

## REVIEW

**for the PhD abstract for the Doctor of Philosophy (PhD) in Chemical Sciences Xu Xieyu on the topic: «Li-conductive ceramic electrolyte with NASICON structure for solid-state batteries», by specialty 1.4.15. Solid State Chemistry**

With the rapidly developing energy storage industry and the demand for clean energy, the further development of secondary power sources is of practical importance. Lithium batteries with solid-state electrolytes are recognised as one of the best ways to achieve higher energy density and safer batteries. In Xu Xieyu's Ph.D. thesis, the mechanical properties of the solid electrolyte were studied by numerical modelling depending on its microstructural features,  $\text{Li}_{1+x}\text{Al}_x\text{Ti}_{2-x}(\text{PO}_4)_3$  solid electrolyte ceramic material with NASICON structure was selected and synthesized, and its physicochemical and electrochemical performance was investigated.

The author has synthesized powdered precursors of the composition  $\text{Li}_{1+x}\text{Al}_x\text{Ti}_{2-x}(\text{PO}_4)_3$  using various methods. The characterisation of the powdered precursors was carried out using a wide range of studies. The influence of particle size, temperature and sintering time on the properties of ceramic electrolyte has been investigated. Based on the data obtained, the author developed a new method to produce thin ceramic membranes with high ionic conductivity and mechanical strength, and successfully used them to assemble a solid-state battery.

The use of a large number of methods for the examination of samples by modern high-precision equipment of domestic and foreign production undoubtedly increases the reliability of the results obtained. The results presented by Xu Xieyu have an important theoretical significance for the study of the properties of materials with the NASICON structure of the composition  $\text{Li}_{1+x}\text{Al}_x\text{Ti}_{2-x}(\text{PO}_4)_3$ . The work has been well tested, the results have been published in 5 scientific articles, and also presented at 4 international and Russian conferences.

The shortcomings of the thesis, as noted in the content of the PhD thesis abstract include the following:

1. The text of the PhD abstract does not provide the theoretical justification for the model used to carry out the numerical modeling using the phase field method.
2. It is not entirely clear for which type of ceramic electrolyte all the electrochemical data are presented.

The work «Li-conductive ceramic electrolyte with NASICON structure for solid-state batteries » meets the requirements established by the M.V. Lomonosov Moscow State University for this kind of works. The content of the work corresponds to specialty 1.4.15. Solid State Chemistry, namely the following directions: 1) development and creation of methods for the synthesis of solid-phase compounds and materials; 2) establishment of "composition-structure-property" correlation for solid-phase compounds and materials; 3) study of the influence of synthesis conditions, chemical and phase composition, as well as temperature, pressure, irradiation and other external influences on the chemical and chemical-physical micro- and macroscopic properties of solid-phase compounds and materials, as well as the criteria defined in paragraphs

2.1-2.5 of the Regulations on the awarding of academic degrees at the M.V. Lomonosov Moscow State University, and also drawn up in accordance with the requirements of the Regulations on the Council for the Defense of Dissertations for the Doctor of Philosophy in Chemical Sciences, M.V. Lomonosov Moscow State University.

Thus, applicant Xu Xieyu deserves to be awarded the academic degree of the Doctor of Philosophy (PhD) in Chemical Sciences in specialty 1.4.15. Solid State Chemistry.

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03.05.2024

*I certify V.V. Zefirov's signature.*

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