

Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Maksim Zakharkin

PhD Program: Materials Science and Engineering

Title of Thesis: NASICON-type $\text{Na}_{3+x}\text{Mn}_x\text{V}_{2-x}(\text{PO}_4)_3$ cathode materials for sodium-ion batteries

Supervisor: Professor Keith Stevenson

Name of the Reviewer: Daniil Itkis

I confirm the absence of any conflict of interest

(Alternatively, Reviewer can formulate a possible conflict)

Signature:



Date: 21-12-2020

The purpose of this report is to obtain an independent review from the members of PhD defense Jury before the thesis defense. The members of PhD defense Jury are asked to submit signed copy of the report at least 30 days prior the thesis defense. The Reviewers are asked to bring a copy of the completed report to the thesis defense and to discuss the contents of each report with each other before the thesis defense.

If the reviewers have any queries about the thesis which they wish to raise in advance, please contact the Chair of the Jury.

Reviewer's Report

It is a nice thesis aimed at developing sodium-ion batteries, which attract increasing attention in the recent decade. In the papers, we often read that the lithium-ion battery (LIB) market is fastly growing, and LIBs will expand to nearly all niches. However, most of the energy stored in electrochemical systems still resides in lead-acid batteries. Sodium-ion batteries can effectively substitute the lead-acid ones if they achieve a reasonable price and show the power density high enough. Both of these properties are largely defined by the electrode materials used. The work of M.Zakharkin is an excellent example of practical materials development driven by an in-depth understanding of the fundamental processes occurring inside, instead of a trial-and-error route.

The title definitely reveals the thesis contents. The text is clearly written and has a classic structure. It is divided into a literature review, a chapter devoted to methodology, and a discussion of the results, which is a set of separate chapters. The literature review is useful and provides a general understanding of the current state-of-the-art. The chapters describing the author's results are logically connected, and the work looks holistic. Experimental studies and data analysis were carried accurately and described in detail. The authors and his colleagues used a combination of basic and advanced electrochemical tools coupled with

lab- and synchrotron-based XRD and XAS in operando mode. Operando observation of the changes in materials chemistry during battery operation is today's leading-edge practice and makes the results look quite compelling.

The papers co-authored by M.Zakharkin are published in widely acknowledged journals, including ACS Applied Materials and Interfaces, Journal of Power Sources, and Electrochimica Acta. Publishing in these journals ensures that the relevance, novelty, and scientific level are high. The key results are reported in the papers where M.Zakahrkin is a first author, so his contribution is undoubtful.

As a comment for the future, I would suggest the author think of the chemical reasons for manganese to promote performance degradation while expanding the solid-solution region for the considered compounds and enhancing the specific energy.

Summing up, in my opinion, M.Zakharkin can formally defend the thesis, which is high-quality scientific work. I am observing the evolution of this work for a few years listening to Maxim's talks at the conferences and workshops, and I can assure the Jury that the candidate has grew up professionally.

Provisional Recommendation

☒ *I recommend that the candidate should defend the thesis by means of a formal thesis defense*

☐ *I recommend that the candidate should defend the thesis by means of a formal thesis defense only after appropriate changes would be introduced in candidate's thesis according to the recommendations of the present report*

☐ *The thesis is not acceptable and I recommend that the candidate be exempt from the formal thesis defense*