

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: **Prof. Xavier Correig Blanchar**

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

Topicality of doctoral thesis:

The thesis consists of the porous anodic alumina (PAA) assisted growth of functional nanostructured ZrO₂ and HfO₂ metal-oxides and their subsequent characterization by SEM/TEM, XPS and other techniques. In the thesis there is also the study of their applicability as a dielectric in the manufacture of passive components (ZrO₂), in the manufacture of integrated microcapacities (ZrO₂), implementation in of bioceramic coatings to improve osteointegration (ZrO₂), in the manufacture of switched resistances (HfO₂) and in improving the antireflective and hydrophobicity properties in coatings (HfO₂).

The technology developed is highly innovative and sophisticated and is at the best level compared to the bibliography.

Likewise, several very interesting applications are proposed in the articles, although they are at an early level of development, except in the use of PAA-ZrO₂ in the manufacture of integrated capacities, in which some chip prototypes have already been fabricated.

Meeting the goals set:

The thesis is pursuing six objectives, reflected in 6 publications. The first 4 objectives correspond to 1) the PAA assisted growth and characterization of nanostructured ZrO₂ layers (nanopillars, nanodots, etc.) using different conditions and electrolytes, 2) Its potential application as a dielectric in passive components, 3) Development of passive integrated components with nanostructured ZrO₂ as a dielectric and 4) The study of its application as a bioceramic material in body implantable devices. The last 2 objectives refer to 5) The growth and characterization of HfO₂ layers and their application in hydrophobic and anti-reflective coatings. All objectives have been met to a good extent.

Problem solving and dissertation results:

In my view, the main result of the thesis is to fine-tune the ZrO₂ and HfO₂ layer growth method through porous alumina-assisted anodizing, a very new, sophisticated, robust and cheap technology, which can be included in very interesting applications in the field of chip manufacturing, biomedicine and materials science. At the same time, the characterization techniques used (basically SEM/TEM and XPS), when using equipment with high performance, allow excellent monitoring of the properties of layers and manufactured devices.

One aspect that has not been clear to me about the articles has been the modeling of growth processes. The figures generated are of a very high quality, but I do not know if they are the result of a quantitative 3D modeling process, in which the thermodynamic laws that model the anodization process have been used in a software package.

Importance for practice or development of the discipline:

In the thesis it is demonstrated that the anodization of nanostructured ZrO₂ and HfO₂ layers is possible, and that the quality of the layers is excellent. There is also demonstrated that nanostructured ZrO₂ layers are to be used successfully as a high-quality dielectric in the fabrication of integrated capacitors. However, the other applications of ZrO₂ (bioceramic coatings) and the application of HfO₂ (hydrophobic and antireflecting materials) are not developed enough in the thesis and its industrial scale it's not demonstrated. As an example, is it feasible to fabricate ZrO₂ coatings adapted to the dimensions of photovoltaic solar panels? This should be discussed in the corresponding article.

Formal adjustment of the thesis and language level:

The articles have been published in very relevant and high impact journals. This is the reason why I consider that the developed methodology and the results are correct.

The articles are very well written, they are very rigorous and thorough, and the introductions are very complete and well referenced. The discussion of the results is also very appropriate.

Questions and comments:

I only have two issues in the thesis:

- In three out of 6 authors, Mr Kirill Kamnev is not the first author, although it seems that his contribution is very relevant.
- A global discussion of the thesis results, enhancing the strengths, limitations and possibilities of the developed technologies is lacking.

Conclusion:

It's an excellent thesis, with very good results and promising applications of the developed technologies.

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



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Prof. Xavier Correig Blanchar