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

The development and production of energy storage systems with the possibility of repeated accumulation of electrical energy is an important attribute of the economy of a developed country. The limited supply of fossil energy sources, as well as the widespread deterioration of the environmental situation are leading to increase in the consumption of renewable energy and to the inevitable use of electric vehicles. The widespread use of renewable energy sources and electric vehicles is limited by the energy storage devices that depend on it for reasons of safety risk, economy, high capacity and energy efficiency characteristics, among which rechargeable chemical secondary power supplies occupy an important place. Lithium-ion systems have the best specific energy characteristics among all types of batteries today. The use of solid-state electrolytes in lithium-ion batteries enables higher energy density and could also improve the safety performance of such systems. As part of the doctoral thesis of Xu Xieyu, the $Li_{1+x}Al_xTi_{2-x}(PO_4)_3$ composition Li-conducting ceramic electrolyte with the NASICON structure were synthesized, their structure and properties were studied. No doubt, this work seems relevant in the framework of improving existing, research and development of new energy-intensive and efficient rechargeable chemical power supplies.

The author obtained thin ceramic membranes of solid-state electrolytes with the composition $Li_{1+x}Al_xTi_{2-x}(PO_4)_3$ by different methods and approaches. A comprehensive analysis of both the ceramic precursors and the resulting materials was carried out, taking into account their production history. The influence of heat treatment on the densification processes and the final microstructure of the ceramic electrolytes was studied. As part of the work, the author developed a method for the production of thin ceramic membranes for solid state electrolytes with high ionic conductivity and high mechanical strength, and used it to produce a prototype solid state battery.

The work has been carried out at a high experimental and theoretical level, the results are characterised by a significant degree of novelty and may be of interest to specialists in the field of solid state chemistry, inorganic chemistry and materials chemistry. In general, Xu Xieyu's thesis is a complete scientific work, the abstract is written coherently and logically, the conclusions of the thesis reflect the essence of the work done.

The following comments arose regarding the work:

1. It is not entirely clear from the PhD abstract that the electrochemical test data are dependent on the type of electrolyte: in the form of tablets or thin ceramic membranes? Are there differences in the electrochemical characteristics of cells depending on the form factor of the solid electrolyte?
2. Has the effect of surface roughness on the overvoltage at the lithium anode interface been tested?

The above comments do not change the overall favourable impression of Xu

Xieyu's work. In view of the above, I believe that the complex of software, modern equipment and approaches to obtaining materials allows us to confidently assert the scientific novelty and relevance of the results obtained, and their reliability and correctness is beyond doubt. Based on the work, 5 scientific articles were published in peer-reviewed international journals and presented at 4 International and Russian conferences.

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 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 Candidate of Chemical Sciences in specialty 1.4.15 - Solid State Chemistry.

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