Report on the 36th IUVSTA Workshop, Plzen, Czech Republic, 20-24 October 2002

**The mechanisms of formation and applications of hard nanostructured coatings**

The Workshop was attended by 54 scientists who came from 16 countries and was held in a small hotel located between the city centre and the University of West Bohemia. The local conference chair was Professor Jaroslav Vlcek who, with Professor Jindrich Musil and colleagues made excellent arrangements for this meeting including an interesting visit to their research laboratories at the university.

A wide range of different aspects of this field was covered in the many presentations, including recent and new data on hard coatings, studies of nucleation and growth mechanisms, thermal stability of hard coatings, oxidation resistance, wear resistance, hardness measurement methods and commercial applications. The power of differential scanning calorimetry for following the recovery of residual stress and eventual phase transformation was demonstrtated

It was agreed by delegates that more effort is needed to study structure evolution. This is highly sensitive to the presence of low concentrations of a second species, for example the presence of Sn when depositing Al which leads to development of large grains, or, the presence of O during Al deposition which causes small grains to form. During ion assisted growth competitive growth of one orientation is seen for TiN formation where the lower surface diffusion of Ti on a particular face can lead to the (111) orientation dominating. For the ultra-hard nc-TiN/a-$Si_3N_4$ system the mechanism of formation of nc-TiN is still not clear and there was some heated debate that it could not be a spinodal decomposition process in the bulk but, more likely, an event triggered at the gas-surface boundary. What was repeatedly reported was that the Si content has to be of the order 9 atomic percent, the N atomic level in the ion-assist process high and a percolation network of the amorphous $Si_3N_4$ phase of about 1 monolayer thickness must be formed to get the superhard nanocrystalline structure. An amorphous phase content of 20 molecular percent is often (wrongly) cited. The actual molecular percentage of $Si_3N_4$ is 7 percent and the quoted 20 percent refers to the number of atoms in the silicon nitride molecule compared to all the atoms in the mixture. With the correct mixture and ion-assist conditions TiN crystal sizes are of order 5-6nm and hardnesses approaching 100 GPa have been reported. More important the material is stable when heating up to 1100$^{o}$C and retains its hardness after cooling down again.

Several presenters noted that hardness (H) was not the main criterion when choosing the most useful practical coating but a high H/E was better (with E being the Young's modulus). Multilayers of nanometer dimensions with alternate layers of high E and low E perform well because the low E layer (e.g. $CN_x$) allows slip during bending of the component.

Many other nanocomposite systems were discussed including ncTiN/a-C:H which can have hardness up to 40GPa and has a low coefficient of friction making it useful for extrusion components, ncTiC/a-SiC/a-C:H which has higher coefficient of friction and is suitable for bearings, Ti-Al-N which may form a nanocomposite structure during use, Ti-Al-Si-N which is stable up to 850$^{o}$C, $Ti_xSi_yC_z$ which is hard and has a high coefficient of friction, and W-Si-N which has a hardness which increases on annealing from 27-40GPa and has good oxidation resistance. Ta-N layers were shown to form coherent delta TaN (111)/gamma $Ta_2N$ (0002) nano-lamellae films with hardness in the 40-45GPa range. In addition to the hard coatings a series of more-ductile coatings were also mentioned of the form nc-metal-nitride/soft phase material which have better practical application.

Delegates generally agreed that the role of film stress in coatings, originally thought to be of importance, was seen to be of little practical use since the stress-related hardness increase is only of the order of a few GPa and this increase will usually be lost again when annealing the sample.

Several practical applications of new nanocomposite hard coatings were reported. These include Ti-Al-Si-N for cutting tools, carbon nano-ropes and nano-tubes for hard discs, MEMS and biomedical application, low friction Cr/C multilayers and $MoS_2$-Ti films for low friction, low wear use in punches.

The participants all agreed that the Workshop had been exceptionally timely and useful and the support of IUVSTA which made this meeting possible was gratefully acknowledged.

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Co-Chair.