Electrization metal samples when changing their temperature or mechanical deformations

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Exists a large quantity of diagnostic methods of the study of the properties of materials and models. But from the view of researchers thus far slipped off the very promising method, based on a study of the electrostatic potential of such models. This method consists in the fact that with heating or deformation of metallic models on them the electric potential appears. In the work an experimental study of this method is carried out and its theoretical substantiation is given.

The keywords: thermodynamic potentials, electrostatic potential, chemical potential, electron gas, crystal lattice.

1. Introduction

Exists a large quantity of diagnostic methods of the study of the properties of materials and models. But from the view of researchers thus far slipped off the very promising method, based on a study of the electrostatic potential of such models [1-5]. Earlier, the occurrence of static potential has also been observed in the superconducting windings of tori and the introduction therein dc [6-10].

The majorities of the existing diagnostic methods of the control of properties and characteristics of materials and models is based on the application of various external actions, which can change the properties of such objects. The special interest present the methods of the nondestructive testing, and also those methods, whose application does not require action on models themselves. A study of the properties of materials and models into the dependence on their temperature, the pressures, the actions of different kind of irradiations, mechanical stresses and the dynamics of these processes, the kinetics of phase transitions are of great interest. In this paragraph the method, based on the measurement of the electrostatic potential of models, which gives the possibility to conduct such studies by simple method, is examined.

In the literary sources, in which is discussed a question about the possible dependence of charge on the speed, it is asserted that the dependence of magnitude of the charge from this parameter would lead with heating of conductors to an increase in their negative potential. Specifically, this assertion constantly is given as the argument of the fact that the charge cannot depend on speed.

If in any structure coexists several thermodynamic subsystems, then their chemical potential must be equal. In the conductor there are two subsystems: lattice and electron gas, electron gas in the conductors at usual temperatures is degenerate and is subordinated the statistician Fermi-Dirac, his chemical potential is determined from the relationship [11]

$$\mu = W_F\left(1-\frac{\pi^2(kT)^2}{12W_F{}^2}\right), \tag{1.1}$$

where

$$W_F = \frac{h^2}{2m}\left(\frac{3n}{8\pi}\right)^{\frac{2}{3}} \tag{1.2}$$

is Fermi energy, h is Planck's constant, and n, m are electron density and their mass.

From relationships (1.1) and (1.2) is evident that chemical potential of electron gas with a temperature decrease increases, reaching its maximum value at a zero temperature. It also depends on electron density.

In general form chemical potential for any subsystem can be found from the following expressions

$$\mu = \left(\frac{\partial U}{\partial N}\right)_{S,V} = \left(\frac{\partial F}{\partial N}\right)_{T,V} = \left(\frac{\partial W}{\partial N}\right)_{S,P} = \left(\frac{\partial \Phi}{\partial N}\right)_{T,P}$$

where N is number of particles, and the thermodynamic potentials U, F, W, Φ represent internal energy, free energy, enthalpy and Gibbs potential respectively. But, if we find chemical potential of lattice, using one of these expressions, then it will be evident that with a temperature decrease this potential decreases. Thus, it turns out that chemical potential of electrons with a temperature decrease grows, and it decreases in lattice. But as then to attain so that they would be equal? Output consists in the fact that chemical potential of electron gas depends on the density of free electrons, and so that this potential with the decrease of temperature also would decrease, must with a temperature decrease decrease a quantity of electrons. This means that for retaining the electroneutrality during cooling of conductor from it the draining of electrons must be provide ford, and with the heating their inflow is provide ford. If we this do not make, then with the heating at the model will appear positive potential, but during the cooling negative.

For the experimental confirmation of this behavior of conductors one should connect to the sample under investigation electrometer with the very high internal resistance and begin model to cool. In this case the electrometer must register appearance in the model of negative potential.

Especially strong dependence will be observed at low temperatures, when the heat capacity of electron gas and lattice of one order. However, what must occur upon transfer of model into the superconductive state? During the passage the part of the electrons will begin to be united into the Cooper pairs and in the region of Fermi energy will begin to be formed the energy gap of the forbidden states. Moreover, for the remained normal electrons this there will also be forbidden zone; therefore for them only places of higher than the upper edge of slot will remain permitted. This will lead to the fact that it will not be sufficient vacant places for the remained electrons, therefore, in the case of the absence of the draining of electrons from the model, it will acquire negative potential.

