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SEM Investigations of TiB_2 and TiBN Coatings Produced by DC Magnetron Sputtering

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Binary nitrides (TiN and CrN) and ternary nitrides (TiAlN and CrAlN) have become excellent coatings for engineering applications, where protective coatings are required to increase the lifetime and performance of cutting tools [1-3]. Research conducted on the development of nanostructured ternary nitride coatings found that with a nanograin structure, the coatings were of much higher hardness than those of the coarser grain size and this was influenced by the nitrogen pressure during deposition [4-5]. More recent research has shown that TiN and TiAlN are excellent coatings for machining ferrous products, whereas CrN and CrAlN have been found to exhibit unique properties for machining non-ferrous alloys. For this reason, alternative surface coatings need to be investigated.

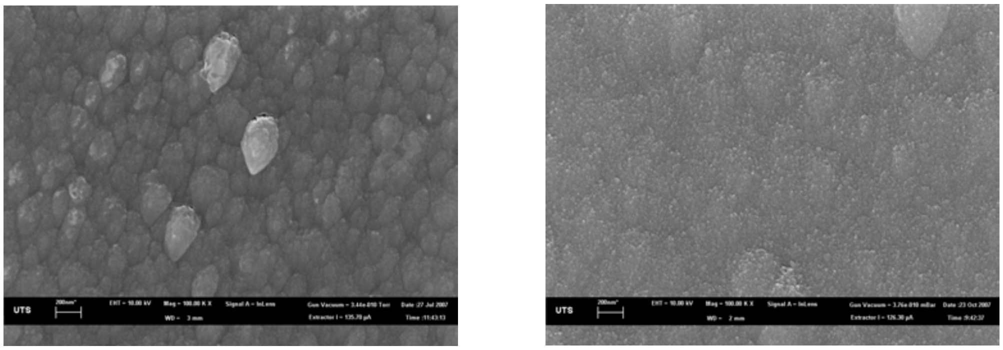
Other materials that have been studied for coating purposes are TiB_2 and TiBN. The combination of high hardness and chemical resistance make these coatings good for applications such as die casting and aluminium machining [6-8]. Although TiB_2 has numerous outstanding properties, there are still a few problems yet to be overcome. Being very hard, the coating is extremely brittle. This in turn can lead to the chipping of the coating, which is no use for corrosion and wear resistant coatings. TiB_2 also exhibits very poor adhesion properties when coated on most substrates and has been reported to be soluble in iron and consequently would not be ideal for engineering applications where iron and steel (ferrous materials) are the products to be machined.

This work has investigated a variety of ways to overcome the adhesion problems of TiB_2 and TiBN to substrates. The use of; a) different interlayers between the substrate and the coating, b) multilayers of TiN/TiB_2, TiN/TiBN, and TiN/TiB_2/TiBN, c) varying the bias across the substrate, d) varying the substrate temperature, and e) gradually changing the composition of the individual layers, are methods that have been addressed with the aim of improving the bonding/adhesion properties of the coatings. This paper will report the results on the production of TiB_2 and TiBN coatings as well as their multilayer counterparts by reactive DC magnetron co-sputtering.

Figure 1 shows the surface morphology of TiB_2 and TiBN. The single layer TiB_2 and TiBN coatings have a similar morphology consisting of a cauliflower structure that has a finer grain structure within. The TiBN has a more uniform, fine grain structure with a surface grain size around 20nm. However the TiB_2 has a more densified structure and consists of grains around 40nm in size and a micro-hardness above $3300HV_{2g}$.

