LASER SCANNING MICROSCOPY OF SUPERCONDUCTIVE PARAMETERS OF IRON-CONTAINING CHALCOGENIDE FeTe FILMS

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The temperature of superconducting transition T_c of the iron-containing chalcogenides films is higher than in bulk samples of the same composition. Some of these substances become superconducting only in thin films [1].

This feature of iron chalcogenides is associated with the mechanical strain arising at the film-substrate interface because of misfit of crystal lattice parameters of the film and the substrate. The width of superconducting resistive transition ΔT_c of such films is larger while the critical current density is essentially less than in other superconductors with close T_c .The reason of this remains unclear.

The technique of laser scanning microscopy (LSM) has been applied in our investigations. The technique is based on the registration of change in a global characteristic of the thin film sample which depends on the superconductivity of local regions of the sample.

The direct current is passed along the sample and the ac voltage *V* arising in each cross-section of the sample during scanning it by ac modulated laser beam is measured. The beam intensity allows heating the film up in the illuminated point. Occurrence of a resistive region in the film causes a change in the voltage being registered. This voltage change is the output signal of the measuring system which we call its response.

The analysis of the response from various points of the film allows us to conclude about uniformity of superconducting properties of the film, in particular, about the critical current distribution. The LSM technique is described in our review [2] in more detail.

The objects under study are the thin film samples of FeTe obtained by laser deposition. The detailed description of the film preparation is reported in [1]. The film sample patterning necessary for the LSM studies (in the shape of a bridge connecting two banks) was formed in advance by means of a special and more powerful optical laser.

The data obtained on the 130 μm-long, 30 μm-wide bridge (Fig. *1a*) are presented in the work. The resistive transitions for this sample obtained at various measuring currents are shown in Fig. *1b.* The temperature values at which the LSM-response maps were registered are denoted by squares (Fig. *1c*). The black color corresponds to absence of response while the white color corresponds to the maximal response for all pictures in Fig. *1c*.

The responses in the left column of images are presented in the common scale. In the right column the same LSM images are shown in individual scaling with maximum contrast for each image since the LSM response differs significantly for different points of the resistive transition. The white color on the image corresponds to the maximal LSM response at each given temperature. This allows us to analyze the spatial structure of the response at each temperature in more detail.

It should be noted that transition width ($\Delta T_c / T_c \approx 0.3$) is great even at the minimal measuring current. Significant increase of the superconducting transition width due to shifting its end to lower temperatures occurs with increasing the measuring current, while, the beginning of the transition is not shifted. Such behavior is characteristic for the samples consisting of superconducting areas connected by "weak links". At the same time, areas with the various T_c are distributed in the sample uniformly.

The LSM maps have shown that the response appears practically over all the sample right at the beginning of superconducting transition (point 10 in Fig. 1).

At the further reducing the temperature, the spatial structure of the response does not vary essentially while the response amplitude grows proportionally to *dV/dT*.

The response disappears when the transport current falls below the critical current accounting the laser influence at the given temperature.

