Point-Contact Spectroscopy Features of MoRe Superconducting Alloy

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The development of quantum devices (SQUIDs, Rapid Single Flux Quantum, RSFQ) is gaining high interest nowadays, and superconductors are the basis for creating these devices. Creating and improving the superconducting properties of superconductors is the key to creating and improving these devices Our MoRe alloy under study is a low-temperature superconducting alloy that has high anti-corrosion properties, resistance to mechanical stress, and is also resistant to thermal cycling. To improve the properties of MoRe, we used the mechanical method of surface treatment HPT (high-pressure torsion). This method leads to the formation of ultrafine granular structures and even nanocrystal line materials, therefore changing their properties.. Two 1 mm thick, 1.5 × 2 mm Mo-Re plates were placed between two 45 mm diameter high carbon steel anvils with a Brinell hardness of 68 and working surfaces polished to a mirror shine. A force of two tons was applied to the anvils, resulting in a pressure of 60 *kbar* on the samples. Under this uniaxial pressure, the upper anvil rotated making five revolutions.

The $Mo_{48}Re_{52}$ foil, produced by rolling the initially cast ingots, exhibited a grain structure elongated along the sample edges. Metallographic analysis revealed structural modifications induced by the processing technique. After polishing and etching the sample surfaces in 35% nitric acid for 20 seconds, the microstructure was examined using a KERN OKM-173 metallographic microscope equipped with an ODC-832 camera under polarized blue light to enhance contrast. The polished sample is shown in Fig. 1(a). Figures 1(b) and 1(c) display the coarse, elongated grain structure observed prior to high-pressure torsion (HPT) processing, while Fig. 1(d) illustrates a reduction in grain size and pronounced anisotropy in grain orientation following the treatment.