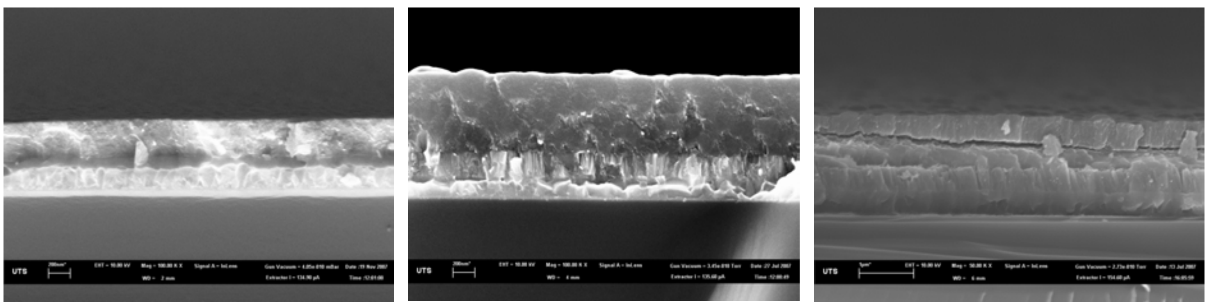
The two coatings exhibited some adhesion problems with respect to the substrate. When only using a Ti interlayer for the TiB_2 coatings, there appeared to be a lack of interaction between the Ti and TiB_2 (Figure 2a). The introduction of a second interlayer of TiN improved bonding between the Ti and TiB_2 (Figure 2b). TiB_2 was also investigated as an interlayer for TiBN coatings (Figure 2c). As can be seen, cracking between the TiB_2 and TiBN layers occurred. A method in rectifying this problem is being researched involving the introduction of the nitrogen gas at different rates. This would allow a slower change between the two layers, creating a transitional layer with both phases.

Multilayered coatings of TiN/TiB_2 layers were also produced in an attempt to achieve much harder coatings and improve mechanical properties. The alternate layers of TiB_2 and TiN were deposited onto the substrate ranging in thicknesses between 50nm and 200nm (Figure 3). The multilayer coatings revealed the grain size to decrease with a decreasing layer thickness (Figure4). The grain size reduced to as low as a few nanometres on the 50nm thick surface layer. Also, with the decreasing grain size, the hardness increased by over 1000HV (Figure 4).



a) b)

Fig. 1: a) shows the surface of a TiB_2 coating and b) shows a TiBN surface



a) b) c)

Fig. 2: The cross sections of TiB_2 coatings using a) Ti interlayer, b) Ti and TiN interlayers and c) Ti-TiN-TiB2 interlayers below TiBN, which shows cracking between TiB_2 and TiBN layers.

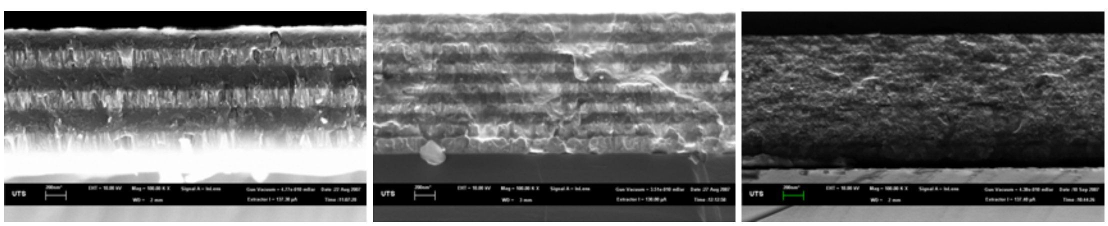


Fig. 3: Cross sections of multilayered coatings of thickness 200nm, 100nm and 50nm.

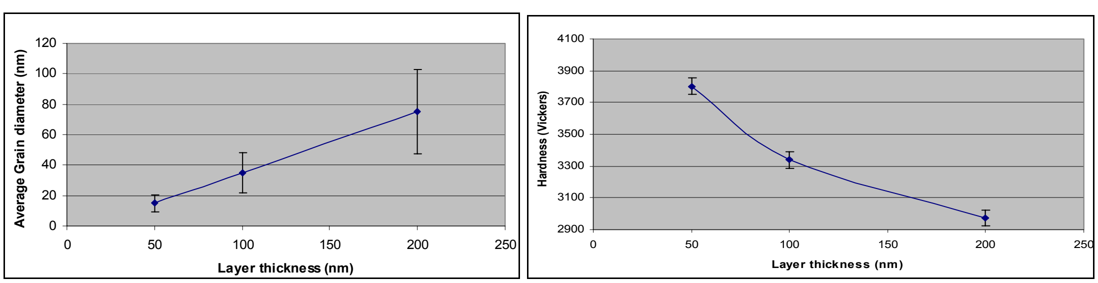


Fig. 4: The results of the multilayered nanocomposite coatings. These figures show the relationship between layer thickness and the grain size and hardness of the coatings.

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