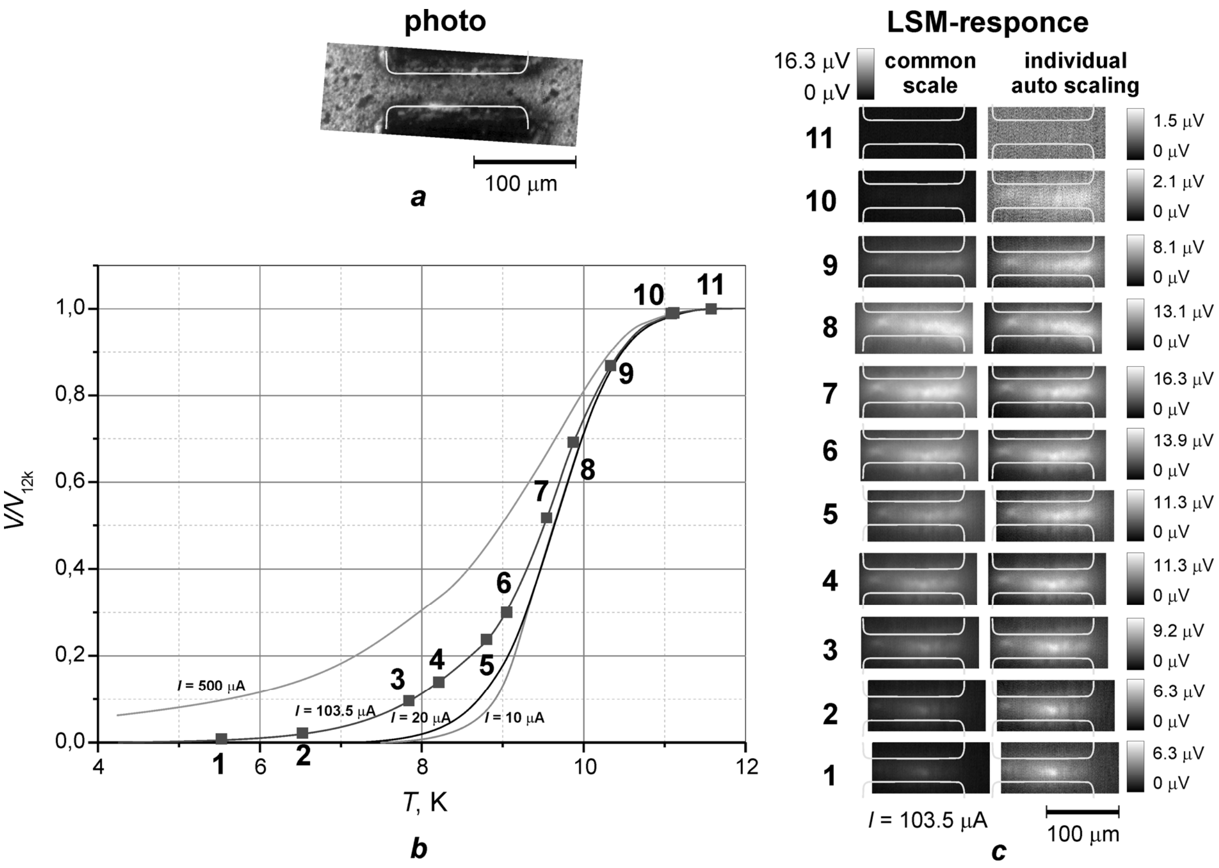

Figure 1. Microphoto of the sample (*a*), superconducting transition for different measuring currents (*b*) and images of LSM-responses in various points of the transition (*c*)

LSM-studies at the fixed temperature and various transport currents through the sample have been carried out to find the distribution of critical currents over the sample. The voltage-ampere characteristic (VIC) of the sample at temperature 6.7 K (the initial part of this dependence — fig. *2b*) is shown on fig. *2a*. The values of currents for obtaining the LSM-responses shown on fig. *2c* (representation of images is similar to fig. *1c*), are marked by squares.

At increase in the measuring current the response is observed in those cross-sections of the sample for which the measuring current exceeds critical magnitude taking into account the influence of a laser beam. Some regions in the sample pass into a resistive state already at the current of 50 μA. It is visible, that with the increase of a transport current more and more new areas consistently pass to a resistive state. Thus differential resistance on the sample VIC ($R_{dif} = dV/dI$) increases, exceeds resistance in normal state R_n, and then goes down reaches R_n.

The LSM-images analysis shows, that in the sample there are regions at which the resistivity arises only at great currents. These local areas of the sample have critical currents tens times as high as the critical current of the whole sample.

At temperature below the point of transition of liquid helium to the superfluid state (when conditions of the heat-conducting path from the sample considerably improve) at currents grater than 7 mA on the VIC leaps of voltage are observed.

They correspond to transition of significant regions of the sample having high critical currents to a normal state (see the curve at $T = 2$ K on fig. 3).

Thus, carried out researches show, that the critical current of the sample is limited by presence of "weak links"; structural blocks with various T_c and I_c are distributed in regular intervals about sample volume; in the sample there are structural blocks with high values of a critical current tens of time exceeding an integrated critical current of the film sample.

Considering, that the data of the work [1] prove high chemical uniformity of the film and superconductivity in such systems is explained by the strains on the film—substrate interface, this revealed heterogeneity of superconducting properties can be explained, in particular, by heterogeneity of the strains on this interface.

