

PVD Process Provides Superior Adhesion, Dense Coating Structure to Increase Tool Durability

David C. Bell, President & CEO

Phygen, Inc.

Minneapolis, Minnesota

Among the many challenges facing die toolmakers are premature failures of the tooling caused by heat checking, soldering, corrosion or oxidation and erosive wear. These failures cause production delays and increase the overall cost of operations. During the last 10 years, PVD processes have been used to deposit thin, hard coatings on engineering components — such as forming and cutting tools — to significantly reduce tool wear. The coatings have permitted more cost-effective machining processes and helped to fulfill the increasing demands put on production processes in terms of performance, reliability and environmental compatibility.

Typical thin film coating materials usually are carbides and nitrides of transitional metals, which have the beneficial properties of high hardness, excellent wear resistance, chemical inertness and thermal stability. However, the ultimate performance of hard coated tools depends on the type of the deposition technology used to apply the coating. Often, conventional coating technologies used for titanium nitride (TiN) or chromium nitride (CrN) cannot meet the latest industry standards.

One solution is a coating technology based on the principles of plasma acceleration, which results in a higher plasma density and an intense low energy ion bombardment during the coating deposition. Phygen, Inc. has patented a Physical Vapor Deposition (PVD) technology that allows deposition of a wide variety of coatings (metals, alloys and compounds) to produce Phygen® ST.3 Super-Tough™ Coating. The coating exhibits superb hardness and wear resistance compared to conventional PVD and CVD-based or thermal diffusion coatings.

Coating Applications

Typical coating applications for the die casting industry include uses on tooling, core pins and mold inserts. The benefits of the process being discussed in this article are illustrated by a successful application at Intermet's Minneapolis plant, which produces close tolerance die cast components for major electronics manufacturers.

The company had a problem with soldering and breakage of core pins on a job using a 950 ton Buhler machine, casting AL413. The core pins were making holes for self-tapping screws that needed a low draft (taper) of ½ degree per side, compared with the 1-2 degrees per side that die casters typically require. To improve release and eliminate metal penetration or soldering, the company had tried a variety of coatings without success. Running 24 hours-a-day, the job came out of the machine at least once every other day before switching. That cost Intermet about four hours of downtime for repairs and reheating each time. Once the company started using Phygen

ST.3 SuperTough™ Coating on the pins, the job ran for three weeks without a single broken core pin.

Mike Dahlen, process engineer, noted that there were several measurable benefits for Intermet because of the reduction in downtime. First, the job was completed ahead of schedule because they had allowed time in their production planning for extended maintenance. This also allowed the company to expand capacity by doing other jobs on the same machines, increasing productivity and revenues.

Depending upon the particular use, there are several distinctive features of the coating that benefits toolmakers and die casters.

- *The coatings are less brittle than conventional hard PVD coatings, enabling them to withstand much higher mechanical loads.*
- *The coatings possess low friction properties (a coefficient of friction less than 0.1) under proper lubrication and oxidation conditions.*
- *The coatings are chemically and thermally stable in the air up to at least 1550°F.*
- *The coatings are chemically inert and provide excellent barrier protection against corrosion because of their dense, non-columnar microstructure.*
- *The process does not change critical dimensions of properly heat treated tools or precise components.*
- *The coatings can be easily stripped with no harm to the substrate at the end of a tool's useful life; then tools can be repaired, refinished and coated again.*

Technology & Research Activities

Phygen was founded in 1994 with the objective of being a technology leader in the PVD coatings industry in order to develop top performing new coatings for die casting, metal forming and plastic injection molding. The company invested six years of research and development activity to perfect new systems and processes.

The technology developed by Phygen provides a unique combination of coating properties by creating a dense, non-columnar coating structure having the highest possible adhesion level to virtually any substrate material. The microstructure of the coating is precisely controlled by proprietary process parameters. As a result, this coating actually constitutes a single phase, stoichiometric, nanocrystalline chromium nitride having a highly textured dense structure. The fine-grained structure and high cohesive strength of these chromium nitride coatings

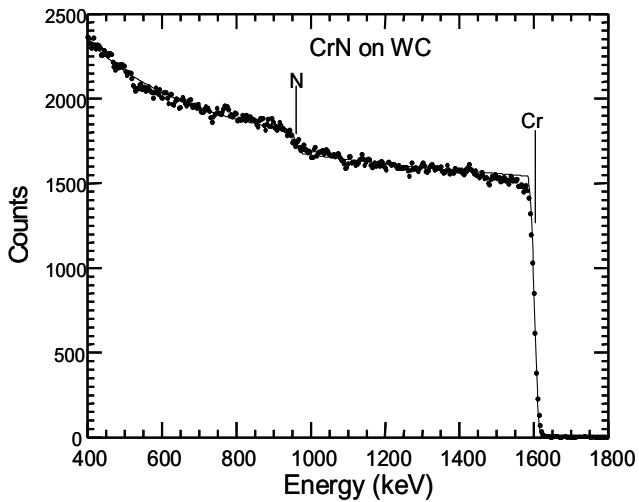


Fig. 1 – Rutherford Backscattering Spectroscopy (RBS) results confirm 100 percent stoichiometric composition of Phygen's ST.3 SuperTough™ Chromium Nitride.

allow the deposition of extremely tough and hard coatings that have higher abrasive wear resistance and protect the substrate better than any other conventional PVD processes.

Extensive testing at major laboratories and research institutions has confirmed the stoichiometric chemical composition of the Phygen coating. Research conducted by Othon Monteiro at Lawrence Berkeley National Lab, Berkeley, CA, found no presence of any other elements or crystallographic phases, proving that the unique properties are solely the result of the proprietary deposition process used to apply the coating.

