1. INTRODUCTION

Electronic–topological transitions (ETTs) of the 2.5th order have been theoretically predicted for pure metals subjected to elastic strains [1] and were experimentally detected for the first time in [2] by analyzing the changes in the superconducting characteristics of nontransition metals with a low impurity concentration subjected to uniform compression. Those studies served as a basis for the development of a new direction of research, which has led to a number of fundamental theoretical and experimental results [3–11]. The authors of those works theoretically explained the manifestation of an ETT in the superconducting characteristics of metals and alloys [3, 4], obtained quantitative ETT parameters for some systems [5–9], found a correlation between the specific features of the manifestation of an ETT in the superconducting and normal properties of metals and alloys [8, 9], and detected the effect of scattering processes on an ETT [10, 11].

Numerous investigations have shown that the Fermi surface topology changes during an ETT under any external influence on the Fermi energy that makes this energy reach a critical point in the electronic spectrum (e.g., the influence of pressure, impurities, or a magnetic field).

Electron Localization during an Electronic–Topological Transition in Mo–Re Alloys

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Abstract—Oscillations in the superconducting transition temperature \( \Delta T_c(P) \), in the critical magnetic field \( \Delta H_c(P) \), in the thermopower \( \frac{\alpha}{T} (T^2) \), and in the electrical resistivity \( \rho(T) \) (\( P \) is pressure) of \( \text{Mo}_{1-x}\text{Re}_x \) alloys are observed at low temperatures against the background of specific features related to an electronic–topological transition (ETT) in these alloys. The oscillations are sensitive to the impurity concentration: they increase when the Re impurity concentration is close to the critical concentration \( C_c \) at which the ETT occurs. Oscillations are also detected in the concentration dependences of the temperature coefficient of resistivity \( \frac{\partial \rho}{\partial T} (C) \) and the thermopower derivative \( \frac{\partial (\alpha/T)}{\partial T^2} (C) \) of \( \text{Mo}_{1-x}\text{Re}_x \) alloys at low temperatures. The former and latter oscillations are shown to correlate with each other. These specific features are assumed to result from the ETT and to be related to the localization of the part of the electrons that fill a new cavity in the Fermi surface during this transition.

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Studying alloys with a high impurity concentration has shown that the effect of an impurity on the electronic density of states \( \nu(E) \) is most important during an ETT; the action of an impurity as a scattering center decreases the ETT-related effect only slightly [8, 9]. The effect of temperature on an electronic spectrum is also complex. On the one hand, the temperature, as well as the pressure, can change the Fermi level [12] and fine electron–phonon interaction effects, which manifests itself mainly at low temperatures [13]. On the other hand, the temperature blurs the specific features related to the fine structure of an electronic spectrum at \( T > 30 \) K [11].

Using Mo–Re alloys as an example, one can see that an ETT leads to a change in virtually all properties of the initial metal [8, 9, 14]. This fact is unusual and requires special consideration.

The purpose of this work is to consider the fact that an ETT causes other (finer) specific features related to the appearance of localized electronic states [15] for a small group of electrons against the background of a continuous electronic spectrum. These effects are small as compared to the specific features of a topological transition, and their detection requires rather sensitive techniques. A topological transition [1, 3] is associated with specific features in the electronic density of states...
3. RESULTS AND DISCUSSION

3.1. Superconducting Transition Temperature

The ETT is associated with the appearance of an additional small electron group in Mo–Re alloys at \( C_r \approx 10 \) at. % Re. This transition manifests itself as an extremum in the \( \frac{\partial T_c}{\partial P} (C) \) derivative [8] and the thermopower \( \frac{\alpha}{T} (c) [9] \). When studying the superconducting characteristics, the Fermi energy \( E_F \) was changed by varying two parameters, namely, the impurity concentration and pressure. An addition of Re impurity increases the number of electrons as compared to that in the initial metal and thereby rather roughly shifts \( E_F \) toward the critical energy \( E_c \) in the electronic spectrum of Mo, whereas a change in the pressure is a fine tool for scanning the energy scale in small steps. This method made it possible to detect not only a topological transition (i.e., an extremum in the \( \frac{\partial T_c}{\partial P} (C) \) dependence) in Mo–Re alloys but also finer pressure-induced changes in \( T_c \), such as \( T_c(P) \) oscillations at a fixed Re concentration. These oscillations were first observed in Mo–Re alloys at concentrations \( C \geq C_r \) in [16].

Figure 1 shows additional, previously unpublished experimental data on the \( \Delta T_c(P) \) and \( \Delta H_c(P) \) dependences for several characteristic values of the Re concentration (11, 15, 19 at. %) in Mo–Re alloys; the letter \( \Delta \) denotes the differences between the quantities measured at \( P \neq 0 \) and \( P = 0 \). For an alloy with 11 at. % Re (which corresponds to the ETT), the oscillation amplitude is low (≈0.02 K), whereas for an alloy with 19 at. % Re (which is above the ETT point) the oscillation amplitude reaches a noticeable value (≈0.1 K) and decreases with increasing pressure.

Using these samples, we measured both the superconducting transition temperature \( T_c \) and the critical magnetic field \( H_c \) at various pressures. The values of \( T_c \) and \( H_c \) were measured in different cryostats without moving the samples: \( T_c \) was measured in a device at various temperatures, whereas \( H_c \) was measured at liquid-helium temperature in a superconducting solenoid in fields of up to 20 kOe.

The variations in \( \Delta T_c(P) \) and \( \Delta H_c(P) \) with pressure measured on the same samples agree qualitatively with each other, which indicates that the measurements of these dependences are reliable. The oscillating character of the variations in the superconducting characteristics cannot be explained in terms of the ETT. However, this effect results from the presence of a critical energy \( E_c \) in the electronic spectrum at which the ETT occurs. In [16], it was assumed that the oscillations in the \( \Delta T_c(P) \) dependence correspond to a quasi-discrete spectrum of the electronic density of states, which appears against the background of the continuous spectrum in a small energy range near \( E_c \)