Chemical potential of lattice depends also on stresses and number of dislocations, and conduction electrons will also track this process.

2. Experimental study of the appearance of electric potential in the metallic models.

Figure 1 shows the temperature dependence of the electrostatic potential of model, made from niobium-titanium alloy, with a change in its temperature within the limits of 77-4.2 K.

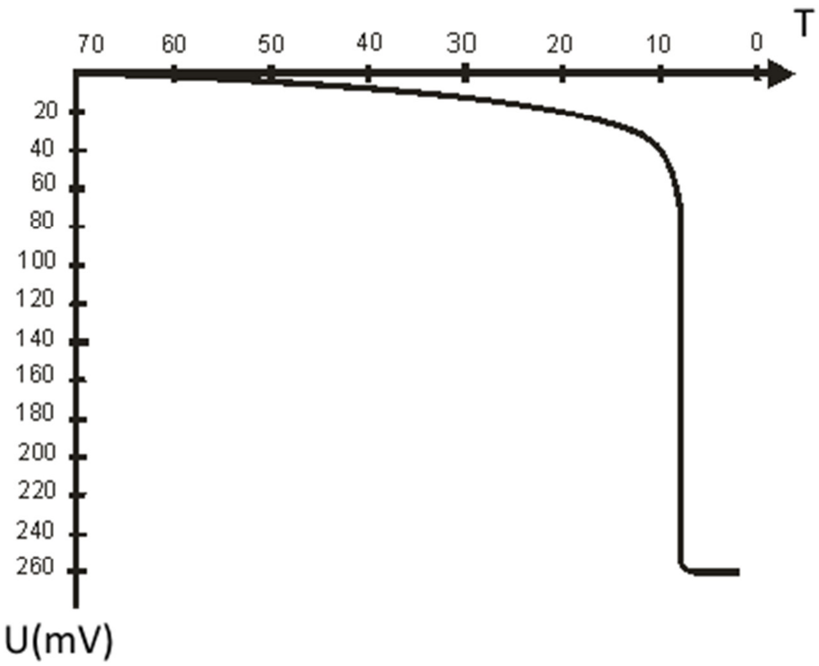

Fig. 1. Dependence of the potential of niobium-titanium model on the temperature.

It is evident that with the decrease of temperature the negative potential grows first sufficiently slowly, but in the temperature range of the passage of model into the superconductive state is observed a sharp drop in the potential.

A study of the influence of mechanical stresses and kinetics of dislocations on the electrostatic potential of models was conducted employing the following procedure. For this copper flask with the thickness of the walls ~ 3 mm of. and by volume ~5 liters of it was placed into vacuum chamber, from which could be pumped out air. The end walls of flask were executed in the form hemispheres. The internal cavity of flask in conducting the experiments was found under the atmospheric pressure. Pumping out or filling into vacuum chamber air, it was possible to mechanically load its walls. Flask itself was isolated from vacuum chamber bushing from teflon resin and thus it had high resistance relative to the housing of unit. One of the typical dependences, obtained with such experiments, is represented in Fig. 2. It is evident that the amplitude of effect reaches ~100 mV, dependence has strong hysteresis, moreover an increase in the negative potential corresponds to the tension of the walls of flask. In the figure the circuit on the hysteresis loop was accomplished clockwise. It follows from the obtained results that mechanical stresses of model lead to the appearance on it of electrostatic potential. The presence of hysteresis indicates that the formation of dislocations bears the irreversible nature. In this case the irreversibility of the influence of dislocations on the electrization is connected with the fact that dislocation they can, falling into potential wells, to be attached on the heterogeneities of crystal structure.

