Experimental observation and analysis of action of light magnetic monopoles on multilayer surfaces

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ABSTRACT . The mechanism of creation of hollow macroscopic periodic channel formed on a surface and in a volume of a MDS-structure during experiments with a high-current vacuum-tube diode at collapse conditions in anode is studied. It is shown that the reason for the appearance of such a trajectory can be the interaction of a magnetically charged particle with paramagnetic and diamagnetic surface layers of the MDS-structure. Particles with magnetic charge can be formed during the shock action of a high-current electron beam and the subsequent self-compression of the frozen magnetic field of the beam. It is shown that the great specific energy release, $dQ_{tot} / dl \approx -10^6 GeV / cm$, spent on the formation of this channel can be due to the processes of nuclear synthesis which are occuring with participation of MDS-structure surface nuclei stimulated by magnetically charged particles. It is shown that these particles have small mass (much less then 10^{-22} gram) and are, most likely, light magnetic monopoles as proposed by George Lochak.

1 Introduction

From 1999, the staff of Kiev Electrodynamics Laboratory "Proton-21" has performed about 15.000 successful experiments on the formation of a superdense state of many targets (state of electron-nucleus collapse [1-3]) with the associated fundamental transformation of nuclei with the help of a high-current electron driver in the system analogous to a high-current high-voltage pulse diode.

During numerous experiments at “Proton-21” traces of ordered thermo-mechanical impact on surfaces of MDS (“metal-dielectric-semiconductor”) targets, distant from the collapse zone, were recorded. By their configuration, these macrotracks are analogous to those observed on photoplates and presented in work [4]. But the energy spent in the formation of the former turn out to be by many orders higher. The origin of these macrotracks can be ascribed to none of the well-known particles. Below, we present the results of the analysis of the characteristics of these macrotracks and the properties of particles (particles with magnetic charge) which can form macrotracks.

2 Identification of a periodic hollow macrotrack

The mutual arrangement of the main elements of the experimental setup is shown in Figure 1.

The passage of the electron beam described as a high current pulse $J(t)$ between the cathode and anode leads to the appearance of an azimuthal magnetic field $H_{\theta}(r)$. These cathode and anode were produced from chemically pure *Cu* (purity of 99.99%),

Under the action of the pulse current, a zone of collapse of the anode substance is formed in the anode [1-3]. A target was positioned at a distance of about 10 cm from the collapse region, composed of a standard *MDS*-structure consisting of a *Si* plate covered by both a thin layer of SiO_2 and a thicker layer of *Al*. On the surface of *Al*, we have found a very thin film of oil compounds (*H*, *C*), whose origin is related to the operation of an oil vacuum pump. The registered object was a macroscopic hollow track (channel) in the form of an oscillating trajectory with a constant period $\Lambda \approx 60$ µm. This track deepens periodically in the target volume through the *Al* layer (and partly through SiO_2) and appears on its surface, by simultaneously oscillating with an amplitude of about 20 µm parallel to the target surface. The total length of the continuous part of the track is $L \approx 2000$ µm, its width is 3.5 µm, and its thickness is about 1.3 µm (approximately equal to the *Al* layer thickness). On the target surface near the places of the periodic appearance of the track, characterised by a volume of melted and then solidified Al, a small amount of solidified *Si* is present. The direction of the symmetry axis of the trajectory of the main extended track (consisting of two segments) corresponds to the vector of the azimuthal magnetic field.

