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Referee report

for the PhD thesis entitled

Microstructure and properties of nanocristalline hard coatings and thin film nanocomposites

submitted by Mgr. Milan Dpota.

Introduction

The topic of the work is to characterise thoroughly certain promising nanocrystalline coatings and to correlate the determined microstructural properties to the deposition parameters on the one hand and to the hardness of the coatings on the other hand. This is presently a very relevant topic which enjoys increasing attention both from a scientific standpoint and in view of possible applications. Hence, the topic of Mr. Dopitas research is well suited for the preparation of a PhD thesis.

Evaluation of the scientific content of the thesis

Mr. Dopita evaluated a set of Me-Al-N as well as Me-Al-Si-N samples (Me = Ti, Cr, Zr) which were deposited by cathodic arc evaporation. Each type of film was represented by seven samples differing in composition due to a varying position of the substrate with respect to the two arc cathodes used. The systems were well chosen as they are promising and in part already investigated in the literature, however, with many questions being still unanswered. The layers were carefully characterised with X-ray methods complemented by high resolution XTEM, thus delivering phase composition, texture, crystallite size, mutual disorientation of the grains and lattice strain. Film composition was measured by EPMA and hardness was obtained by using the CSM method as well as conventional nanoindentation. Obviously, the candidate understands these demanding methods as well as the underlying physics very well.

All data evaluation including the consideration of possible sources of error is performed carefully. The structural results are discussed in dependence on the composition of the sample. The overall deposition parameters have been kept constant, however owing to the varying position of the samples they experience different angles of incidence of the energetic ions from the arc cathode which makes up an important modification of the deposition condition over the set of samples of each system. There are plenty of results. Most interesting appears to me the evolution of phase composition with changing transition metal-to-aluminium ratio: With high transition metal concentration, a single fcc phase is observed which - at increasing Al content - is accompanied by a second crystalline phase, wurtzite AlN (w-AlN). At the highest Al content, only the w-AlN phase is found. In the samples with additional silicon the Si atoms are dissolved in the fcc phase at low Si concentration. At higher Si content, an amorphous SiN_x phase is found as a third phase.

Each of the Me-Al-N materials showed a hardness maximum at a certain Me/Al ratio which appeared to depend on the kind of transition metal. The author shows that the samples with maximum hardness consist of two crystalline phases (fcc and w-AlN) which - in this case - have approximately equal volume ratios. Addition of silicon leads to a reduction in alignment of neighbouring grains which is an indirect prove for the existence of a very thin amorphous a-SiN_x interlayer between the grains which might be useful to accommodate local strain maxima which otherwise could cause cracking. This effect is considered to be responsible for the increased maximum hardness value in case of silicon addition observed for the films with Me = Cr and Ti.

In total, Mr. Dopita gives an impressive very detailed picture of the microstructure of the investigated materials systems and discusses the interdependence of chemical composition, microstructure and hardness convincingly on the basis of sound knowledge and understanding of the physics behind.

Assessment of presentation and form

The thesis is in the form of a relatively short summary and eight papers published between 2006 and 2008 in high-level journals which are authored or co-authored by the candidate. In three cases he is the first author. The presentation in the summary as well as in the papers is well organised and very clear. The English language usage is very good and there are only few printing errors. Related work is properly referred to and the results are well illustrated by figures, tables etc..

Conclusion

In my country it is not customary to make papers published together with others a part of a thesis without detailed explanation of the contributions of each co-author. Therefore I want to elucidate my basic assumptions when making the conclusions given below: I understand that Milan Dopita used the excellent scientific environment in Freiberg, in particular the knowledge and skills of scientists who are specialised in certain methods. These scientists, mentioned by him in the acknowledgement, make up most of his co-authors. I suppose that they essentially contributed their knowledge in special fields, but that the overall analysis given in the summary was essentially made by Mr. Dopita himself.

This lets me conclude that the thesis of Mgr. Milan Dopita is a very valuable piece of scientific work. It contains several novel results including those which I have mentioned above.

The results contribute to the understanding of the interaction of preparation condition, structure and mechanical properties of hard nanocomposite layers, which represent a very promising new class of thin film materials. Hence, M. Dopitas thesis will help to form nanocomposite films tailored for particular applications in future.

Without any doubt the author has shown with the thesis that he is well be able to perform creative scientific work.