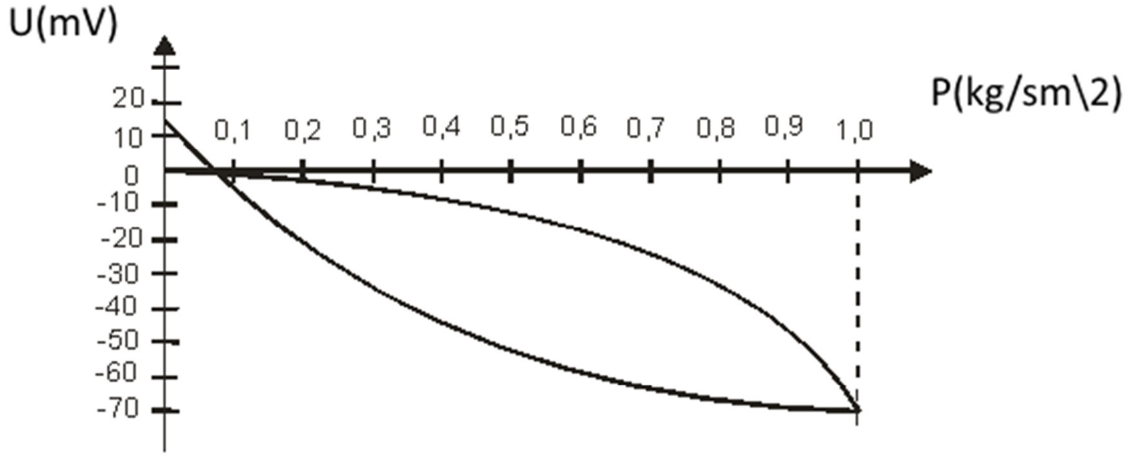

Fig. 2 Dependence of the potential of copper flask on the external pressure.

It follows from the carried out examination that also the appearance of rapid (impact) mechanical loads also must lead to the appearance in the isolated metallic model of pulse potential. This question was investigated on the installation, whose schematic was given in Fig. (3)

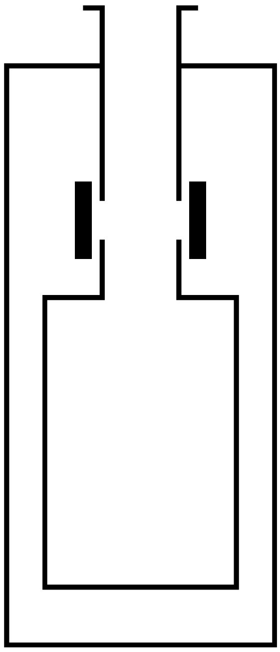

Fig.3. Installation diagram for investigating the appearance of the pulses of electric field with the impact loads.

Internal capacity is suspended to the external screen with the aid of wide neck. For eliminating the galvanic contact between the external screen and the internal capacity the neck has a section. Odd parts of the neck are connected by the insulating plates, which in the figure are designated by the short black sections of lines. The inner container is made of aluminum in the form of a cylinder whose end walls are formed as hemispheres. This design of the end walls is necessary in order to avoid deformation during the bombings of explosives in the inner tank. Common form installations for investigating the dynamic loads on the aluminum flask and the component parts of the installation are shown in Fig. 4 and Fig. 5.

Fig. 4 General view of the installation for the study of dynamic loads.

Fig. 5. Position Type unassembled.

During the inclusion into neck from a height 1 m of the bottom of the internal capacity of the rod with a weight 200 g between the external screen and the internal capacity is observed the voltage pulse, shown in Fig. 6. In order to avoid to the appearance of additional pulses with a lateral drop in the rod after the impact of its end about the bottom of flask, the side of rod is wound by soft tissue. Data of this experiment correspond to the experimental data, obtained with the copper flask, the code its tension led to the appearance on the flask of negative potential. With the impact of the end of the rod about the bottom of flask also occurs the local deformation of its bottom, with which in the point of impact occurs the tension.

