Morphology of Cd and Te inclusions and their effect on the internal electric field and stress distributions in CdMnTe crystals

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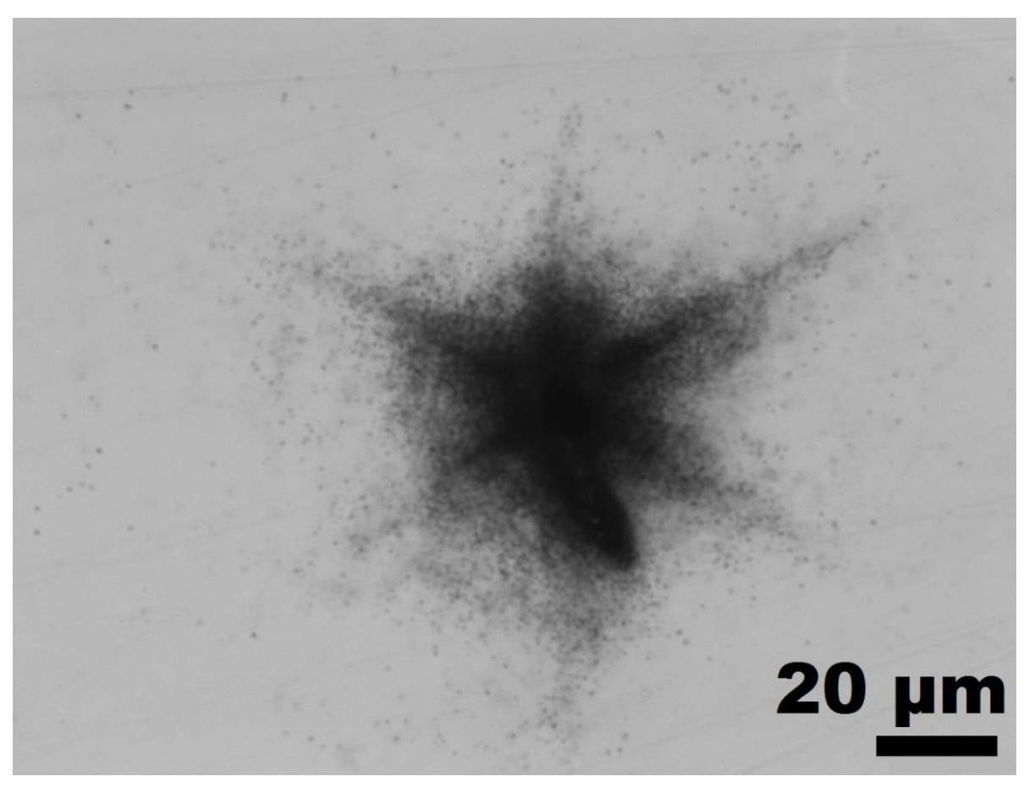
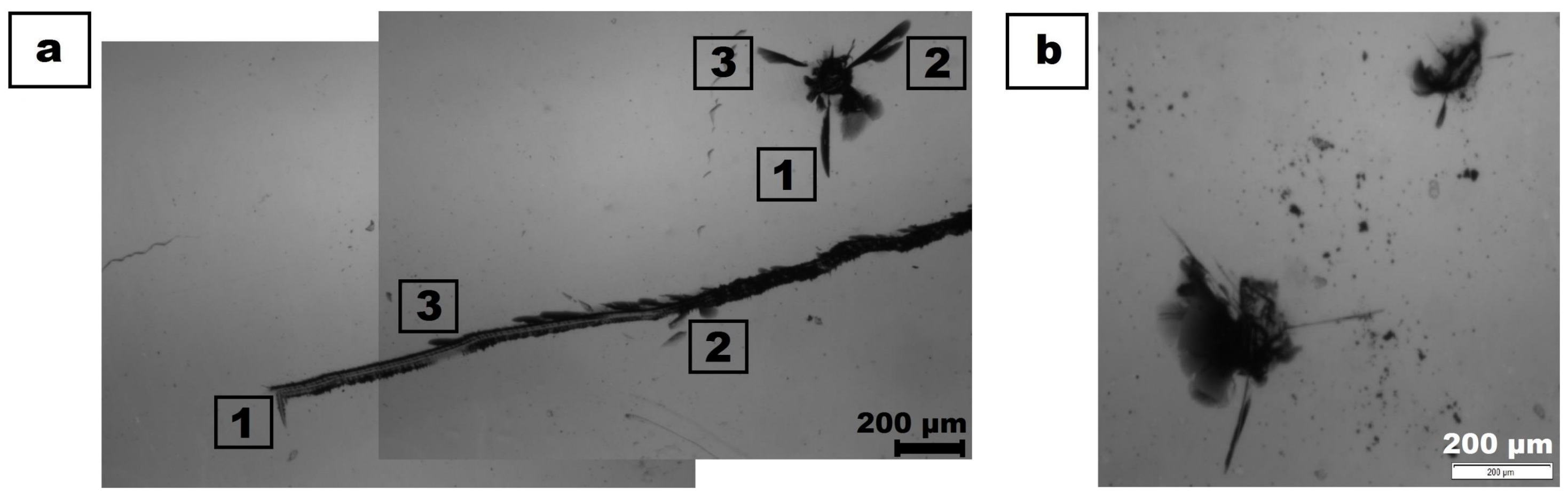
Introduction