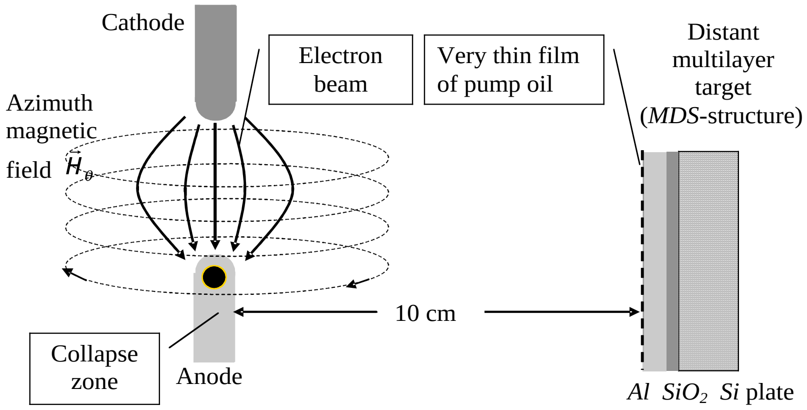


Figure 1.General scheme of the experiment

The general view of the *MDS*-structure surface with an oscillating track and the separate fragments of the track on the surface and in the volume of *Al* coating the *Si* substrate are given in Figures 2 - 4. On Figure 5 the fragment of the area of reflection of the unknown particle on the surface is given.

It follows from Figures 2 and 3 that the track is present only in those spatially separated regions of the target surface (regions 1 and 2), where the *Al* coating is present on the surface. Moreover, the track on these two regions was the obvious continuation of the trajectory of a single moving nonidentifiable particle. At the same time, we see no evidence for the interaction in space between the two regions with *Al* coatings. We note that the *Al* layer is paramagnetic, and the two remaining layers of the *MDS*-structure (*Si* and SiO_2) are diamagnetic. Thus, the strong thermo-mechanical action occurred only in the paramagnetic region. This effect is clearly demonstrated by Figure 4, where we see the inlet of a track on the end surface of *Al*.

The volume and mass of melted *Al* in the region of the macrotrack are, respectively, $V_{Al} \approx 10^{-8}$ cm^3, $M_{Al} \approx 2.7.10^{-8}$ g. The minimum energy which must be spent for the heating and melting of *Al* in the volume of the macrotrack is

$$Q_{Al} = (C\Delta T + \Delta H)M_{Al} \approx 1.5.10^{-5}\,J \approx 10^{5}\,GeV \qquad (1)$$

With regard for the additional energy spent for the heating and ejection of *Si*, the heating of the remaining unmelted part of *Al*, and the ionization of all the products in the region of the macrotrack, we can estimate the total energy as $Q_{tot} \approx 2.10^5$ GeV. The specific energy release is very great

$$\frac{dQ_{tot}}{dl} = -\frac{Q_{tot}}{l} \approx 10^6\ GeV\ /\ cm \tag{2}$$

We note that results (1) and (2) differ by 10^6 times from the data presented in [4]. Below, we will show that the simple braking of particles (including those with magnetic charge) cannot ensure both the energy release (1) and (2) and the observed form of the tracks.

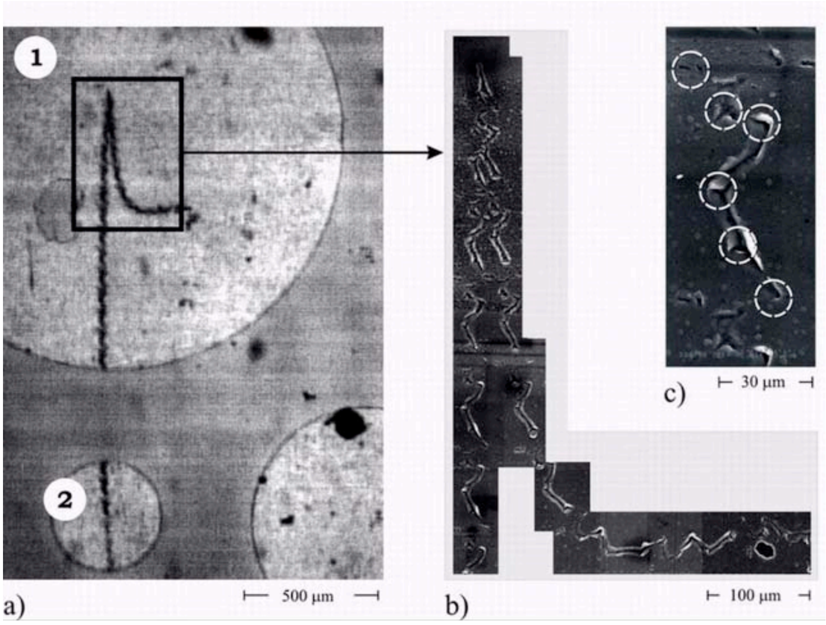


Figure 2. a) The general view of *MDS*-structure with the tracks;
b) and c) - fragments of track, 1 and 2 - thin *Al* layers on *Si* surface.