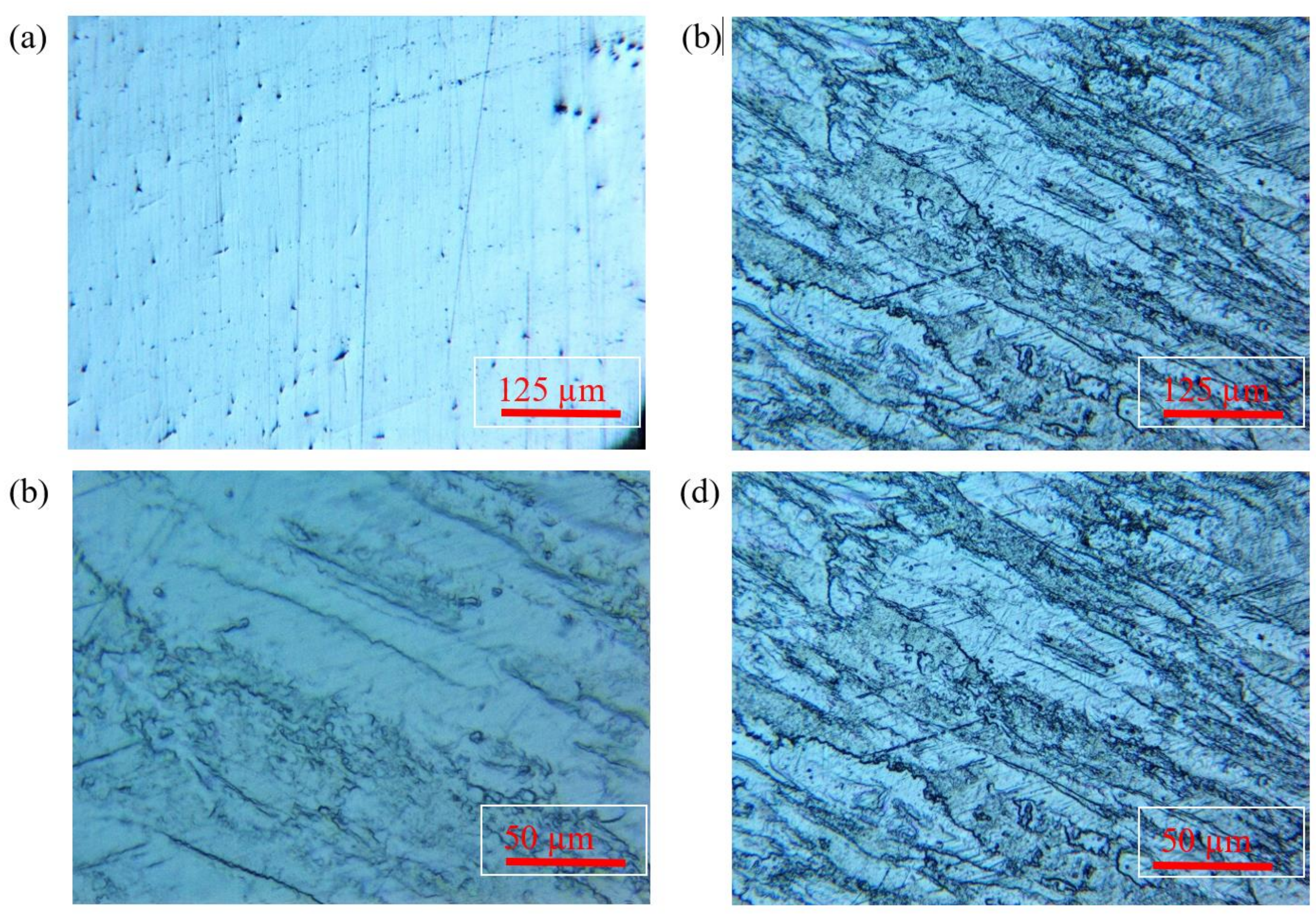

Fig. 1. Metallographic images of $Mo_{48}Re_{52}$ foil before (a)–(c) and after the HPT treatment (a) and (d). The polished surface is the same for both cases (a). The surfaces after etching with 35% nitric acid for the original sample at two scales (b) and (c), and for the HPT treatment sample (d).

One of the methods for studying the fundamental characteristics of superconductors is point spectroscopy, which is based on the Andreev reflection effect at the interface between a superconductor and a conventional metal. The MoRe-Ag S-N interface was used for point spectroscopy of the superconductor surface. The differential conductivity of the sample was measured at a temperature below the transition of 4.2 K. Fig. 2 (inset) shows a slight increase in the sample's T_c after HPT treatment from 8.9 to 9.4 K. In Fig. 2 (main panel), the measured $G_s(V)$ curves actually had a rather flat area in the vicinity of the zero bias voltage without any visible peaks, which indicates the presence of the effects of tunneling single-electron scattering.

