ANOMALOUS BEHAVIOR OF THE ELECTRIC RESISTANCE AND THERMOELECTRIC POWER OF METALLIC SAMARIUM AT HIGH TEMPERATURES

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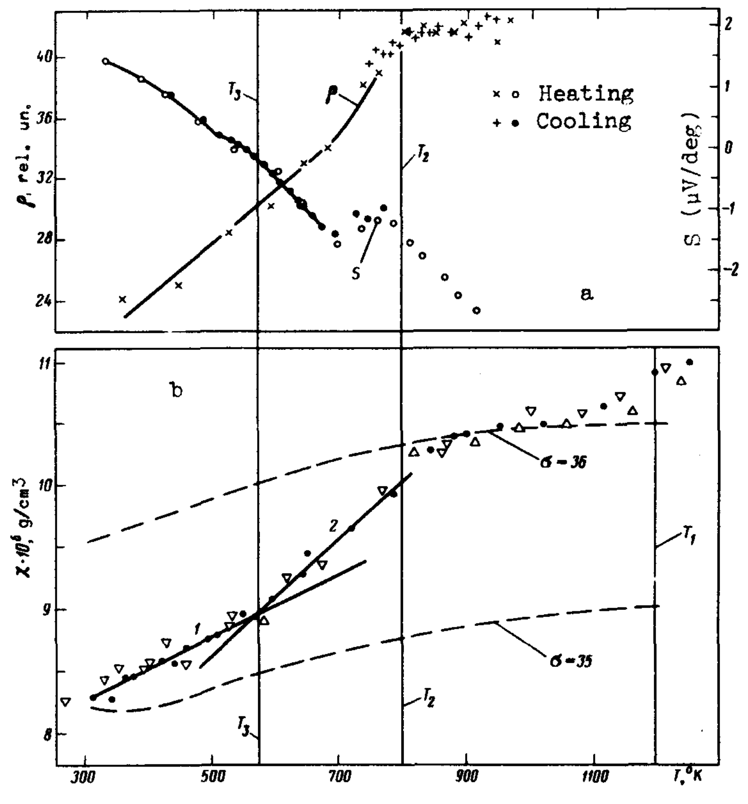
The resistivity ρ and the absolute differential thermoelectric power (TEMF) S of metallic samarium, insofar as we know, were investigated previously only below room temperature [1, 2]. Figure a shows the results of our measurements in the temperature interval 300 - 1000°K, for grade SMM-1 samarium, in which, according to the data furnished by the manufacturing plant, there is not less than 99.44% Sm, the iron impurity is less than 0.01%, but no analysis was performed for gases. At a temperature T_2 = 780 - 800°K, the values of ρ and S change anomalously. Such an abrupt change in the electric properties is customarily associated with a phase transition. For Sm there is a known structural transition at T_1 = 1197°K [3] and two magnetic transitions at 12 and 106°K [1]. The latter is assumed by the authors of [1] to be the Neel point. The temperature dependences obtained by us for ρ and S allow us to assume that Sm experience one more phase transition at T_2.

At present there are no definite theoretical or empirical indications concerning the character of the change of the electric properties in any of the phase transitions. However, preliminary conclusions concerning the nature of the anomaly can be obtained by analyzing some details of our data and the published data.

1. The thermoelectric power and the magnetic susceptibility χ frequently experience jumps during structural phase transitions. In particular, χ of Sm



a) Resistivity ρ and absolute differential thermoelectric power S of samarium as a function of the temperature; b) paramagnetic susceptibility χ of three samarium samples (points) and its theoretical value at two values of the screening constant σ (dashed curves) as functions of the temperature [8].

itself, as seen from Fig. b, increases jumpwise at $T = T_1$. At $T = T_2$, the values of S and χ change in a different manner. In addition, if the transition were structural, this would mean that Sm is paramagnetic at $T > 106°K$. In the paramagnetic region, the plots of ρ of other light rare-earth metals (REM) have a convex form [4]. A dependence of this type should be expected also for the paramagnetic samarium, but actually the dependence is practically linear. But an approximately linear dependence is frequently observed for REM in a magnetically-ordered state (see Figs. 25.18 - 25.22 in the book [5]). A more probable conclusion is therefore that Sm experiences a magnetic rather than a structural transformation at the temperature T_2.

2. At 12 and 106°K there is a pronounced anomaly of the electric resistivity, but an equally pronounced anomaly of the thermoelectric power can be seen only in the former case [2]. At 106°K it is difficult to see any deviation from smoothness of the S(T) curve. But in all known cases, the thermoelectric power of elementary magnetically-ordered metals changes strongly in an order-disorder type of magnetic transformation [6], including in the case of REM [2]. To the contrary, it has been noted that the magnetic transformation of the order-order type in antiferromagnetic chromium is not accompanied by any singularity in the behavior of the thermoelectric power [7]. This favors the conclusion that Sm is magnetically disordered at $T = T_2$ but not at $T = 106°K$. Notice should also be taken of a small kink in the S(T) curve at $T_3 \approx 575°K$ (the ordinates T_2 and T_3 show the start of the unusual behavior of the thermoelectric power on going from the paramagnetic into the magnetic region).