Other studies using Scanning Electron Microscopy (SEM) analysis performed by scientists at Argonne National Laboratory, Argonne, IL, revealed the non-columnar, equi-axially grained microstructure of the chromium nitride coating. Most commercial PVD coatings typically feature numerous voids through the coating. This is a result of their columnar structure and their growth in a line of sight process. The voids affect the protective ability of the coating against a harsh environment, and the columnar microstructure makes the coatings weaker under repetitious mechanical loads or thermal cycling

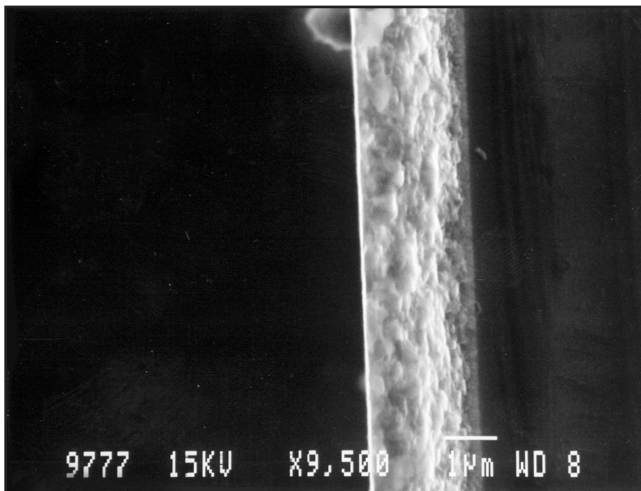


Fig. 2 – SEM image made using secondary electrons on a fractured cross-section of the chromium nitride film deposited on a silicon wafer. The silicon wafer substrate is seen to the right of the film.

conditions. SEM results in Figure 2 show Phygen coatings are free of these shortcomings.

In addition to these general test results, the coating process has been extensively tested by major companies in the die casting industry as well as research institutions.

Scientists at the Colorado School of Mines, Golden, CO, led by Dr. John Moore, director of Advanced Coating and Surface Engineering Laboratory (ACSEL), conducted development work on the surface engineered coatings for die casting dies. Phygen ST.3 SuperTough™ Coating was evaluated against a variety of conventional hard coating and surface treatment technologies using laboratory experiments as well as production cycle tests.

The tests showed Phygen's coating had particularly good resistance to soldering and cracking. Many conventional coatings failed because they appeared to be incompatible with the highly corrosive molten aluminum environment. They also lost their integrity due to soldering, cracking after thermal cycling, or as a result of washout.

The research focused on a comparative in-lab evaluation of wetting ability of different coatings in a molten aluminum by direct measurement of contact angles and area of spreading of an aluminum drop (sessile drop test) on the surface at high temperatures. The higher the contact angle and the less the percentage of spreading area of a molten aluminum drop over the surface, the better the soldering resistance of the surface.

Figures 3-5 show the results of contact angle measure-



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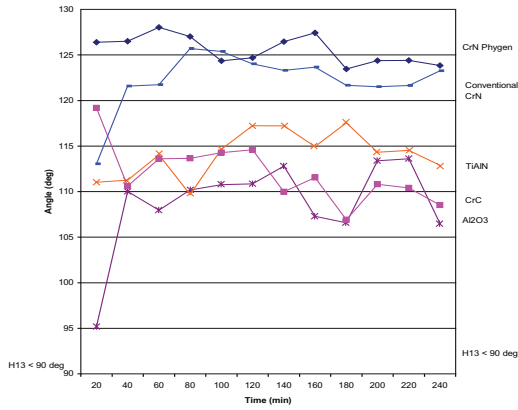


Fig. 3 – Liquid 360 aluminum melted upon various thin films at 770°C in an argon atmosphere.

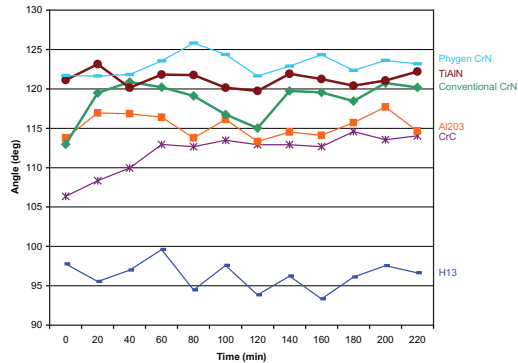


Fig. 4 – Liquid 390 aluminum on various thin films at 770°C in an argon atmosphere.

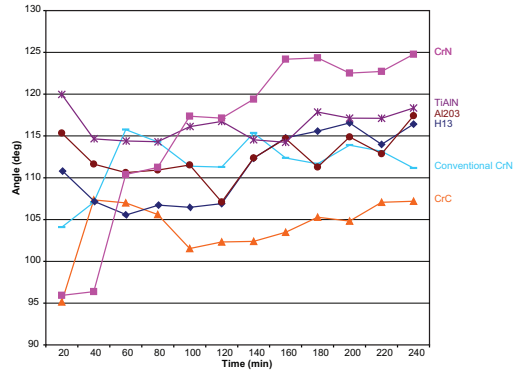


Fig. 5 – Liquid 390 aluminum melted upon various thin films in 770°C in an argon atmosphere.

ments conducted for most common die casting aluminum alloys contacting the surface of a bare H13 mold steel and different coatings at high temperatures in a protective atmosphere of argon. The coating demonstrates the highest contact angle value for all tested alloys, meaning the least wetting ability in the molten aluminum alloys.

The results of these tests conclusively demonstrate the value of Phygen's ST.3 SuperTough™ Coating for the die casting industry as well as other applications. Other uses include coatings for shafts and bearing surfaces; wear surfaces that need to be protected from erosion or corrosion; and severe applications where conventional PVD coatings fall short.

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