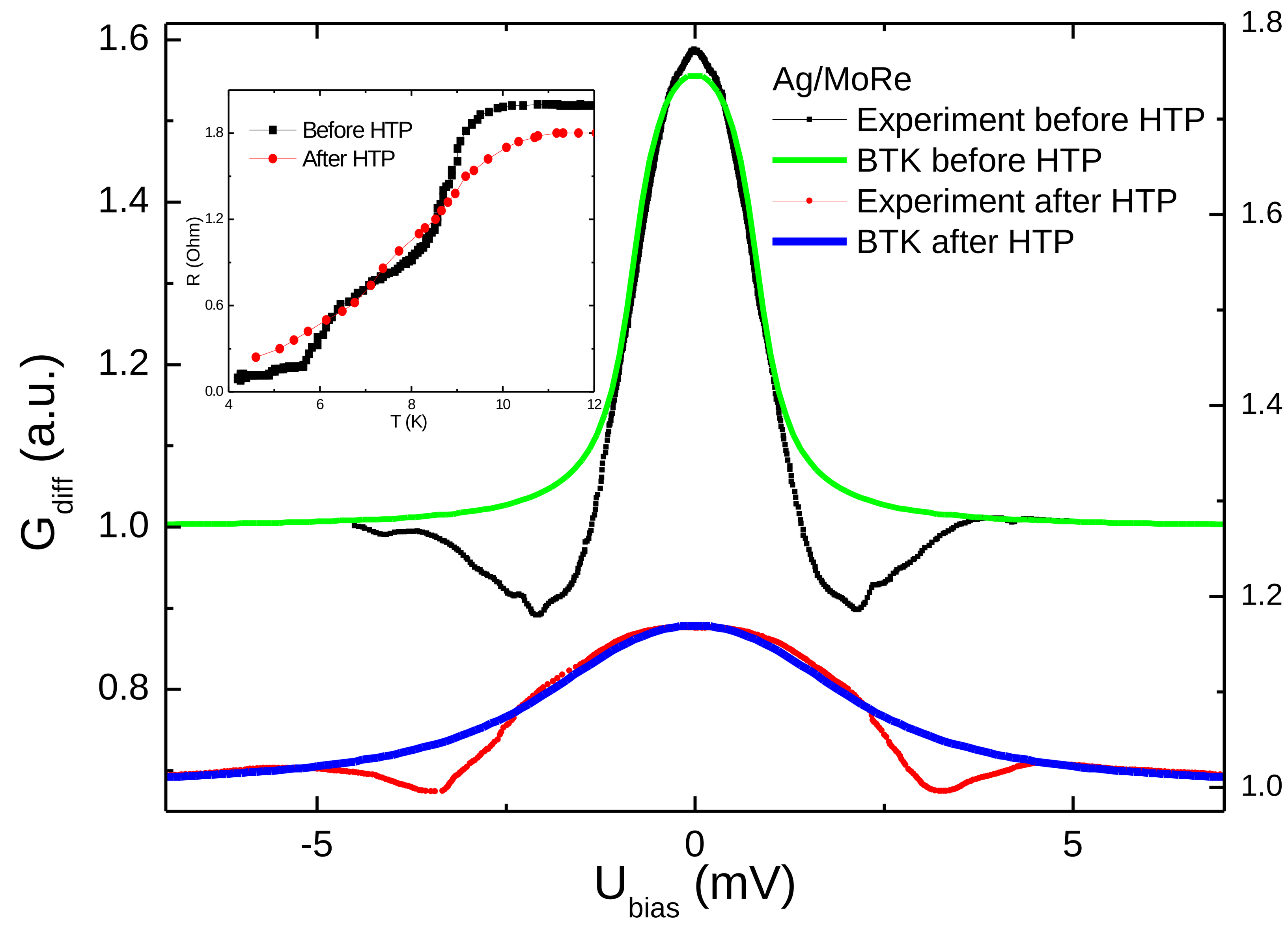

Fig. 2. Differential conductance G(V) = dI(V)/dV measured for the upper surface of a representative Ag/Mo-Re point contact at T = 4.2 K (the main panel) and the temperature-dependent resistances of the Mo-Re plate (the inset). In both cases, curves 1 and 2 correspond to the characteristics before and after the HPT treatment, respectively. Fitting parameters for calculated G(V) characteristics were $\Delta 1 = 0.81$ meV, $\Gamma 1 = 0.18$ meV, Z1 = 0.14 and $\Delta 2 = 1.60$ meV, $\Gamma 2 = 1.51$ meV, Z2 = 0.11.

Interpretation of the curves according to the Blonder-Tinkham-Klapwick model, with the transparency parameter Z = 0 (Andreev reflection approximation), gave values $\Delta_1 = 0.81$ *meV*, and $\Delta_2 = 1.62$ *meV*, respectively, before and after HPT. The ratio of the energy band gap to the critical temperature from the BSC theories has a universal value of $2\Delta/Tc = 3.52$, which is sensitive to the strength of the electron-phonon interaction. In our case, $2\Delta/Tc$ = 2.1 before HTP, which corresponds to the depletion of the superconducting phase on the sample surface, and $2\Delta/Tc$ = 4.2 after HTP, the value not only returns to the typical one but also increases, thereby indicating the presence of a strong electron-phonon coupling after treatment.

The explanation of the electron-phonon interaction is considered in terms of the theory of phonon-opened conduction in amorphous strongly coupled martializes. Due to HTP treatment, the study of fundamental parameters of the superconductor takes place on the surface, which changes from a granular to an amorphous structure. Considering where $\alpha^2F(\omega)$ is the ‘Eliashberg electron-phonon spectral function’ ”where α^2 is the interaction strength, $\alpha^2F(\omega)$ is the phonon density of states depending on the frequency ω of phonons, the growth of the electron-phonon interaction strength $\lambda = 2\int_0^\infty \frac{\alpha^2F(\omega)}{\omega}dx$ with disorder is controlled by the increasing role of low-frequency transverse phonon excitations. However, this doesn't necessarily lead to an increase in T_c, since there is another energy scale that both decreases $\omega_{log} = exp\left(\frac{2}{\lambda}\int_0^\infty \alpha^2F(\omega)\omega^{-1}\ln\omega \; d\omega\right)$ which characterizes the energy scale of phonons for pairing in the strong coupling limit. The interaction of these two factors determines whether the critical temperature of the superconducting transition will increase or decrease with increasing disorder. If considered separately, Re increases Tc with increasing disorder due to a decrease in ω_{log} despite an increase in λ, but the alloy itself does not exhibit such behavior, so no increase in Tc is observed.

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