Ionoluminescence in helium ion microscopy

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Helium ion microscopy (HIM) is a novel technique for material characterization and modification. A He^+ ion beam with a spot size of 0.29 nm and an energy of several keV is used for probing a sample. In HIM an image is acquired by collecting secondary electrons, backscattered He or photons (Figure 1). Each of these signals provides different valuable information about the investigated sample. We are specifically interested in the ionoluminescence (IL) phenomenon. IL is a radiative relaxation of the sample's electronic system, which has been excited by the incoming ion beam.

In this contribution we present the latest results on IL in HIM. Light emission, induced by the highly focused He^+ beam, was observed for such materials as semiconductor films and nanowires, also perovskites, containing rare-earth ions. We observed quenching of the luminescence from the bulk semiconductor samples, however, the light emission from the nanowires is more stable.

Extensive studies were performed on alkali halides samples. There, the ionoluminescence is caused by emission from the various crystal defects (colour-centers), which are created by the incoming ion beam. The small beam size available in HIM provides an opportunity to locally change the material properties. This can be used to create patterns of luminescent structures, which is demonstrated in Figure 2. However, the feature size is limited not just by the beam diameter, but by the actual beam interaction volume. The increase of the modified area with the beam current was studied using NaCl crystals. We also investigated the IL signal dependence on the ion fluence. In case of NaCl and KCl, the IL signal increases with fluence. For the case of CaF_2 luminescence quenching was observed. Interestingly, the IL signal kinetics were found to be dependent on the scanning parameters such as pixel separation and ion current density. Thus, a He^+ ion beam not only induces light emission, but has a dramatic influence on the optical properties of the materials itself.

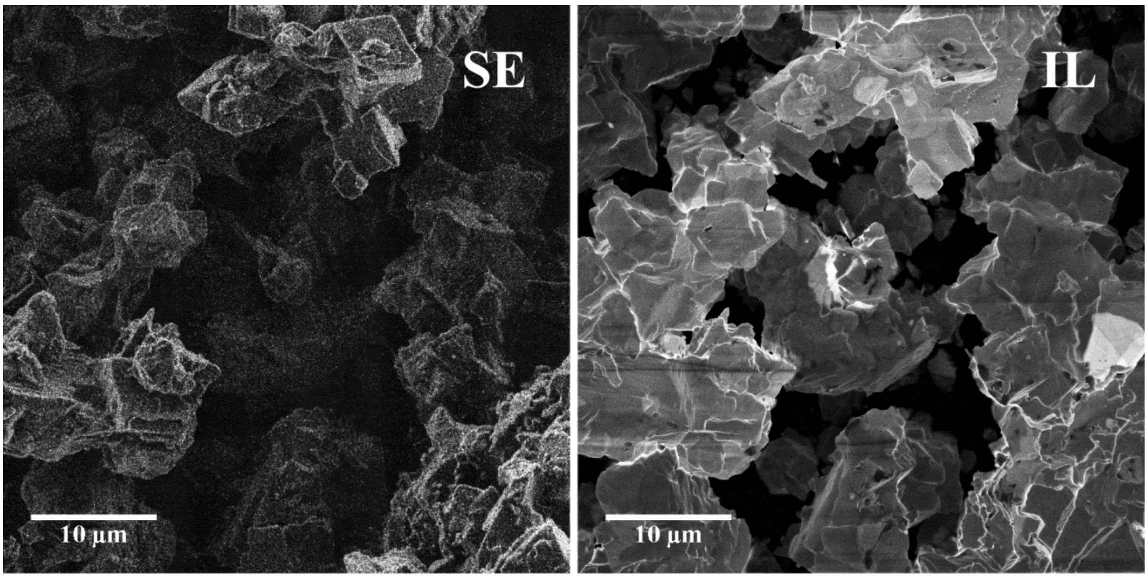

Fig. 1. *Secondary electrons (left) and ionoluminescence (right) images of CaF_2 crystals. FOV is 45 µm, He^+ beam energy is 35 keV.*

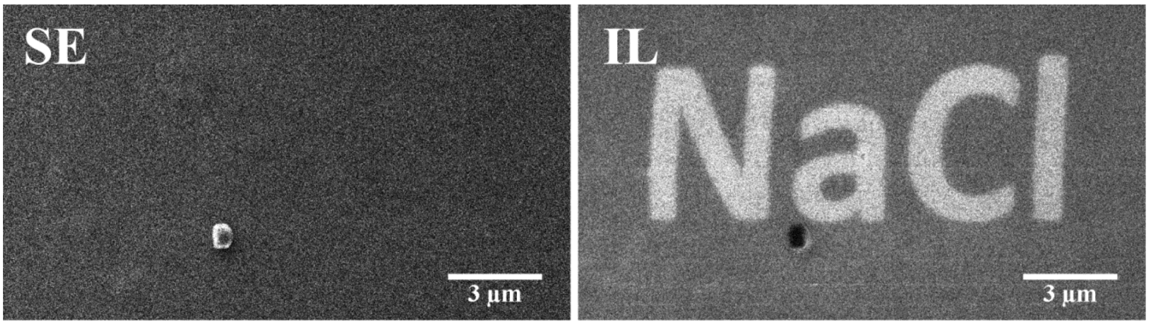

Fig. 2. *Secondary electrons (left) and ionoluminescence (right) images of a luminescent pattern on NaCl crystal. FOV is 18×10 µm, He^{+} beam energy is 35 keV.*

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