CdMnTe belongs to the group of semiconductors, which is currently studied for room-temperature nuclear detectors. In this application homogeneous crystals are demanded. In Bridgman-grown crystals the presence of inclusions is typical. One should distinguish between inclusions and precipitates, whose origins are different. Inclusions are generated at the crystallization front, whereas precipitates are formed during cooling down due to retrograde solidus. In this work by saying „inclusions" and „precipitates" we mean second phase particles size of which is bigger and smaller than 1 µm, respectively. The size of precipitates is typically on the order of nanometers. Te inclusions and precipitates are quite difficult to avoid in this material. If a stoichiometric mixture is used as the source material, it will be Te-rich at the growth temperature because there is a high partial pressure of Cd compared to that of Te. Thus, growth under an excess of Cd seem to be a reasonable approach. As a result of these two processes the concentration of Cd vacancies could be reduced, as well as the amount and size of Te inclusions. This could lead to a better carrier transport and thus, a better detector performance. On the other hand, Cd-rich growth or inadequate annealing in Cd atmosphere could lead to the formation of Cd inclusons. It is essential to find the balance between these two issues and to characterize the impact of Cd and Te inclusions on the crystal properties.

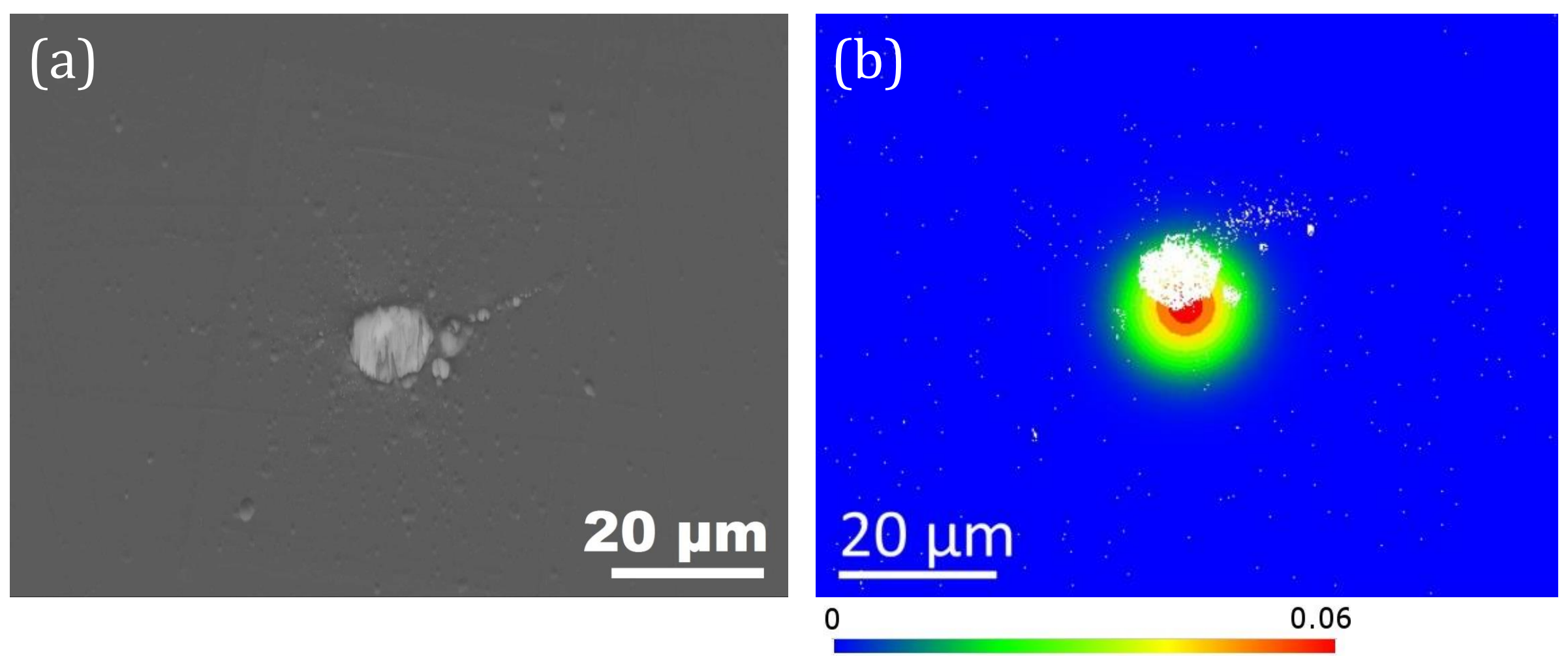
Cd inclusion – CdMnTe crystal grown under Cd-excess



