Growth and spectroscopic studies of $Na_2W_2O_7$ crystals doped with Ce^{+4} and Cr^{+3} ions, promising scintillation detectors of elementary particles

V.D. Grigorieva, M.I. Rakhmanova, A.A. Ryadun

[1]Nikolaev Institute of Inorganic Chemistry, SB RAS, 630090 Novosibirsk, Russia

grigoryeva@niic.nsc.ru

Studies of "dark matter" is an important fundamental branch of modern cosmology and theoretical physics. Cryogenic scintillation detectors based on single crystals of tungstates ($ZnWO_4$, $CaWO_4$, $Na_2W_2O_7$) can be used to register "dark matter"; they register extremely rare signals of interaction of Weakly Interacting Massive Particles (WIMP) with the nuclei of the detector material [1].

The important requirements to scintillation materials for the search and registration of such rare events are luminescence, light yield, energy resolution, high level of radiation purity. Necessary radiation purity level and optical quality of scintillators require the development of special technologies for deep purification of starting materials and new approaches to crystal growth under conditions of low temperature gradients, the production of scintillation elements with a high utilization rate of the costly starting material. Scintillation bolometers based on $Na_2W_2O_7$ must also be of high mechanical strength for their practical significance since bolometric elements of specified form will have to be cut from the crystals. To improve the mechanical and optical characteristics, charge with chromium Cr^{+3} and cerium Ce^{+4} doping was prepared, doped $Na_2W_2O_7$ crystals were grown and their luminescent properties were investigated [2].

$Na_2W_2O_7$ crystals were grown from melt by low-thermal-gradient Czochralski technique (LTG Cz) developed at NIIC SB RAS (Novosibirsk, Russia). Major difference from conventional Czochralski technique is in temperature gradients reduced by two orders of magnitude, below 1 K/cm. Main advantages of LTG Cz are reduced thermoelastic stresses in growing crystals so that they don't influence crystal quality, and suppression of melt components decomposition and volatilization. By LTG Cz many scintillating crystals of record size and optical quality were obtained, such as BGO, $CdWO_4$ and many other [3].

As precursors, Na_2CO_3, WO_3, CeO_2, TiO_2 and Cr_2O_3 powders were used. Initial charge for crystal growth was prepared by solid-state synthesis at 400 °C in muffle furnace according to the reaction:

$$Na_2CO_3 + 2WO_3 \rightarrow Na_2W_2O_7 + CO_2 \uparrow$$

Completeness of synthesis was controlled by weight change due to CO_2 volatilization. Crystallization rate was set at 1.5 mm/h, rotation velocity at 10 rev/min. Diameter of grown $Na_2W_2O_7$ crystals was 30 mm, length up to 70 mm and 40 mm for pure and doped ones, correspondingly.

Figure 1. $Na_2Mo_2O_7$ crystal doped with 0.1 at.% Ce

Figure 2. $Na_2Mo_2O_7$ crystal doped with 1 at.% Cr

[1] Indra, Raj, Kim, H.J., Lee, H.S., Kim, Y.D., Lee, M.H., Grigorieva, V.D., Shlegel, V.N. (2018) *Eur. Phys. J. C*, **78**, 973.

[2] Ryadun, A.A., Rakhmanova, M.I., Grigorieva, V.D. (2020) *Optical Materials*, **99**, 109537.

[3] Shlegel, V.N., Borovlev, Yu.A, Grigoriev, D.N, Grigorieva, V.D. et al. (2017) *JINST*, **12,** C08011.

Keywords: $Na_2W_2O_7$; Czochralski technique; scintillators; elementary particles; luminescence

This work was supported by Russian Foundation for Basic Research (grant No. 20-43-543015).

Acta Cryst. (2021), A**77**, C494