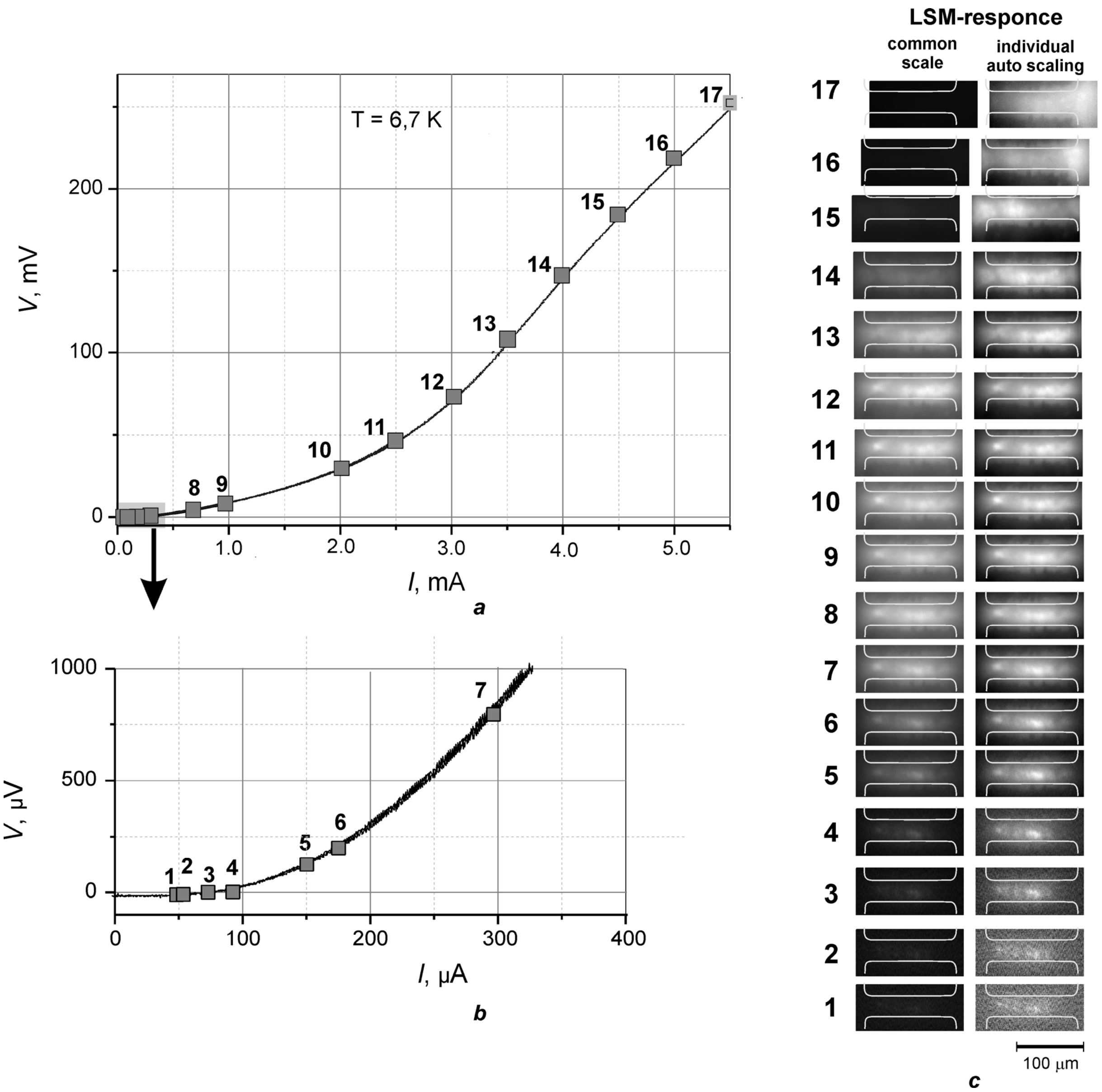

Figure 2. The voltage-ampere characteristic of the sample (a*)*, its initial part (*b*)
and the images of the LSM-responses which have been obtained at different currents through the sample (c)

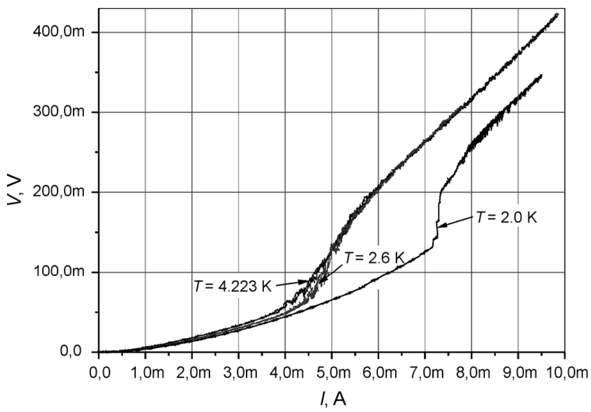

Figure 3. The voltage-ampere characteristics
of the sample above and below the temperature
of transition of liquid helium in a superfluid state

References

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