Advanced Hard Coatings: Towards A Whole New World

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Abstract

BACKGROUND & OBJECTIVES: Improving materials properties is one of the biggest scientific issues of all the times. When it becomes impossible to further manipulate the raw material, one feasible way to push its properties beyond the theoretical limits is to modify the properties of the surface. That is where advanced surface coatings come in. From a manufacturing point of view, tools for machining are of particular interest. These tools are usually made of hard steels and cemented carbide (WC-Co). For specialized applications, such as aluminium machining, diamond or polycrystalline cubic boron nitride are also used. The main problem with steel, is that it exhibits a relatively low hardness (below 10 GPa) which strongly decreases upon annealing above about 600 K. Thus, the majority of modern tools are nowadays coated with hard coatings, in order to: (i) increase the hardness, (ii) decrease the coefficient of friction, and (iii) protect the tools against oxidation. A similar approach has been recently used to obtain a longer duration of the dies for aluminium die-casting. Multi-component and nanostructured materials represent a promising class of protective hard coatings due to their enhanced mechanical and thermal oxidation properties. METHODS: Three different thin hard nitrogen-rich coatings were mechanically, microstructurally, and thermally characterized: (i) a 2.5 micron-thick nano-layered CrN-NbN, (ii) a 11.7 micron-thick monolayer TiAlN, and (iii) a 2.92 micron-thick multilayer AlTiCrxNy. The main feature of the CrN-NbN coating is the fabrication by the alternate deposition of 4 nm thick-nanolayer of NewChrome (new type of CrN, with strong adhesion and low coating temperature). All the three coatings can reach values of hardness and elastic modulus exceeding 20 and 250 GPa, respectively. Their main applications include stainless steel drawing, plastic materials forming and extrusion, and aluminum alloys die-casting. The here studied TiAlN (SBN, super booster nitride) is one of the latest evolution of TiAlN coatings for cutting applications, where maximum resistance to wear and oxidation are required. The AlTiCrxNy combines the very high wear resistance of the Cr-coatings with peculiarities of the Al-containing coatings, such as high thermal stability and high-temperature hardness. All the coatings were deposited on a S600 tool steel. The coatings were subjected to two different thermal cycling tests: (i) 100 thermal cycles consisting of 60 s dwelling time, respectively at the high- (573 to 1173 K) and at the room-temperature, and (ii) 100 thermal cycles consisting of 115 s dwelling time, at same temperatures of the first test, followed by 5 s dwelling at room-temperature. The temperature induced hardness and elastic modulus coating variations were measured by nanoindentation. RESULTS: During thermal cycling, the TiAlN monolayer coating and the AlTiCrxNy multilayer coating showed a high oxidation resistance even at high temperature, while the CrN-NbN nano-layer coating undergoes a oxidation phenomena, for temperatures above 873 K. CONCLUSIONS: The investigated coatings showed a sufficient-to-optimal thermal response either in terms of mechanical stability, such hardness and elastic modulus, and in terms of oxidation degradation.