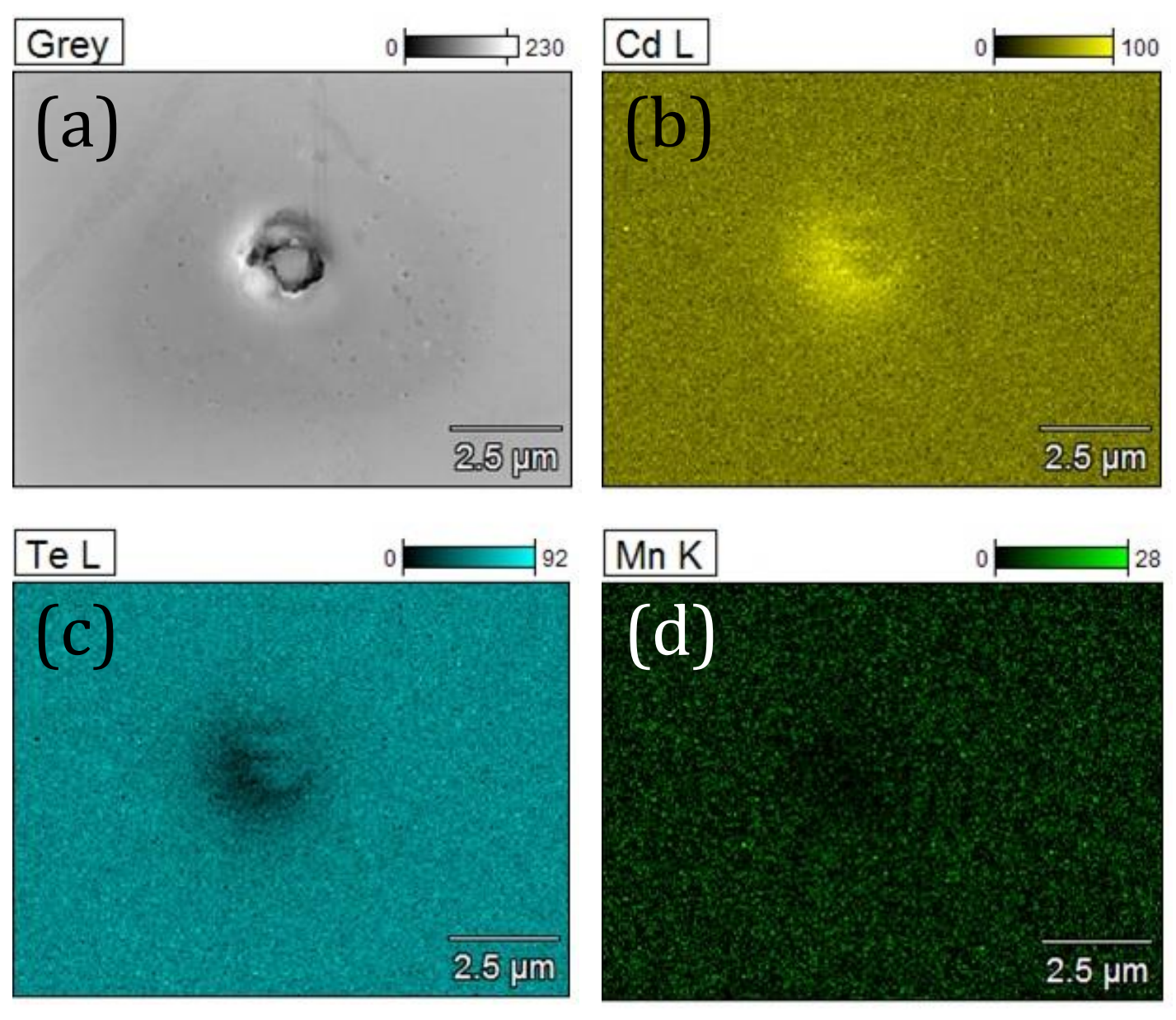
IR image. Morphology of Cd inclusion



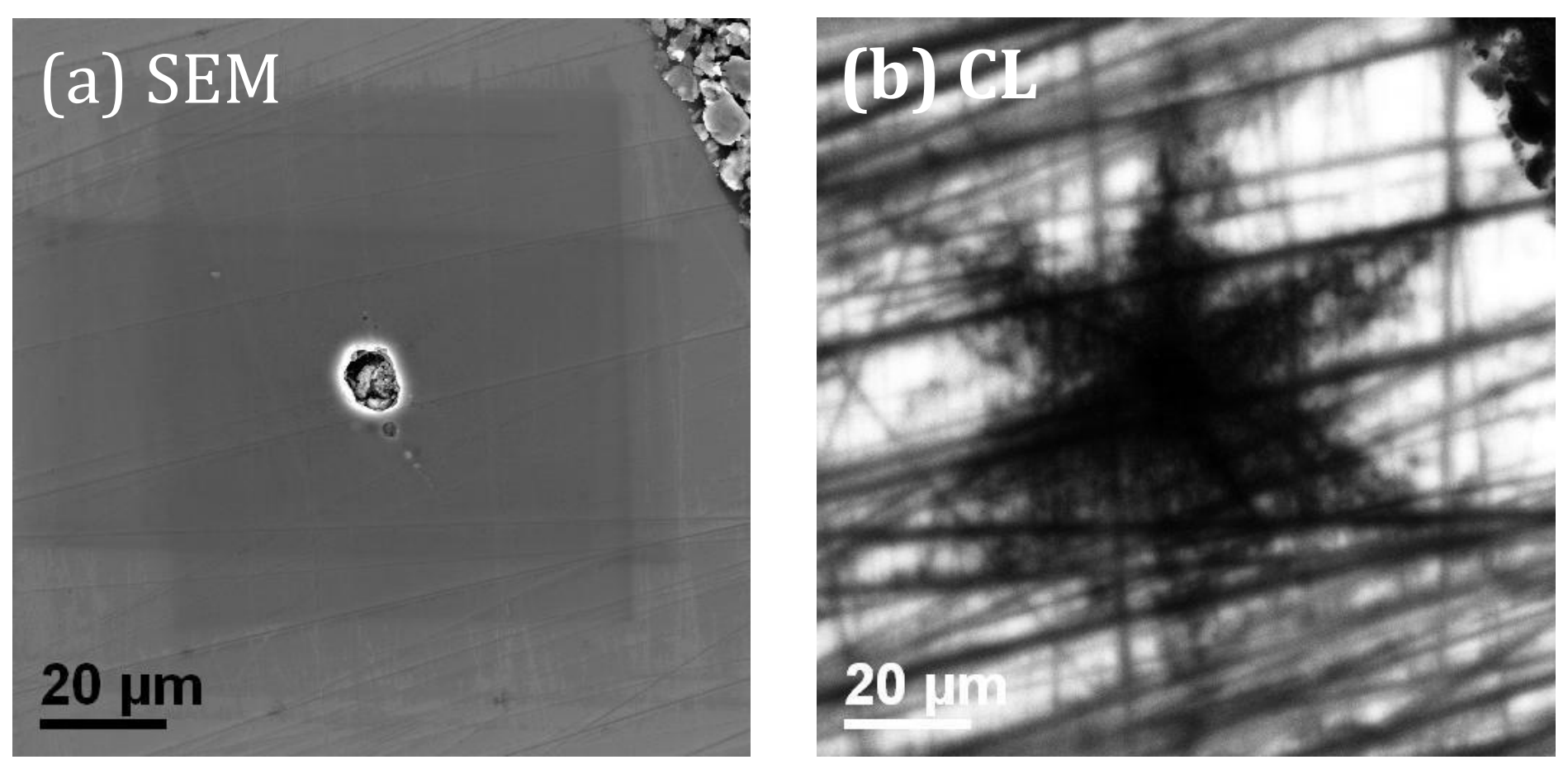
IR image of line and point scratches on the surface of CdMnTe: (a) a bit out of (111) orientation; (b) (111) orientation. Numbers 1, 2, 3 correspond to cracks in (110), (101) and (011) easy-cleavage planes.



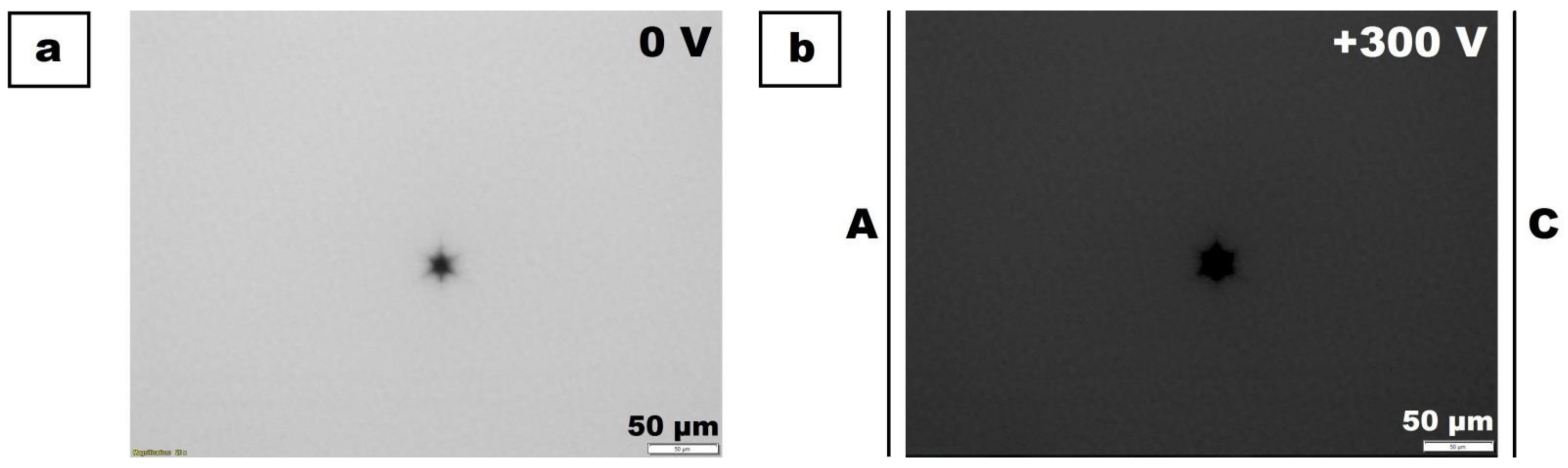
Cd inclusion. (a) SEM image; (b) EBSD map with legend.