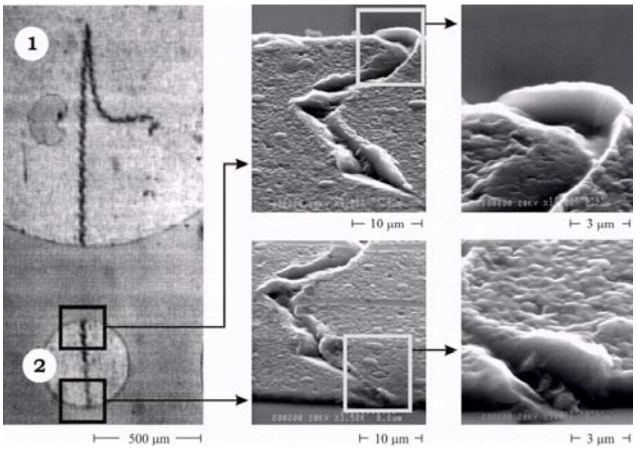


Figure 3. Fragments of a track on the surface of aluminium in area 2 at different magnification. Periodical "canyon" is the result of action of unknown particle.

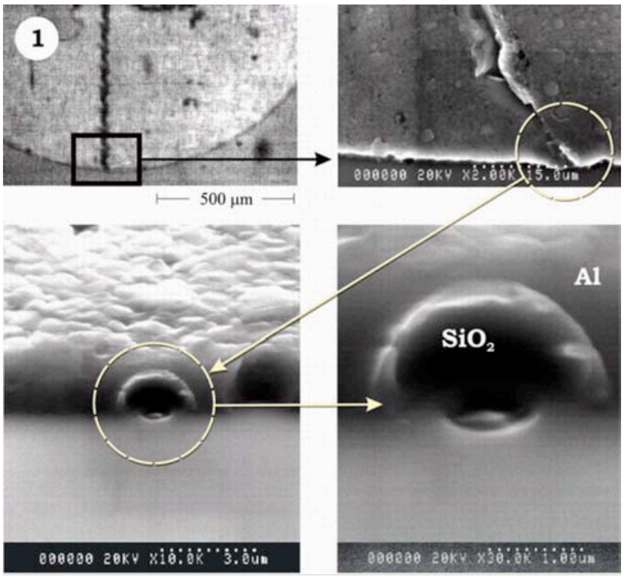


Figure 4. The photos of the same fragment of the track. Two last photos present the inlet of track in volume of a SiO_2 layer.

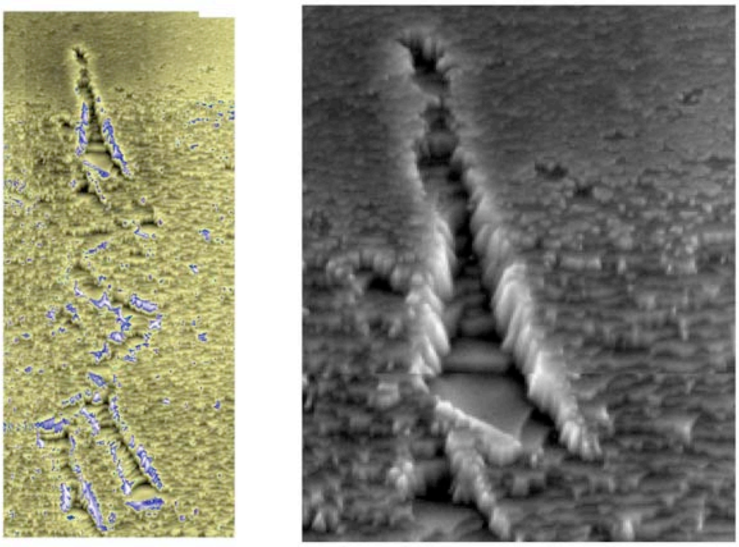


Figure 5. Fragments of the area of reflection of unknown particles on the MDS surface (area 1 on the Figures 2 and 3).