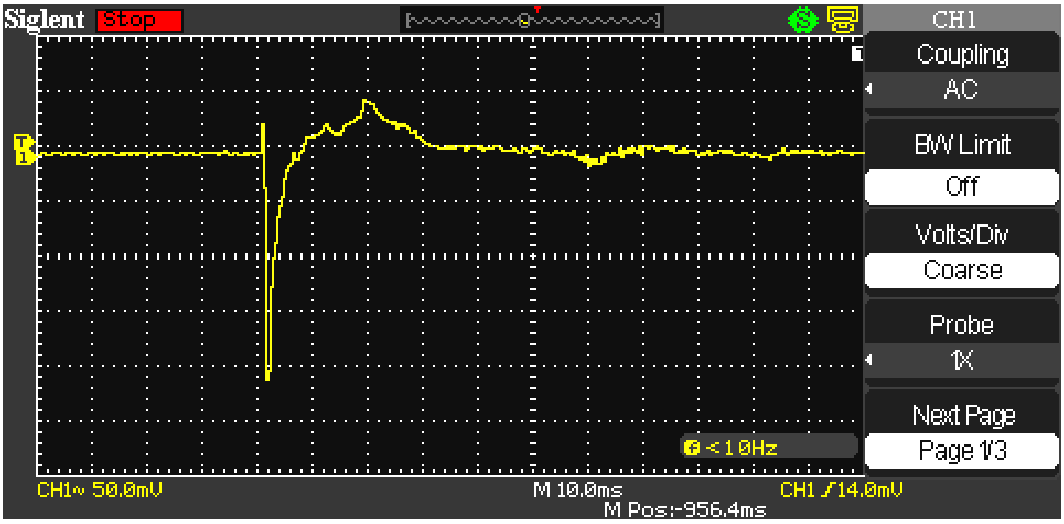

Fig. 6 . Shape of pulse after a drop in the rod on the bottom of internal capacity.

If we inside the aluminum flask explode the charge of small value, then is observed the voltage pulse, shown in Fig. 7.

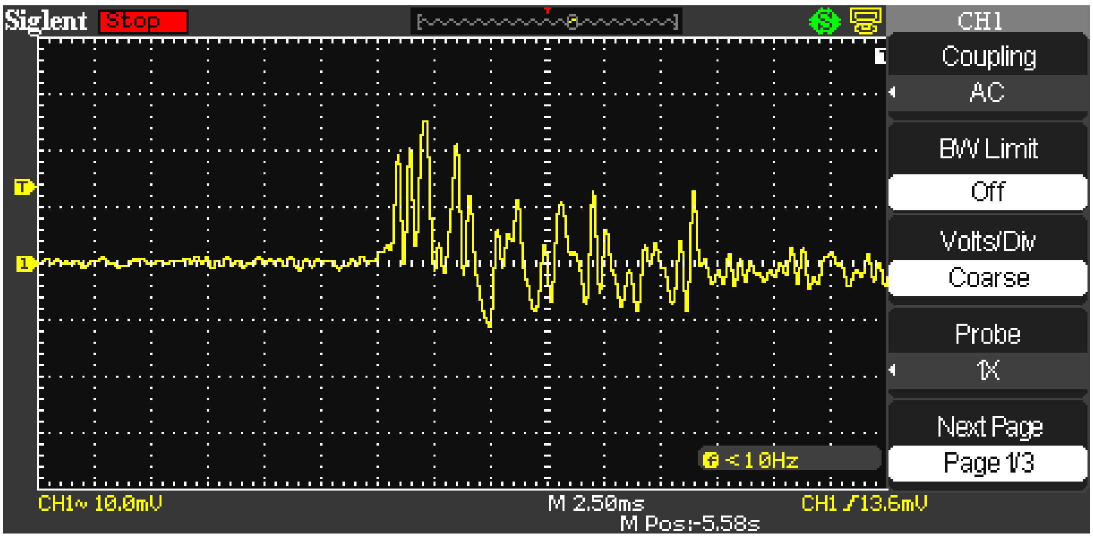

Fig. 7. Form of the voltage pulses, obtained with the explosion of explosive in the aluminum flask.

Repeated repetitive pulses of different polarity, observed in the oscillogram, are the consequence of the multiple reflection of shock wave from the walls of the flasks, which lead to its deformation. Moreover there are pulses corresponding to both the tension of the walls of flask and to their compression.

Obtained data attest to the fact that this method can be used for investigating the rapid deformation processes in the metallic models.

3. Conclusion

In the article the promising method of diagnostics of metallic models, based on a study of the electrostatic potential of such models, is described. This method consists in the fact that with heating or deformation of metallic models on them the electric potential appears. In the work an experimental study of this method is carried out and its theoretical substantiation is given.

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