(a) SEM image, and EDX elemental distribution maps of (b) Cd, (c) Te, (d) Mn.

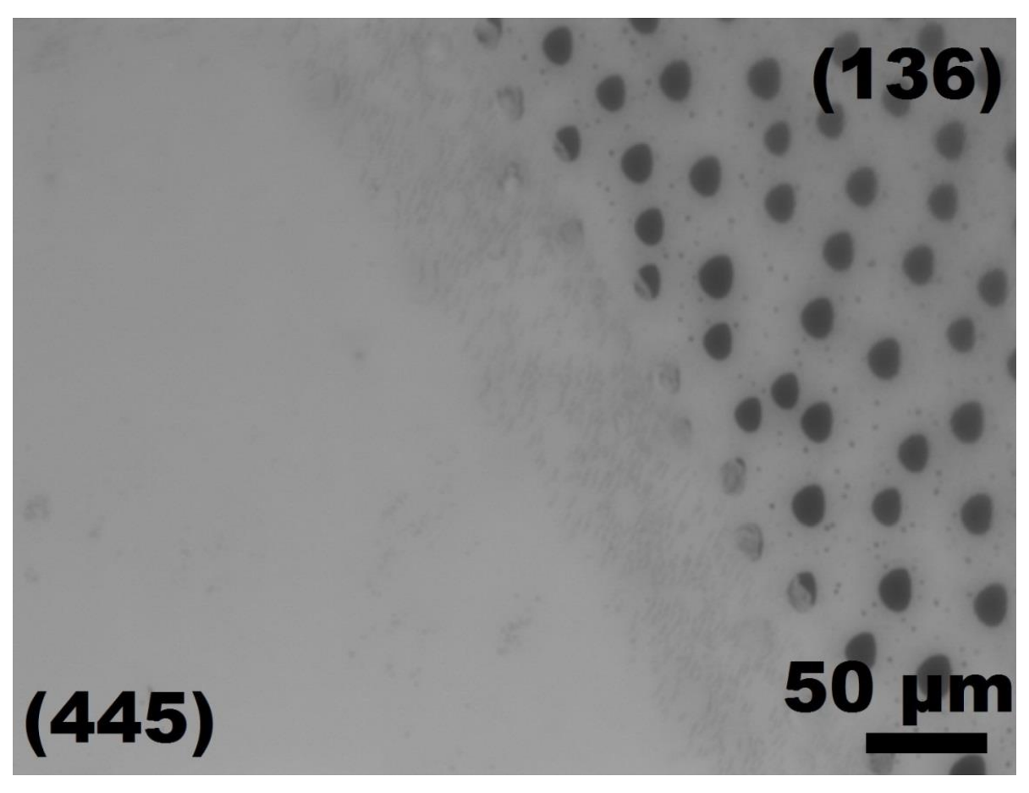


(a) SEM image; (b) and corresponding CL map at 300 K.