The natural question arises: Which particle can form such a strictly ordered track?

The invariable value of the period of oscillations of the trajectory of the type of a "caterpillar trace" and the identical character of damages of the *Al* surface in the limits of all the parts of the track testify to the fact that the average linear velocity of the nonidentifiable particle along the entire trajectory was constant. With regard for all the features of the trajectory and the great energy release it becomes obvious that the formation of such a trajectory can be related to two scenarios:

- The target surface has interacted with a particle possessing a great kinetic energy W_k which exceeds the quantity Q_{tot} by many times, and, therefore, the great energy release dQ/dl did not affect W_k, the character of the motion and interaction of the particle (e.g. this particle consisted from 10^{16} or more atoms with 0.1 eV moving energy which may cause totally more than 10^5 GeV energy);
- The particle had a small velocity v and a relatively small kinetic energy W_k, and the very great energy release registered in experiments and the

formation of a macroscopic track are related to that the moving nonidentifiable particle stimulated the running of energy-gained nuclear reactions along the trajectory of motion.

The first scenario is logically contradictory and does not agree with experimental data. This is conditioned by the fact that a particle with great kinetic energy must have a great momentum. However, this contradicts the fact that the particle changed its own trajectory and the direction of motion frequently and in an ordered way. Moreover, we observe a very sharp change in the direction of motion (by an angle close to 180^0) at a single point. This kind of motion corresponds to particles with small energy and small momentum. But such particles cannot supply the great amount of work necessary to create the fracture of the target surface!

The second scenario seems to be more justified, and we consider it in detail. In the framework of this scenario, the hypothetical particle, whose interaction with the target forms a specific macrotrack, must satisfy a number of requirements:

- The particle must stimulate the occurrence of nuclear reactions with a very great energy release and local fracture of the target;
- The specific energy release stimulated by the particle should be the same along the whole track;
- The particle must not participate in nuclear reactions, i.e. it must come into the reaction zone and leave it in an invariable form;
- The particle itself must affect the formation of its own ordered trajectory;
- Its motion must be different in paramagnetic and diamagnetic media.

It is obvious that such requirements do not allow one to identify the particle under consideration with one of the known neutral particles or particles with electric charge. There are very weighty reasons to assume that such peculiarities of the interaction can be related to the motion of a particle with magnetic charge (it can be one of the modifications of the Dirac monopole). Below, we will consider this hypothesis in detail.

3 3. Peculiarities of interaction of magnetically charged particles with *MDS*-structure

The magnetically charged particles can appear (at least, in principle) in extremely strong magnetic fields, which takes place in a high-current diode in the region of compression of the beam current in the anode volume. In this case, a micropinch is formed, and the magnetic field frozen in the superdense plasma of a spherical plasma layer is compressed to the size of the collapse zone. A minimum value of the elementary magnetic charge was determined by Dirac from the general principles of quantization:

$$\frac{g}{e} = \frac{k}{2}\frac{\hbar c}{e^2},\ k = 0, \pm 1, \pm 2, ... \tag{3}$$

The Schwinger model admits only even values of k in the quantization condition, which leads at once to the minimum charge of a magnetic monopole $g \approx 137e$. When they leave the collapse region, these particles undergo the action of the accelerating azimuthal magnetic field of the current, $H(r) = 2J / rc$, and move along an untwisting spiral round the axis of the current J. For one turn round the current J, the particle can gain the energy

$$\Delta W_{JM} = \oint gH(r)dL = 2\pi RgH(R) = (4\pi g / c)J = 0.05J(\text{Amperes})[MeV] \tag{4}$$

In particular, if the residual current in the diode $J \approx 1...10$ kA, we get ΔW_{JM} = 50...500 MeV. At the orbit radius R = 10 cm, the rate of increase in the energy is

$$\frac{d\Delta W_{JM}}{dl} \approx 1...10\ MeV / cm \tag{5}$$

It is seen that $d\Delta W_{JM} / dl$ turns out as $10^8...10^9$ times weaker than the experimentally registered energy release dQ_{tot} / dl on the target surface. Hence, the released energy cannot be directly related to the acceleration of the magnetic charge by the magnetic field.

