CVD and PVD Hard Coatings for Industrial Applications: Present Status and Future Needs

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Hard coatings play a fundamental role in the tribological protection of numerous device components, like cutting and forming tools, automotive engine and rotating parts, wind energy turbines, and numerous aerospace applications. In this work, the most recent findings in the synthesis, mechanical and tribological properties of hard coatings deposited by CVD and PVD will be reviewed. The research on designed multilayers and nanocomposites films will be highlighted. Typical industrial applications for cutting tools and bearings will be also discussed. Needs for novel applications in emerging markets, like e-vehicles, will be envisioned.

Keywords: hard coatings, PVD, CVD, tribology, industrial applications.

1. Introduction

Nowadays, hard coatings having thickness of just a few microns play a fundamental role in the tribological protection of numerous device components, like cutting and forming tools, automotive engine and rotating parts, wind energy turbines, and numerous aerospace applications. These hard coatings are usually obtained by Chemical Vacuum Deposition (CVD) and Physical Vacuum Deposition (PVD) technologies. The estimated market volume worldwide for this kind of coatings (done by service coating companies) was estimated to be about US$ 750 Million during 2019 and it is projected to reach a revised increase (due to COVID-19) of 50% by 2027.

2. Materials

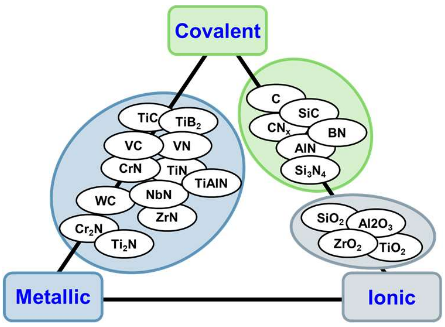

Figure 1: Single-phase hard coating materials classified by their chemical bonding character (After [1]).

Tribological coatings can be classified according to their hardness H as "soft" ($H < 10$ GPa) and "hard" ($H > 10$ GPa). First hard coatings introduced in the market during the 1980's were single-phased binary materials like TiN, TiC and CrN. Binary hard coatings can be classified according to their bonding characteristic as metallic, covalent or ionic hard materials (Figure 1). The metallic hard materials have the highest toughness and the best adhesion to metallic substrates, the covalent ones are very hard and strong, and the oxide hard coatings are very stable and inert.

The performance of these first commercial single-layer hard coatings were later enhanced by combining them through co-deposition and/or by the introduction of novel designs, like composite, graded, and multilayer structures, and the combination with soft coatings to decrease friction. For instance, Figure 2 shows a nanoscale multilayer carbon-based coating patented by the company SKF and used in bearing applications. The functional coating combines a special metal adhesion layer for steel substrates, WC/C multilayers to increase hardness and wear resistance, and a soft top graphitic layer for the run-in period.

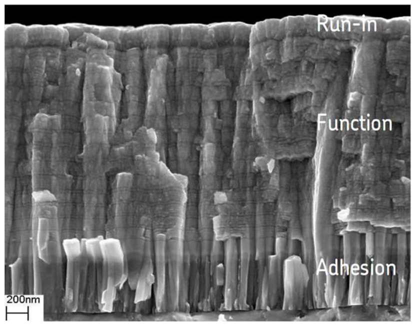

Figure 2: Patented nanoscale multilayer carbon-based coating from SKF used in bearing applications [2].

In the last years, novel developments still in the research stage include the possible use of self-adaptive coatings, MAX phases, and high-entropy nitride coatings. Furthermore, the availability of sophisticated coating equipment enables the continuous quality increase on coated cutting devices and possibility of high-scale production and therefore coating cost reductions.

3. Present Status and Future Needs

At present, the highest market demand is still in the areas of coated tools and hard decorative coatings, but there is an increasing interest of tribological hard coatings for automotive, aerospace, and wind generation. The biggest problem in these applications is the low-scale production, which hinder their use due to high coating costs.

4. References

[1] Holleck H., Schier V., "Multilayer PVD coatings for wear protection.," Surface and Coating Technology 76-77, 1995, 328-336.

[2] Broitman, E., Zhou, "Things You Should Know About Diamond-like Carbon Coatings," Proc. WindEurope Conf. at the Global Wind Summit, 25-28 Sept 2018, DOI: 10.5281/zenodo.4287480.