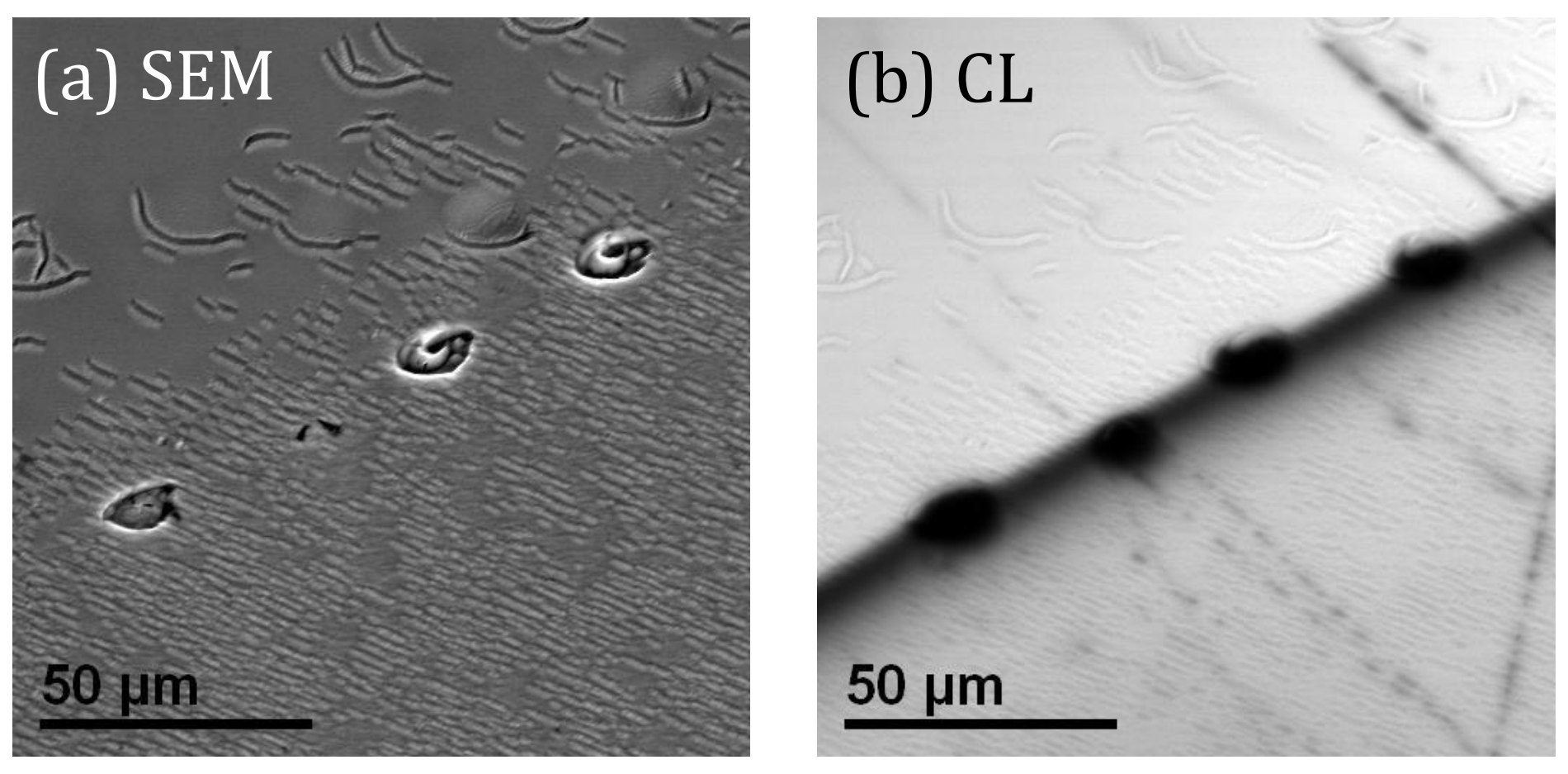


Cd inclusion. (a) IR image; (b) Pockels image.

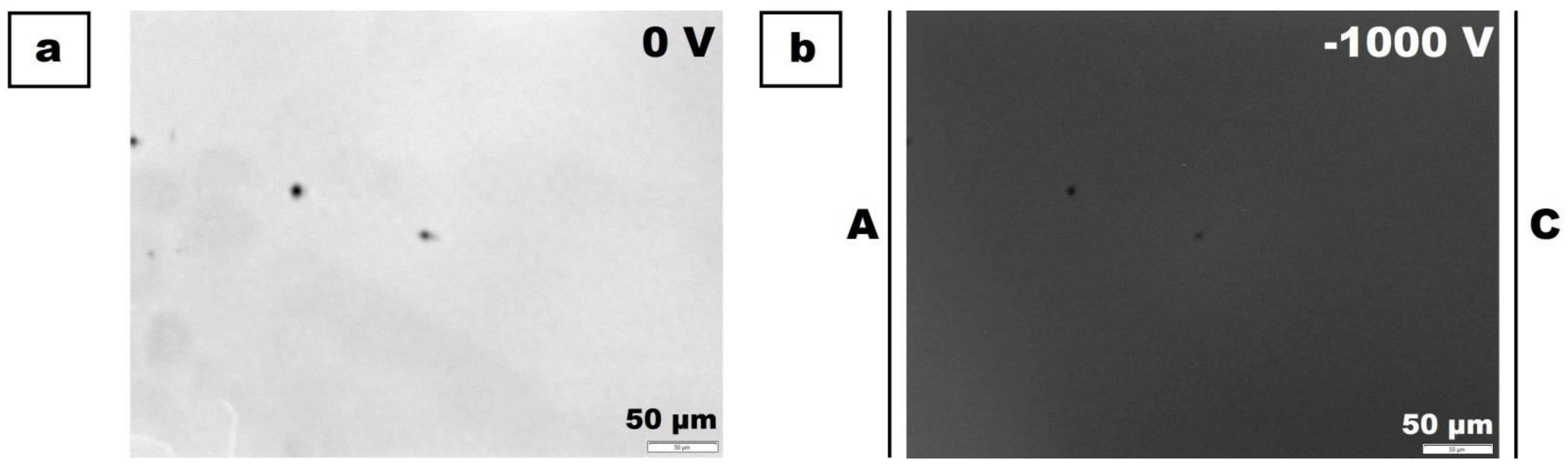
Te inclusion – CdMnTe crystal grown under Te-excess