Consider the features of the interaction of such particles with a substance. The formula for the specific loss of energy of a magnetic charge

$$\frac{d\Delta W_Q}{dl} = -\frac{4\pi n_e e^2 g^2}{m_e c^2}\ln\left(\frac{4m_e v^2}{< e\varphi >}\right) \tag{6}$$

follows easily from the standard Bethe-Bloch formula for the deceleration of an effective electric charge $Q^* = gv/c$. This formula implies that the ionization losses of a moving magnetic charge do not depend on its mass and depend slightly on its motion velocity.

For an *Al* target ($n_e \approx 7.10^{24}$ cm^{-3}), we get the rate of loss of the energy of particles as

$$\frac{d\Delta W_{Q^*}}{dl} \approx -(30...40)\,GeV/cm \qquad (7)$$

It is clear that the specific energy losses of a magnetic charge due to a deceleration, dW_{Q*}/dl, exceed essentially the rate of increase in the energy $d\Delta W_{JM}/dl$ of the same magnetic charge in the magnetic field (5). At the same time, the specific energy losses (7) of such a charge due to the deceleration are by many orders less than the experimental value (2) of the energy release dQ_{tot}/dl.

Apparently, another, more realistic source of the huge energy released in the formation of a macrotrack should exist. This corresponds to the second scenario. One of the possible answers follows from the observation of a macrotrack. An oscillating macrotrack is a result of the strong thermo-mechanical action on the *Al* layer, which causes the melting and the breaking of this layer and leads to the formation of distinctive channels (holes) periodically "diving" under the layer surface. The upper surface of the *Al* layer turns out to be splashed by drops of melted *Al* and *Si*. In our opinion, the formation of such a trajectory can be a result of the combined effect of forces related to the electrodynamic interaction of a hypothetical magnetically charged particle with the separate layers, present on the *MDS*-structure surface, and the processes coupled with the direct effect of the nuclear reactions related to the magnetic charge on the magnetic properties of these layers.

The outer layer of an *MDS*-target (*Al*) is paramagnetic, and the two inner ones (*Si* and SiO_2) are diamagnetic. The permeabilities of these media are the following:

$$\chi_{Si} = -0.53*10^{-6},\ \chi_{SiO2} = -1.13*10^{-6},\ \chi_{Al} = 1.65*10^{-6},\ \chi_{vacuum} = 0 \qquad (8)$$

A characteristic of the interaction of a magnetic charge with a magnetic field is that any diamagnetic is pushed out from the region where the magnetic field is strong (this is equivalent to the repulsion of the magnetic charge from a diamagnetic), whereas any paramagnetic is pulled in the region with a strong field and, respectively, attracts the magnetic charge. Such an interaction means that the *Al* layer is a potential well for the magnetic charge, and the layers of *Si* and SiO_2 are potential barriers with different heights (if we consider the oblique fall of a particle on the *MDS*-structure surface from the vacuum side). To confirm the reality of this interaction, we determine the height of the effective potential barrier, which corresponds to the surface of a diamagnetic and is able to reflect a particle with magnetic charge, if its kinetic energy in the direction normal to the surface is less than the barrier height

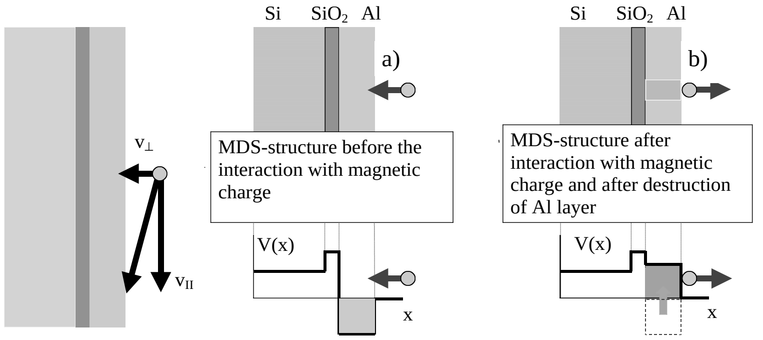
$$\Delta W = 4\pi\chi g^2 / r_0 \tag{9}$$

