Thermomechanical electric field spectroscopy

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Abstraks

Work examines the new, previously not known method of investigating of models and materials, based on the measurement of the electric potential of models. Method gives the possibility to investigate their thermal characteristics, phase pass the mechanical characteristics of
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1. Thermomechanical electric field spectroscopy

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.

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.

If in any structure coexists several thermodynamic subsystems, then their chemical potential must be equal. In the conductor there are two subsystems: lattice and electronic newspaper. 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

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

where

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

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

From relationships (1) and (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 - 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 a quantity of electrons. This means that for retaining the uncharged 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 realization of electric field spectroscopy of conductors to the model should be connected electrometer with the very high internal resistance and cooled the model. 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. Therefore many electrons will prove to be excess and the negative potential of model sharply will grow, that also is observed in the experiment.

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

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.

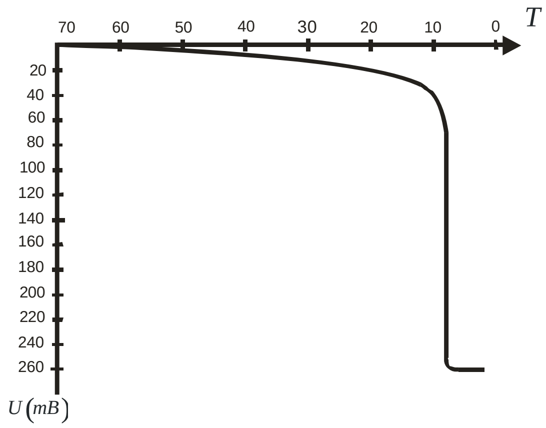

Fig. 1. Dependence of the potential of niobium-titanium model on the temperature.

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

A study of the influence of mechanical stresses and kinetics of dislocations by the method examined was carried out employing the following procedure. For this copper flask with the thickness of the walls ~3 mm and by volume near 5 liters of it was placed into vacuum chamber, from which could be pumped out air. 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. Copper bulb with a wall thickness ~ 3 mm. and a volume 5 liters was placed into a vacuum chamber from which the air could be pumped. Internal cavity of the flask was in experiments at atmospheric pressure. Evacuating or admitted into the vacuum chamber of the air can be stressed mechanically its walls. Itself flask was separated from the vacuum chamber sleeve of teflon and thus has a high resistance relative to the housing unit. Typical dependence of the potential of the bulb from her stress is shown in Fig. 2. That the amplitude of the effect reaches 100 mV, has a strong dependence of the hysteresis, the stretching of the walls of the bulb corresponds to an increase of negative potential.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 bulb. 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.

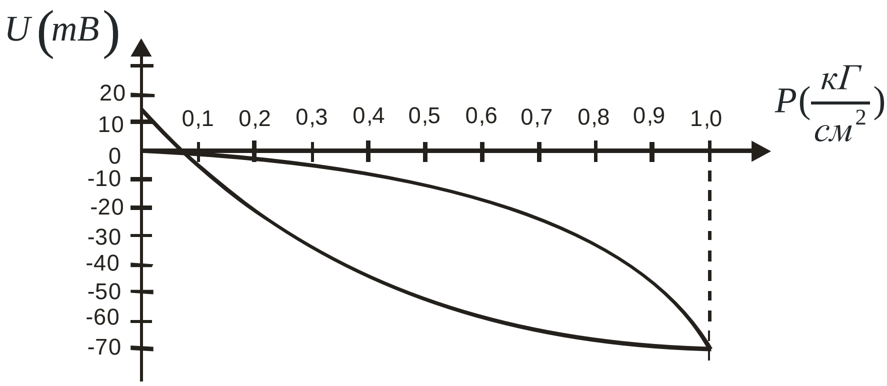

Fig. 2. Dependence of the potential of copper bulb on the external pressure.

Thus, the proposed method of investigating the physical characteristics of materials and models, gives the possibility to investigate their temperature properties, the kinetics of phase transitions, and also their mechanical properties. It is promising for investigating of metals and semiconductors. With its aid it is possible to investigate the phase transition of the first order, connected with melting and crystallizing the objects indicated. This method is especially promising, since in a number of cases it is nondestructive, and for its realization complex equipment does not be required.

Reference

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