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Low-temperature radiation effects in wide gap materials

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Ionizing- and particle irradiation plays an important role as a purposeful modification of material substances to improve their functionality and also allows to implement a thorough analysis of the various material intrinsic properties applying a probing regime of irradiation. The present special journal issue is devoted to low-temperature radiation effects with special attention to radiation-induced/modified structural and impurity defects caused by irradiation of wide gap solids, starting from model single crystals up to layered, glassy and hybrid composite materials.

To perform the study with the use of many conventional and up to-date experimental methods, these materials were exposed to irradiation with photons (from IR to VUV-XUV spectral region), x and γ rays, fission neutron etc. The energy absorbed by a material during irradiation is only partly used for the excitation of different types of luminescence applied in scintillators, dosimeters and phosphors for lighting, whereas a significant part of the gained energy is transformed non-radiatively into heat or creation/transformation of structural defects. The ratio between radiative and non-radiative channels of energy dissipation channels depends on many factors and determines the prospects of the material application for certain purposes. As the radiation damage limits many of these applications, the elucidation of the mechanisms of structural defect creation and their possible attenuation/suppression in wide gap materials are of increasing importance.

One review article and 13 regular research papers cover a broad class of wide gap materials, starting from model single alkali halide crystals, both pure and doped [1,3,9,11], widely used for different applications pure and doped CaF_2 and BaF_2 alkali-earth halides [1], rutile-structured SiO_2 and GeO_2 crystals and glasses [6] or CdI_2 layered crystals [12] to less studied tungstate $NiWO_4$ [2,4] and lastly, perovskites $BaLiF_3$ [1] and $BaZrO_3$ [13]. The comprehensive review of the relaxation of the electronic excitations and luminescence of rutile-structured SiO_2 and GeO_2 crystals and their detailed comparison with α-quartz crystals and relevant glasses was given in paper [6]. The advantages and disadvantages of the implementation of the advanced EPR technique with the use of magnetic circular dichroism to different paramagnetic centres in crystals, glasses and glass-ceramics are considered by Rogulis [1].

The creation of Frenkel defects by synchrotron radiation in highly pure NaCl was thoroughly analyzed by Lushchik *et al.* [3]. It was experimentally proved for the first time that only the recombination of non-relaxed (hot) electrons with holes provides the energy (exceeds energy gap by 2–3 eV) sufficient for the creation of Frenkel defects at low temperature. The detailed simulations of the kinetics of low-temperature diffusion-controlled *F, H* center recombination (and its comparison with the experimental literature data) was performed for a series of irradiated alkali halide crystals by Kuzovkov *et al.* [11]. This is the first theoretical study which demonstrates how to extract the energies of defect migration and interaction from experimental kinetics of the defect annealing. This is most important for further analysis of material radiation stability and the comparison with first-principle calculations of defect migration. In particular, such combined theoretical and experimental analysis can help to clarify the charge of migrating interstitial ions, still not defined in oxides. A very unique method of the low-temperature stress in the luminescence studies of scintillating materials was applied by Shunkeev et al. and the influence of the applied deformation on the barrier for the exciton self-trapping as well as on the impurity and intrinsic luminescence efficiency in KI–l crystals was demonstrated [9].

New materials, such as the ScF_3 single crystals with negative-expansion [5], the Er^{3+}-doped $LaInO_3$ providing up-conversion luminescence [8] as well as $BaZrO_3$-based polysterene-perovskite hybrid composites [13] are also studied and reported in the present issue. Besides many conventional experimental methods, such as optical absorption, luminescence, magnetic resonance, etc. [1,6,8–10,12,13], the opportunities of synchrotron radiation techniques are also demonstrated for NaCl crystals and NiWO4 tungstates using both VUV [2,3] and IR [4] light beams. The use of nuclear reactor for the creation of novel radiation-defect-induced jewellery colors of minerals, such as agate (SiO_2), topaz ($Al_2[SiO_4](F,OH)_2$), beryl ($Be_3Al_2Si6O_{18}$) and prehnite ($Ca_2Al(AlSi_3O_{10})(OH)_2$) doped with different concentration of transition metal ions was review by Mironova-Ulmane *et al.* [10]. One more advanced experimental method — the usage of positron radiation for free-volume studies of micro- and macro-modified spinel ceramics was presented and described in [14]. Where necessary, the obtained results were supported by other experimental methods such as SEM, TEM and x-ray diffraction. Special attention was also paid to modern theoretical methods of the electronic band structure calculation [4,5]. A new quantum field approach for the description of highly-excited insulator materials was developed in paper [7].

Summing up, the present issue clearly demonstrates the great progress achieved in recent years in the studies of radiation properties of a wide class of insulating materials. We believe that this issue will be useful for a wide community of researchers working in the area of materials physics and chemistry.

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