Review Report on PhD Thesis

Faculty: **Central European Institute of Technology**
Brno University of Technology in Brno

Academic year: **2022/2023**

Student: **Kirill Kamnev**

Doctoral study program: **Advanced Materials and Nanosciences**

Field of study: **Advanced nanotechnologies and microtechnologies**

Supervisor: **Dr. Alexander Mozalev**

Reviewer: **Assoc. Univ.-Prof. Dr. Andrei Ionut Mardare**

PhD thesis title: Porous-alumina-assisted formation of metal and metal-oxide nanostructures for use in advanced micro-devices

Topicality of doctoral thesis:

In recent years, anodization (and electrochemical techniques, in general) is attracting more and more industrial attention due to its simplicity, low cost and high reliability and reproducibility. As a particular case, porous anodic oxides have direct impactful applications in surface nanostructuring necessary for material functionalization. The anodizing technology is continuously developed, improvement and optimizations approaches being constantly under research for better control over morphology, physical and chemical properties of produced nanostructured oxides.

The work of Mr. Kamnev addresses two major points for development of novel nanostructured metal-oxide materials by anodization. Firstly, the focus is put on the development of refined anodization methods for processing new metallic substrates, directly impacting future electronic, optical, and medical applications. Secondly, the work seeks development of innovative anodization approaches which would go beyond conventional nanopore (nanotube) morphology and synthesis of anodic films populated by nanoarrays of volumetric structures.

I believe this PhD thesis is a very interesting study which responds to current research challenges of material engineering and nanotechnology. The ideas formulated and developed in this dissertation and the results presented in the thesis are a perfect response to current needs of the scientific community.

Meeting the goals set:

Mr. Kamnev has defined a work plan containing six different objectives which were achieved throughout the work. These objectives are scientifically addressed in a logical order and the results are clearly presented.

Firstly, anodization of Al layers superimposed on Zr was addressed, and optimization of the PAA process was successfully performed in order to obtain zirconia nanodots and nanocolumns underneath and within the porous layer, partially filling the porous matrix or fully filling the matrix forming planar alumina-zirconia nanostructured films. Additionally, zirconia nanostructures with dissimilar morphology and topography at the nanoscale were studied by utilizing different electrolytic and electrical anodization conditions.

Secondly, anodization of Al layers superimposed on Hf was addressed and hafnia nanostructures with dissimilar morphologies and nano-topographies were investigated by varying anodization conditions. Also, the memristive behaviour of alumina-hafnia nanostructures was addressed for possible applications in resistive-switching devices.

Problem solving and dissertation results:

This is a very well-structured cumulative thesis and the scientific questions raised are easily followed and their answering leading to the final conclusions are well implemented by providing the original scientific articles published during this work. Thus, the dissertation results are clearly presented in high impact factor journals as summarized in the PhD thesis body.

Based on the peer-reviewing process, the results and conclusions have already been analysed by experts granting their publication. In addition to this, I would emphasize the high scientific focus of the addressed issues, such as challenges of porous anodic anodization of pure Zr justifying its oxide growth model, planarization of zirconia nanoarrays for on-chip microcapacitor integration, nanotopography modulation of zirconia bioceramics for better osteointegration, surface chemistry and nanotopography tuning of hafnia for reducing water affinity or fabrication of antireflective nanostructured anodic hafnia for solar cell applications.

Importance for practice or development of the discipline:

In each of the six scientific reports collected within this cumulative thesis, the anodic nanostructuring of zirconia or hafnia was studied for various future applications. These results describe a clear advancement for the porous anodic oxide formation research, which is a significant branch in the electrochemical community. Future industrial implementation is addressed from different points of view of these applications and I expect the impact of the presented ideas to be rather strong in the near future.

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Formal adjustment of the thesis and language level:

The PhD thesis of Mr. Kamnev has a cumulative type and the format chosen is completely compatible with the typical structures of such manuscripts. It is very clearly separated into six chapters, each introducing one published work. Moreover, each published paper is briefly described in the PhD text before the reader can find it as an attachment.

I suggest improving the original papers presentation by defining annexes, e.g. paper 1 should be listed as Annex 1, etc. The annexes should be presented after the Conclusions section, at the very end of the thesis.

Questions and comments:

Most of the PhD manuscript is formed from published papers. However, the English of the introductory part needs to be thoroughly checked. There are various typos and misused words in the Abstract.

Conclusion:

The presented work describes a very clear study of porous anodic oxidation of both Zr and Hf superimposed on Al. Various levels of pore filling are linked with applications ranging from biomedical devices to microcapacitors, memories and solar cells.

In conclusion, this is a thoroughly documented PhD thesis, which provides very interesting and valuable results of high quality. Mr. Kamnev possesses all necessary practical skills, theoretical knowledge and high motivation for research work. The discussion of results and explanations of problems and questions raised are suitable and focused on the relevant topics, as already proven by the publication of the results in high impact factor journals.

In my opinion, the reviewed thesis fulfils all requirements posed on theses aimed for obtaining PhD degree. This thesis is ready to be defended orally, in front of respective committee.

In Linz, date 29.11.2022

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