3. It is of interest to compare the behavior of the electric and magnetic properties of Sm (Figs. a and b). Arajs and Colvin [8] reached the conclusion that in the interval from room temperature to the melting point $\chi(T)$ of samarium cannot be described by the van Vleck paramagnetism theory, which gives very good agreement with experiment in the case of neodymium and praseodymium, which are the REM closest to Sm. However, the ordinates drawn in the figure through the points assumed to be magnetic transformations in accordance with the electric measurements also separate the singular points on the $\chi(T)$ curve. $\chi(T)$ actually has a kink at a temperature close to T_2. Above this kink, the experimental points fit the theoretical van Vleck curve, and a distinct disparity between experiment and theory takes place only at lower temperatures. Thus, samarium behaves magnetically like a normal rare-earth paramagnet above T_2 but not below this temperature. All this confirms the foregoing assumption that a magnetic disordering of Sm takes place at T_2. The ordinate T_3, corresponding to a small singularity of the thermoelectric power, divides the $\chi(T)$ curve into two parts, which have, as it were, slightly different slopes which we have indicated by the lines 1 and 2. One can therefore assume that some modifications of magnetic ordering takes place at T_3.

Summarizing all the foregoing, it is reasonable to assume that the phase transition observed in Sm at 780° - 800°K is magnetic. The final answer can be obtained only by determining the magnetic structure directly, something not done as yet, but if the foregoing hypothesis is true, then samarium turns out to be the magnet with the highest temperature in the entire rare-earth series, and with a much higher ordering temperature than previously known (293°K for gadolinium [5]). Assuming an antiferromagnetism of this order, samarium is at the same time also the elementary antiferromagnetic metal having the highest temperature (that of chromium is 312°K [5]). Our preliminary measurements made on much purer samarium have confirmed the existence of anomalies, so that these anomalies can hardly be attributed to insufficient sample purity.

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OBSERVATION OF SECOND COMPRESSION IN THE FINAL STAGE OF A DISCHARGE OF THE "PLASMA FOCUS" TYPE

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1. The increased recent interest in thermonuclear installations with superdense plasma of the plasma-focus, θ-pinch, laser-plasma type and similar ones is due to the unprecedented large figures obtained with these installations after the Lawson criterion is reached. "Plasma-focus" discharges have produced in addition, unprecidented neutron yields [1, 2] with a considerable fraction of neutrons of thermal origin [2, 3] and high electron and ion temperatures.

Numerous investigations of the cumulative stage of this discharge (henceforth denoted PF) have made it possible to study experimentally and to adequately describe theoretically [4, 5] the initial phase of PF development, the so-called "first compression," which is characterized by a relatively small neutron yield, a flash of soft x-radiation, a density reaching 10^{20} cm^{-3}, and a temperature $T_e \sim T_i \sim 2 - 5$ keV, as well as by a typical outflow of a considerable part of the mass along the z axis from the focal region, resulting in the high temperature. On the other hand, the data on the final phase of development of the PF are quite skimpy and are limited in practice to investigations of the neutron emission and of the hard x-rays.

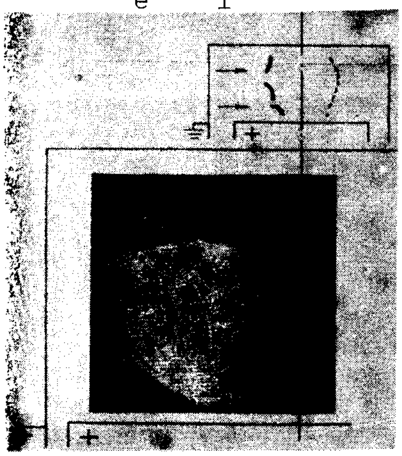

Fig. 1. PF interference pattern obtained during the time of rupture of a current sheath, coinciding with the start of a pulse of hard x-rays. A schematic diagram of the interference pattern is shown on top. The arrows show the locations of the ruptures in the current sheath.

We present here the results of a high-speed interferometry study of this final PF stage, performed with a setup described in [1]. The investigation procedure is similar to that previously employed to study laser plasma [6].

2. It was established earlier that short-wave instabilities of zeroth order develop on the PF surface during the stage intermediate between the first and second compressions [4, 7]. Our investigations have shown that the current sheath subsequently experiences discontinuities, but not in the "neck" of the bridge, as predicted in [8] (Fig. 1). The plasma begins to flow out of the compression region through the produced discontinuities, thereby decreasing further the number of