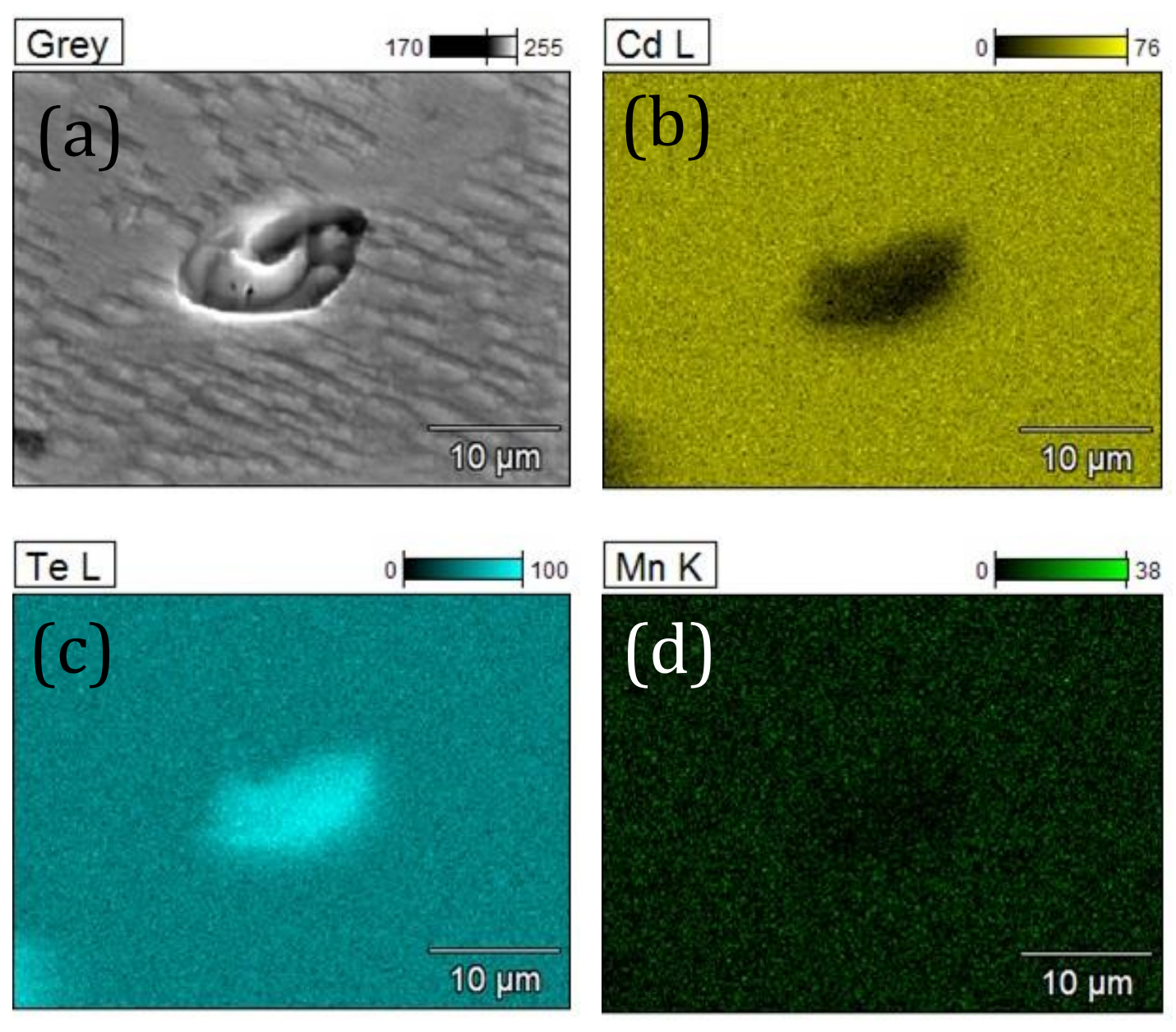
IR image. Morphology of Te inclusions located in the region of (445) and (136)-oriented grains.



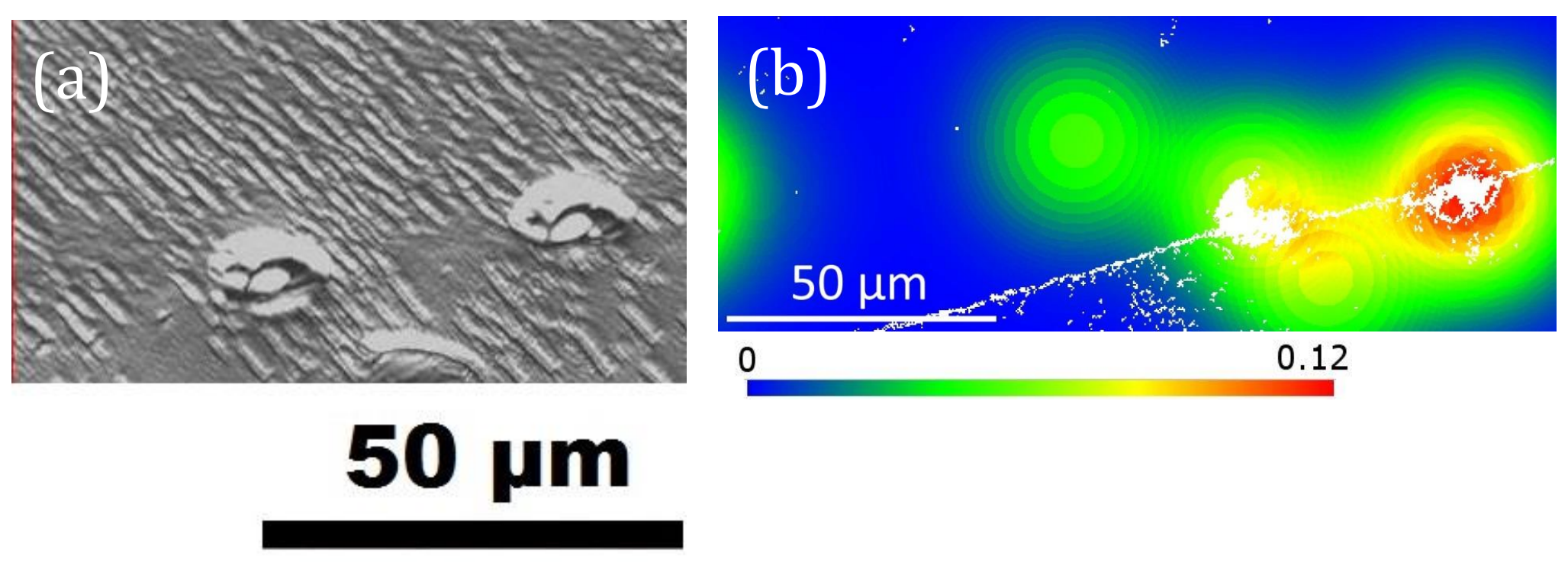
(a) SEM image; (b) and corresponding CL map at 300 K.