This value is defined by the difference of the total energy of the magnetic field

$$H_g(r) = g / r^2 \tag{10}$$

of the particle with a magnetic charge g in vacuum and that in a medium with some specific value of the permeability χ. Here, r_0 is the minimum distance from the magnetic charge to the medium, at which the notion of permeability as a mean characteristic of this medium is valid. We may assume that it equals the classical radius of an atom ($r_0 \approx 0.5$ Å). If we take into account the typical value of $|\chi| \approx 10^{-6}$, then the height of the potential barrier for a magnetic charge on the boundary between a diamagnetic and vacuum is $\Delta W \approx 10$ eV.

Consider a possible scheme of the interaction of a magnetic charge with this MDS structure (Figure 6).



Geometry of interaction

Potential energy of MDS-structure before nuclear reaction

Potential energy of MDS-structure after nuclear reaction

Figure 6. Surface of MDS-structure and its potential energy before interaction with magnetic charge and after such interaction.

We assume that the magnetic charge moves at first from right to left at a small (slanting) angle θ in the direction to the surface (Figure 6a), so that its relative kinetic energy $T_\theta = (p_g \sin\theta)^2 / 2M_g$ is less than the barrier height ΔW. While approaching the surface, the magnetic charge is pulled in the *Al* region due to the attraction to the paramagnetic (*Al*) and then is pushed out away from the potential barrier formed by the layers of SiO_2 and *Si*.

In the region of the *Al* layer, this charge can stimulate the occurring of various nuclear reactions, including the synthesis reactions

$$Al^{27} + p^{1} = Si^{28},\ Al^{27} + C^{12,13} = K^{39,40} \qquad (11)$$

with participation of *Al, H* and *C* entering the composition of a very thin oil film on the surface of *Al* and release of a great amount of energy (ΔE_R = 12...17 MeV).

The occurring of these reactions is indirectly confirmed by the following.

The detailed study of the isotope composition of the substance, being present on the surface of *Al* on both edges (banks) of a periodic track, with the help of a *SIMS* spectroscope revealed the presence of a very small amount of extrinsic elements, whose mass corresponded to the isotopes with mass number A=39 - 40.

4 Possible mechanisms of the influence of a magnetic charge on nuclear reactions

There are a lot of possible mechanisms able to explain the strong influence of magnetic charged particles on nuclear reactions [5,6].

- The value of the local magnetic field $H_g(r) = g / r^2$, which a magnetic charge g creates in the region of localization of internal atomic electrons (at $r_e \leq 10^{-9}$ cm) with velocity v_e, can reach $H_g \geq 10^{11}$ Oe. The effective electric field in the same area $E_{eff} \approx 137 e v_e / r^2 c$, whose value can exceed the screened electric field inside an atom $E_a = Ze / r^2$, acts on moving electrons and sharply changes the configuration of the electron shells of atoms.

Under the application of a very strong magnetic field H_θ (if $E_{eff}(r) >> E_a(r)$ or if $Z<<137$), the electron shells of atoms take the needle-like form of extremely elongated ellipsoids instead of the standard, almost spherical ones (see Figure 7). Their transverse axis (and screening radius) sharply decreases. The decrease in the transverse size of electron shells corresponds to a sharp decrease of the electron screening radius r_{screen} and, respectively, to a very significant increase of the probability of a tunnel effect under the interaction with the nuclei of neighboring atoms. This can lead to a sharp increase of the probability of reactions.

