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Evaluation of Dr Dariusz Kajewski's application for the doctor habilitated degree based on the thesis entitled "Defects and Instability of the Crystal Lattice in Antiferroelectric $PbZrO_3$"

Doctor Dariusz Kajewski who is applying for the doctor habilitated degree is currently employed by the Institute of Physics, Faculty of Science and Technology at Silesian University in Katowice, Poland and holds a position of assistant professor. He began his scientific career after receiving the Master Degree with the thesis entitled "Influence of Niobium Admixture on Phase Transitions and Dielectric Properties of Ceramics (Ba, Pb)TiO_3". Dr Kajewski's graduate research was concerned with studies of ferroelectric properties of complex oxides and he was awarded a PhD degree for the thesis dissertation "Selected Properties of Ferroelectrics with Aurivillius' Structure $SrBi_2Nb_2O_9$ and $SrBi_2Ta_2O_9$ and Their Solid Solutions". After the graduation he continued to work on ferroelectric materials as an assistant professor at the Silesian University.

Dr Kajewski's application for the doctor habilitated degree consists of the "Summary of Professional Accomplishments" along with other documents satisfying all the formal requirements. The application entitled "Defects and Instability of the Crystal Lattice in Antiferroelectric $PbZrO_3$" is based on seven papers published with Dr Kajewski as a co-author. In all these articles the applicant is listed as the first and the corresponding author indicating his leading role in the reported research. The articles were published in well-established, peer reviewed journals and apart from one review article, H5 all of them report original research. It is interesting and somewhat unusual that the application is entirely based on papers published quite recently, with the oldest (H2) published in 2016 and the three key papers (H1, H4 and H5) published last year.

An overarching scientific objective of the research submitted in support of the application is to clarify and better understand effects of defects on the stability of the crystal lattice, phase transitions and ferroelectric properties of complex metal oxides. The research is mostly focused on crystalline $PbZrO_3$ (PZO) which is considered a model antiferroelectric material. The only exception appears to be, reported in H7, investigations of $Pb(Zr_{1-y}Ti_y)O_3$ ceramic alloys doped with Bi. An obvious advantage of such focused research is that it reduces the variability of possible parameters and simplifies the interpretation of experimental results. However, this approach may rise questions about the universality of the results and their applicability to other ferroelectric material systems.

Studies of ferroelectricity is an intricate, multifaceted area of research combining basic solid-state physics and applied materials science. The complexity originates from that fact that the most exciting and practically important ferroelectric properties are found in complex materials systems

that are difficult to synthesize in a reproducible manner. It is a broad field that, in the last few decades attracted sustained interest of numerous research groups all over the world. Most often ferroelectric materials are synthesized in a form of polycrystalline ceramics whose properties are affected by difficult to control and evaluate effects associated with grain boundaries. To avoid this problem Dr Kajewski chose to study single crystals of $PbZrO_3$ (PZO) whose properties were modified with doping. The crystals were doped by two methods. In the first method they were chemically or extrinsically doped by replacing some of the elements of the compound with foreign atoms. Alternatively, native or intrinsic doping was accomplished by changing materials stoichiometry with a high temperature processing of the crystals. It should be noted that the two types of doping cannot be separated and, as is discussed in H3 introduction of the heterovalent Nb dopants induces formation of intrinsic defect which are charge compensating Pb vacancies. Also, as has been demonstrated in H6 further complications can arise from differences in the electric field induced modification of the defect structure at surfaces and in the bulk of crystals.

The single crystals of PZO were grown using the spontaneous crystallization or flux growth method. The chemical or extrinsic doping with Nb or Bi was realized by adding proper oxide to the melt. The crystallized samples were characterized by an impressive range of optical, electrical and structural characterization methods that allowed for comprehensive evaluation of the properties of studied materials. In some instances, the access to different experimental techniques was obtained through collaborations with other research groups. For example, the Raman studies of phonon spectra were made at the Hallym University in South Korea. The successful reaching out to other research groups with complementary expertise well reflects on Dr Kajewski's understanding the scope and needs of his research as well as his organizational skills. The papers included in the application have a clear experimental bias. In all instances they present a wide range of experimental results although it is not always obvious how they relate or complement each other and how they could be combined to develop a more quantitative picture of the studied material. In part this could be explained by the complexity of the studied, intentionally imperfect materials. Also, one should not underestimate a significance of such well planned and executed experiments as they are essential part of scientific discovery and provide a basis for a future development of more quantitative models of these materials.

Apart from the research represented in the current application Dr Kajewski participated in several other projects as a leading and/or contributing co-author. Research on these projects was reported in the publications P1 to P24. It covers continuation of the PhD research on ferroelectrics with Aurivillius' structure as well as quite interesting work on $SrTiO_3$ doped with 3d-transition metals. Although this additional work was mostly based on collaboration with projects led by other researchers it is evident that, in most cases Dr Kajewski played an important role in planning and execution of this research.

Over the last several years the applicant actively participated and presented his research at national and international conferences. There is a noticeable and expected shift from mostly poster presentations several years ago to oral presentations in recent years. Thus, in the last 4 years Dr

Kajewski had 4 oral presentations and was a co-contributor on 2 invited presentation at international conferences. It is important to note that this quite respectable accomplishment confirms international recognition of applicant's contribution to the field of ferroelectric materials. One of the main concerns regarding the application is lack of any extended time visits to foreign scientific institutions. Traditionally longer-term sabbaticals are considered milestones that are essential in professional development of scientists. Unfortunately, Dr Kajewski made only several short-term visits to different European countries and Asia. Also, quite noticeable is applicant's modest number of citations and relatively low h-index. A possible explanation for this could be that, as mentioned above, the application is based on the articles (H1 to H7) that were published quite recently and cannot have statistically reliable citation record.

Teaching and popularization of science appears to be a highly visible and successful part of Dr Kajewski's academic career. He has documented record of teaching classes and laboratory courses on physics and materials science for students of different specialties including medicine and computer science. He is actively involved in organizational activities at the University and his Department by setting-up new research laboratories and user facilities. Finally, it is important to recognize Dr Kajewski's outstanding record of accomplishments in bringing science to the public. He organized and was involved in numerous activities aimed at dissemination of science to high school students, teachers and general public.

In conclusion, Dr Kajewski's application demonstrates that he is an experienced, independent scientist with well documented record of scientific accomplishments. This combined with his commitment to teaching and popularization of science makes him fully qualified for the doctor habilitated degree. I strongly support this application.

Dr Wladyslaw Walukiewicz