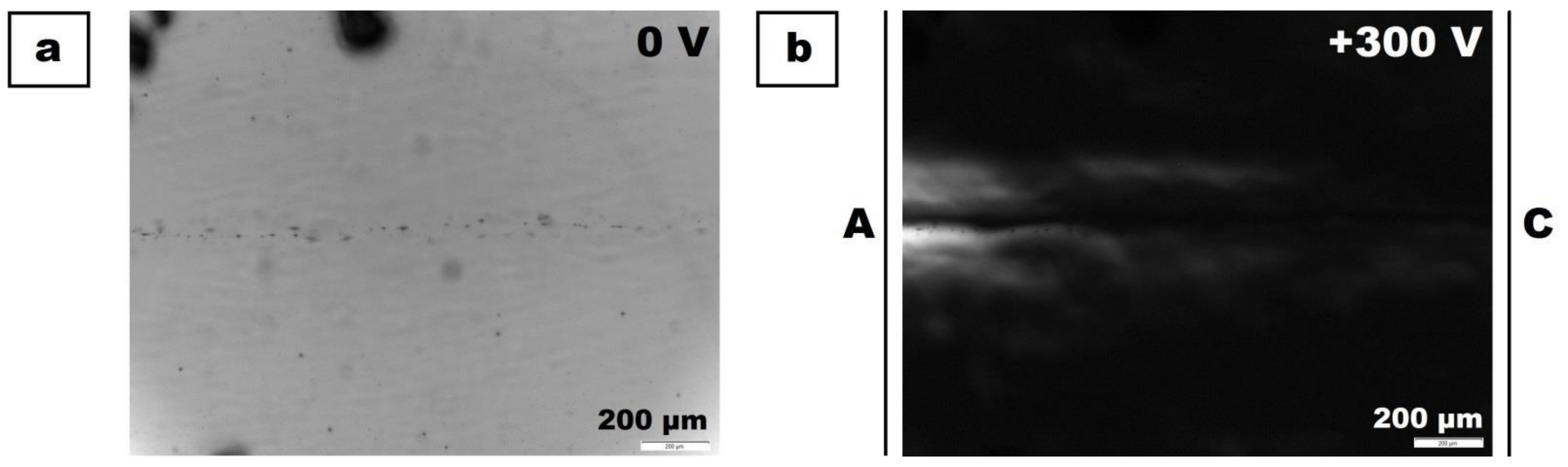
Two separated Te inclusions. (a) IR image; (b) Pockels image.



(a) SEM image, and EDX elemental distribution maps of (b) Cd, (c) Te, (d) Mn.



Te inclusions. (a) SEM image; (b) EBSD map with legend.



Horizontal line of Te inclusions. (a) IR image; (b) Pockels image.

Summary

Tellurium inclusions are spheroidal/polyhedral, while cadmium ones appear star-like. The core size of both Te and Cd inclusions is 5-10 µm. Cd inclusions cause microcracks so that they create star-like defects the size of which is about ten times bigger than the inclusions themselves. Each pair of branches in the star-shaped defect we associate with three easy-cleavage planes (110) of the zinc blende structure. Pockels effect investigations show that separated Cd and Te inclusions do not disturb internal electric field in their vicinity. Only Te inclusions distributed along a continuous plane have an impact on the internal electric field. CL maps confirm that Te inclusions do not generate defects in their vicinity, in contrary to Cd inclusion, which induces microcracks in its neighborhood in the CdMnTe matrix. This originates from the higher thermal expansion coefficient ratio of Cd to CdTe than Te to CdTe. Next, the relative stress analysis was carried out using the electron backscatter diffraction (EBSD) technique, which shows that a Te inclusion causes higher stresses in its environment than a Cd inclusion does. The reason for this is that the Cd inclusion releases the stresses due to a creation of the tensile cracks.

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