1 mg/l at $T_{\rm p} < 60$ s and very small < 0.01 mg/l at $T_{\rm p} > 60 - 100$ s. So, one can suppose that the lithium is an intermediate element of chemical transmutation in the water reactor.

It is important to note that the isotopic composition of the lithium dramatically changed in this experiment. The initial ratio $\rm Li_7/Li_6 = 13.192 \pm 0.004$ (initial sample) is increased up to the ratio $\rm Li_7/Li_6 = 18.996 \pm 0.012$ (activated sample). Note that the lithium atoms and the calcium atoms are not measured in quartz tube wall of plasma-chemical reactor. So, it is possible these new elements are created by RF plasmoid in water. We observed bright red flashes (luminescence) inside water at a stable plasmoid creation regime. The typical frequency of these flashes is about of

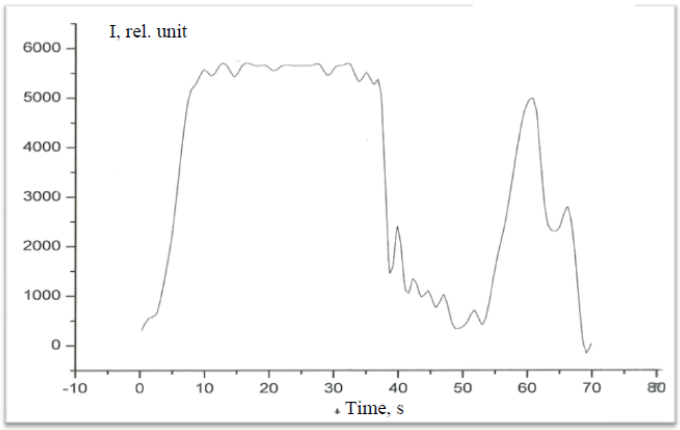

Figure 6. Time evolution of the Li-optical line $\lambda = 671$ nm in heterogeneous plasmoid.

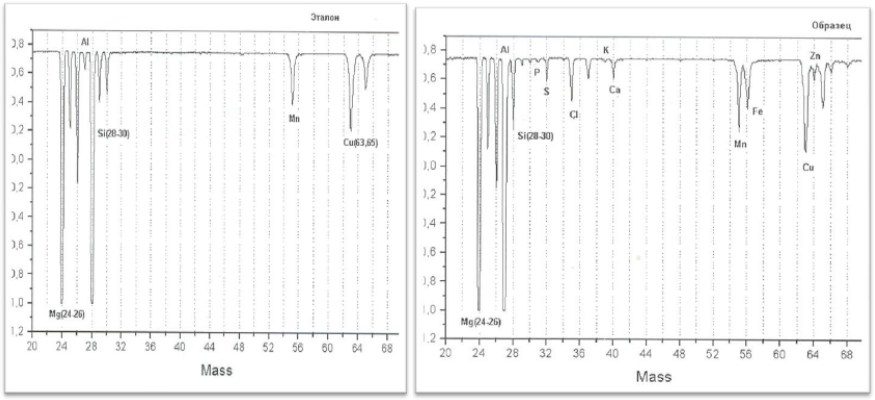

Figure 7. Ion mass spectrometer spectrum of aluminum alloy before experiment (*left*) and after (*right*). Time activation 10 min .

Table 1. Atomic absorption analysis of water sample

	Concentration (mg/l)	
	Li	Ca
Initial water, non-activated by plasmoid	< 0.01	2.2
Tested water, activated by HF plasmoid	0.8	64.7