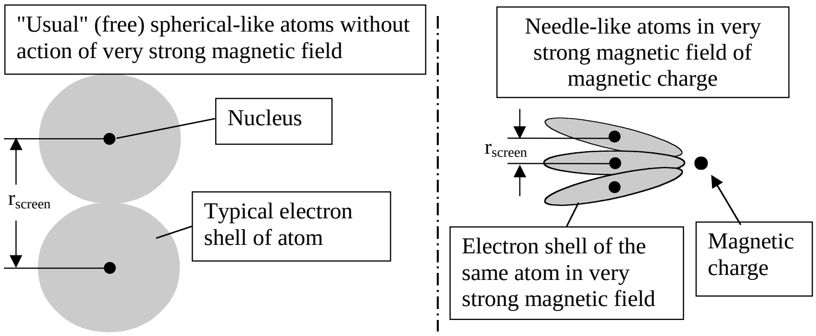


Figure 7. Influence of magnetic charge on electron shells of atoms

- If a magnetic charge g falls on the nucleus surface, the magnetic field in the nucleus is about $H_g \approx 10^{18}$ Oe. Since the nucleons are moving in the nucleus with the mean square velocity $v_n/c \approx 0.1$, each nucleon undergoes the action of the effective electric field, whose amplitude $E_{eff} = H_g v_n/c \geq 10^{19}$- 10^{20} V/cm is comparable to that of the electric field $E_Z \approx Ze/R^2 \approx Z.10^{18}$ V/cm created by the electric charges of all Z protons on the nucleus surface and essentially exceeds the field inside the nucleus.

- If a magnetic charge g falls on the nucleus surface, the magnetic field of the charge exceeds the magnetic fields related to the spin-orbit interaction of nucleons by many orders. As a result, the processes related to the spin-orbit interaction in the nucleus can be completely changed. In particular, the JJ-coupling of nucleons which is typical of nuclei becomes impossible.

Thus, the mechanism of the stimulating action of a magnetic charge on nuclear reactions is conditioned by the effect of H_g and E_{eff} on the spin-orbit and Coulomb interactions of nucleons, on the angular momentum of a nucleus, and, on the whole, on the binding energy of nucleons in the volume of a nucleus. This can lead to a sharp change of the stability line. The effect of a magnetic charge can stimulate the synthesis and fission on the basis of those nuclei which are stable in the absence of the action of a superstrong magnetic field. In particular, to ensure the necessary energy release, each particle must stimulate about 5.10^7 reactions per 1 cm of its trajectory. As a result of the occurrence of such reactions, there is a rapid fracture of the region of the layer of Al which is located near the magnetic charge. In this case, the following situation is realized. Through heating and ionization of this region, the local system of Al atoms transits from paramagnetic to diamagnetic state. As a result, the potential well in the region of localization of the magnetic charge disappears (this happens under the condition $\chi_{Al} > 0$) and is transformed into a potential barrier (this corresponds to the requirement $\chi_{Al*} < 0$) which pushes out the magnetic charge back in vacuum (Figure 6b). Under such an interaction, a great amount of energy will be released. Therefore, it is natural that the Si layer adjacent to Al will be also partially melted and splashed over the surface of Al.

A special situation will occur in the case where the additional force acts on the magnetic charge and compels it to move along the surface in vacuum. Such a force can be the action of the residual azimuthal magnetic field of the diode current. The intensity vector of this field lies on the circumference positioned symmetrically relative to the diode current direction. The accelerating force will act in the same direction. Due to the presence of centrifugal forces, the trajectory of a particle with magnetic charge will be an

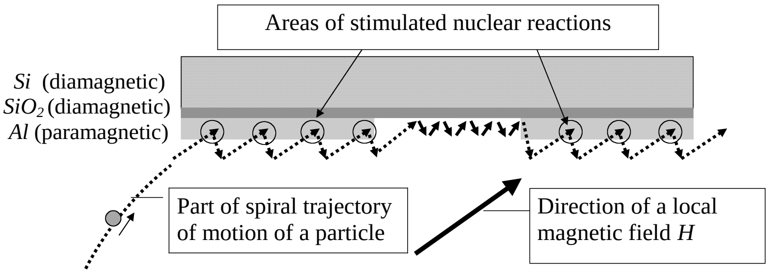


Figure 8. The trajectory of motion of a magnetic charge in a simplified form after its falling on the *MDS*-structure surface in several periods of the spiral.

untwisting spiral beginning in the collapse zone, where magnetic charges can be formed.

In this case, the magnetic charge leaving the place of the first fall on the medium is accelerated along the surface and arrives at the place where the *Al* layer is intact, and its characteristics correspond to a paramagnetic.

