Electric and magnetic characteristic of $Ca_{1-3x-y}Co_y\square_xGd_{2x}(MoO_4)_{1-3x}(WO_4)_{3x}$ solid solution

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Scheelite-type molybdates and tungstates are attractive materials due their a large efficient scintillation yield, X-ray absorption coefficient, and high thermal and chemical stability. A number of these compounds have been developed in the field of scintillation detectors (*e.g.* $CaMoO_4$ or $PbWO_4$), phosphors, and laser materials. New calcium molybdato-tungstates doped with cobalt and gadolinium ions with the chemical formula of $Ca_{1-3x-y}Co_y\square_xGd_{2x}(MoO_4)_{1-3x}(WO_4)_{3x}$ (where x = 0.0050, 0.0455, 0.0839, 0.1430, 0.1667, 0.2000; y = 0.02 and $\square$ denotes vacancies) were successfully synthesized *via* high-temperature annealing of $CoMoO_4/Gd_2(WO_4)_3/CaMoO_4$ mixtures with various content of all reactants. The doped materials adopt the tetragonal scheelite-type structure with space group $I4_1/a$.

The static dc magnetic susceptibilitiy was measured in the temperature range of 2–300 K. Magnetization isotherms were measured at 2, 10, 20, 40, 60 and 300 K using a Quantum Design MPMS-XL-7AC SQUID magnetometer in applied external fields up to 70 kOe. The electrical conductivity $\sigma(T)$ was measured by the DC method using a KEITHLEY 6517B Electrometer/High Resistance Meter in the temperature range of 300-400 K. The thermoelectric power $S(T)$ was measured in the temperature range of 300–600 K using a Seebeck Effect Measurement System (MMR Technologies, Inc., USA). Dielectric properties of the solid solution under study were measured with use of the Broadband Dielectric Spectrometer by Novocontrol GmbH (Germany) equipped with the Alpha Impedance Analyzer with Active Sample Cell and Quatro Cryosystem temperature control. Investigations were performed when a temperature decreased from 373 K to 173 K with the T-step of 5 K.

Magnetic measurements showed an almost ideal paramagnetic state with the weak short-range magnetic interactions and an increase of spin contribution to the magnetic moment with increasing of gadolinium ions in the sample. Comparable values of the effective magnetic moment and the effective number of Bohr magnetons showed that the cobalt ions contribute a small orbital contribution to the magnetic moment. Therefore, poorer gadolinium samples have a stronger spin-orbit coupling effect than the richer ones. The results of the electrical conductivity and thermoelectric power measurements showed insulating behaviour with small values of the *n*-type electrical conductivity of $\sigma \sim 10^{-10}$ S/m.

Broadband dielectric spectroscopy measurements of the solid solution under study showed a small values of dielectric permittivity with $\varepsilon_r \sim 20$ and loss tangent with $\tan\delta \sim 0.01$. Dielectric analysis in the frequency representation showed that no dipole relaxation processes (like with Maxwell-Wagner [1] or Jonscher [2]) were discerned on the real and imaginary spectra. This behaviour is characteristic for the spatial charge polarization, in which the freedom of electron charge or ionic is limited. On the other hand, for the another solid solution sample with a larger number of spin defects, $Pb_{1-3x}\square_xGd_{2x}(MoO_4)_{1-3x}(WO_4)_{3x}$ synthesized by the same route, the relaxation process was observed in dielectric spectra [3].

[1] A. Von Hippel, Dielectrics and Waves, Artech House, London, 1995.
[2] A.K. Jonscher, Dielectric Relaxation in Solids, Chelsea Dielectric Press, London, 1983.
[3] Z. Kukuła, M. Maciejkowicz, E. Tomaszewicz, S. Pawlus, M. Oboz, T. Groń and M. Guzik, *Ceram. Int.* **45**, 4437 (2019).