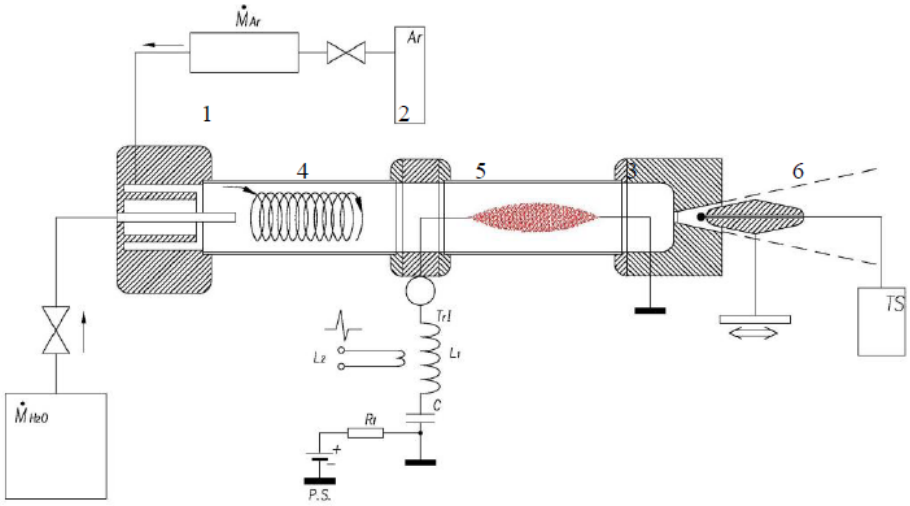

Figure 8. Schematic of experimental set up PVR. 1- swirl generator, 2- argon high-pressure tank, 3- nozzle-cathode, 4- Quartz glass tube, 5- anode, 6(TS)- valve with thermocouple, $M_{\mathrm{H_2O}}$- water steam generator, and M_{ar}- mass argon flow meter.

1–10 Hz (Fig. 4, *left*). The composition of a metal sample activated by heterogeneous HF plasmoid was analyzed by ion mass spectrometer. The typical ion mass spectra of aluminum alloy sample before its activation by plasmoid and after it are shown in Fig. 7. One can see creation of number of new chemical elements (such as phosphorus, sulfur, chlorine, calcium, iron, and zinc) in this mass spectrum. These elements are absent in the initial metal sample, initial Quartz tube and water.

So, *new chemical elements and changes in their isotopic compositions by cluster plasmoid* are created in this experiment. Many of new elements (lithium, potassium, calcium, ...) are intermediate ones. They are created by a plasmoid at definite time delay $T_{\rm p}$ and then these elements are transmuted to the new ones.

3. Energy Release Inside Heterogeneous Plasmoid in Swirl Gas Flow

A new step of our research on heterogeneous plasmoid physics has been made possible by support from the limited liability company "New Inflow". A new plasma vortex reactor (PVR) was designed and then improved on the basis of experimental background described above. *Heterogeneous metal cluster plasmoid* is created by combined discharge (HF+DC) in various gas flows. High value COP $= 2-10$ is obtained in this PVR, to be precise [6]. Detail experimental results obtained in this PVR are considered in this work.

A schematic of the PVR is shown in Fig. 8. Experimental conditions are as follows: argon–water steam mixture $= 1:1$, mass gas flow rate $<$10 g/s, gas flow Mach number $M < 0.2$, static pressure $P_{\rm st} < 2$ bar, mean electric power consumption $<$1 kW, mean thermal output power $<$10 kW, and the erosion electrode mass $<$1 mg/s.

A heterogeneous metal cluster plasmoid (HP) created by combined discharge in swirl flow is shown in Fig. 9. It is revealed that this plasmoid consists of many metal charged micro-droplets and metal nano-cluster halos around them (created by cathode electrode's erosion). The typical negative electric potential of these particles is about –(2–4 kV). Its value is close to the cathode electric potential.

We determined that these nano-clusters absorb hydrogen atoms very effectively. An analysis of optical spectra proves this conclusion. The measured gas temperature of this plasmoid is about 2000 K.

It is important to note that a high value COP of 2–10 is obtained in swirl flow in this PVR. The A COP of 0.5–0.7<1 is obtained in straight gas flow (non-swirl flow). So, swirl flow plays a very important role in excess energy release.

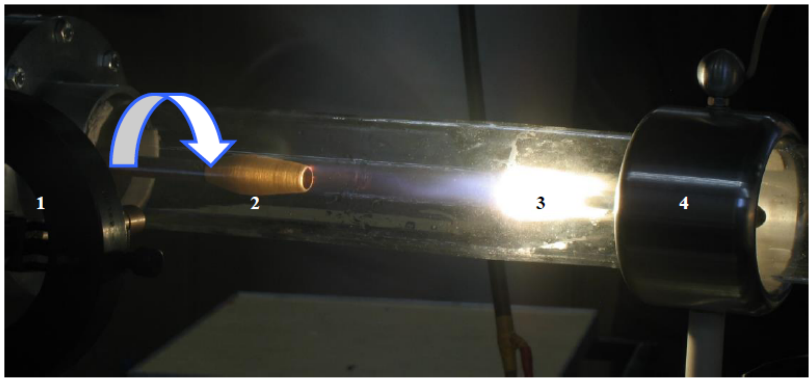

Figure 9. Heterogeneous plasmoid in PVR. Mixture: argon - water steam= 1:1. 1- swirl generator, 2- water vapor injector-anode, 3 – plasmoid, and 4- cathode.

We observed chemical transmutations in this cluster plasmoid. The transmutations may be connected with LENR. Optical spectra, ion mass spectra, soft X-spectra, stimulated α-radioactivity of activated Bi-electrodes prove this conclusion [6].

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