There the charge is again attracted to the layer, stimulates nuclear reactions in it, and then again leaves the layer. The repetition of this cycle leads to the periodic process of interaction of the magnetic charge with the surface and to the formation of a track in the form of a "caterpillar trace". In the region of the surface lying between the *Al* layers (in the middle part of Figure 8), the particle is in the potential well such that its two walls are defined, respectively, by the repulsion from the diamagnetic (SiO_2 and *Si*) and by the action of the magnetic field of the current on the charge. In this region, a magnetic monopole moves along the surface of *Si* not penetrating into the volume and not inducing any damage, which is observed in experiments.

5 The possible nature of the magnetic charge

It is worth noting one more circumstance. In view of the form of a macrotrack (great number of strictly periodic oscillations), we may conclude that the controlling magnetic field is approximately the same along the entire trajectory. This corresponds to a duration of the formation of the mentioned part of the track significantly shorter than the total duration of the current pulse equal to $T \approx$ 30-50 ns. This allows us to assume that the duration of the formation of this part of the track with length $L \approx 2$ mm is at most $T_1 \leq 10$ ns, and the mean longitudinal velocity of motion of the hypothetical magnetically charged particle v_g is greater than $L/T_1 \geq 2.10^7$ cm/s.

It was shown during SIMS investigation that the «point of reflection» of the unknown particle (see Fig. 2(1), Fig. 3(1) and Fig.5) is a small-size random admixture made of iron-cobalt alloy and is a magnetic material with domain magnetic field $H_{int} \approx (6...8).10^3$ Oe near alloy surface.

The typical size of domain wall for such magnetic material is about $\Delta r \approx 2$ micron.

If the magnetic charge of the particle equals $g = (137 - 68)e$ then the magnitude of the magnetic potential barrier in the area of the «point of reflection» equals (see Fig.9)

$$V_M \approx g\, H_{int}\, \Delta r \approx 25...60 \text{ keV} \qquad (12)$$

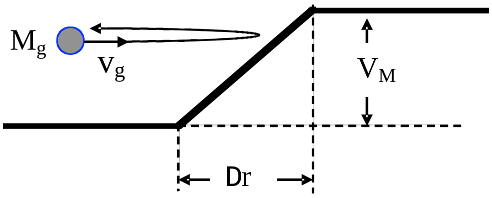


Figure 9. Reflection of magnetic charge from magnetic domain on MDS surface

As a result we have the following estimation for the mass of the unknown magnetic-charged particle

$$M_g << \frac{2V_M}{v_g^2} \approx 10^{-22}\ gram \qquad (13)$$

So, the unknown particle is, most probably, a light magnetic monopole!

Such light magnetic monopoles were suggested by George Lochak and correspond to magnetic-excited states of neutrinos (e.g. [7]). It is possible that these particles were created in collapse zone during the global nuclear transformation of squeezed targets (both protonization and neutronization

[8]) with presence of a squeezing frozen magnetic field with magnitude up to $H \geq 10^{12}$-10^{16} Oe.

6 Conclusion

The above-presented scenario allows us to explain and to quantitatively substantiate the majority of the observed regularities of oscillating hollow macrotracks, based on the assumptions that magnetically charged particles are generated in the collapse region in a high-current diode and these particles can be highly efficient catalysts of nuclear reactions. The periodic character of the macrotrack trajectory can be related to the specificity of the interaction of the hypothetical magnetic charge with the system of paramagnetic and diamagnetic layers on the *MDS*-structure surface. Based on this general reasoning, we may assume that particles with magnetic charge can be formed in the electron-nucleus collapse zone during the shock action of a high-current electron beam and the subsequent self-compression of the magnetic field frozen in the superdense plasma. A specific mechanism of the generation of a magnetic charge can be related to the topological features of the collapse zone. Starting from the above-given estimates, we can conclude that the power of nuclear transformations induced by one particle with magnetic charge in a target made of aluminum is at least

$$P_{tot} \geq (Q_{tot} / T_1) \approx 300\ W! \tag{14}$$

At the same time, it is obvious that the very hypothesis of the generation of magnetic charges in the collapse region, the formation of which is accompanied by an extreme deformation of the frozen magnetic field, requires further theoretical analysis.

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