▶ BY ALAN RICHTER, MANAGING EDITOR

Raising Al

Aluminum-titanium-nitride tool coatings continue to evolve.

Much has been bandied about concerning increasing the percentage of aluminum in AlTiN coatings and the advantages the increase provides. And there definitely are benefits to cutting tools coated with high-aluminum-content AlTiN. But end users need to separate the hype from the reality and understand that optimizing the coating—like a tool's geometric features and substrate—depends on the application.

AlTiN is ideally suited for high-speed, dry/near-dry machining of stainless steel, titanium, high-temperature superalloys and hardened materials, according to industry experts.

"AlTiN retains its hardness even when the temperature is 800° to 930° C (1,470° to 1,700° F) at the tool/workpiece interface," said Haron Gekonde, senior development engineer for Ion-Bond LLC, Duncan, S.C., a provider of physical vapor deposition and chemical vapor deposition coatings and equipment.

This is key as workpieces made of the aforementioned materials generate a high amount of heat in the shear zone. However, how much aluminum content is needed in an AlTiN coating is open to debate.

Balzers

The advantages of AlTiN coatings, such as Balzers' Balinit Futura Nano nano-structured one for drills, mills and hobs, come to the fore when dry machining with high speeds and feeds.

Overcoming the Barrier

Despite numerous successful developments of tool coatings, cutter-coating engineers haven't rested on their laurels. Difficult-to-machine alloys continue to be introduced, and the competition in the tool coating arena is fierce.

"Everybody's leapfrogging each other's coatings," said Don Graham, manager of turning products for toolmaker Carboloy Inc., Warren, Mich. "The best coating on the market has a 4- to 6-month lead before a better coating comes along."

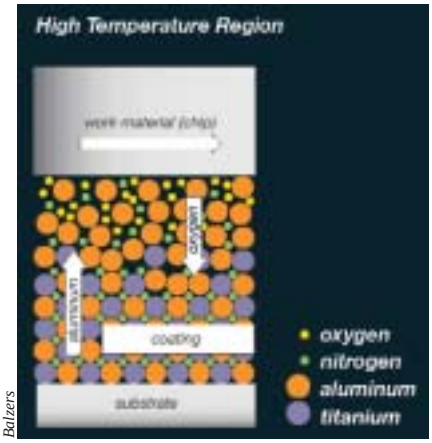
One way to improve an AlTiN coating is to increase its aluminum content. This provides greater strength at higher temperatures with enhanced oxidation resistance, said Fred Teeter, president of Teeter Marketing Services LLC, Sanborn, N.Y., and past president of the Surface Engineering Coating Association, Cleveland.

The most popular theory is that as the temperature at the tool/workpiece interface exceeds about 1,380° F, the aluminum "grabs" oxygen from the air, converting the coating's outer surface to aluminum oxide, or alumina scale. "Everybody believes it to be true, but we haven't seen proof," Graham explained.

This Al_2O_3 layer prevents further oxidation and protects the tool from the high temperatures generated at the tool/workpiece interface. And the more aluminum content in the coating, the thicker the layer of aluminum oxide.

However, increasing the aluminum content is easier said than done. The direct-current process is usually employed to apply a PVD AlTiN coating onto a cutting tool, but the process isn't effective for creating a coating with more than about 65 percent aluminum because an electrically insulating barrier is created.

"When a coating becomes electrically insulating, a straight-DC bias of 100 volts or so is ineffective, because a direct current can't be drawn through an insulating material," explained Dave



Balzers

When the temperature at the tool/workpiece interface becomes greater than 1,380° F, aluminum atoms move through a coating's lattice to the surface of the tool. There, a reaction between the aluminum and oxygen takes place, resulting in the formation of a thin layer of aluminum oxide, or alumina scale. This scale protects the coating from further oxidation.

Glocker, president of Isoflux Inc., a Henrietta, N.Y.-based coating equipment manufacturer. "You have to change your process to allow you to bias an electrical insulator, which means applying an AC or pulsed-DC bias onto the substrate or using a radio-frequency process."

He indicated an additional problem arises when trying to produce an AlTiN coating with more than 65 percent aluminum. "For example, when you sputter a target that consists of 70 percent aluminum in nitrogen, the target surface also becomes insulating," Glocker said. "Therefore, you have to accommodate not just an insulating coating but the probability of an insulating layer on your target as well."

To overcome these problems, the coating equipment needs to be capable of depositing electrically insulating materials. "It is possible. We do it. Others do it, but the equipment is not traditionally used in the industry," Glocker said.

Coolant Considerations

Equipment for producing high-aluminum-content AlTiN coatings is likely to become more common, though, as more parts producers embrace dry and near-dry machining to reduce production and environmental-compliance costs.

The more temperature-resistant aluminum an AlTiN coating has, the more heat goes into the chips as they leave a workpiece. As a result, little or no coolant is required to help carry heat away from the tool/workpiece contact surface. This is especially beneficial when machining nickel-base metals, since the cutting edge is exposed to temperatures up to 1,500° F.

Although coolant, filtration equipment and disposal represents about 15 percent of a shop's operating expense, Teeter said the cost of complying with environmental legislation is the main motivator for reducing coolant consumption. He noted, too, "With less coolant, there's less cleanup of parts."

Glocker concurred. He added, "And saving money helps as well."

Supernitride Coatings

A range of AlTiN-coated cutters is available with more than 65 percent aluminum. For example, Carboloy offers a coating with 67 percent aluminum, and IonBond provides one with 70 percent aluminum. CemeCon announced last June that it developed technology for producing Supernitride coatings with an aluminum content of about 80 percent.

Supernitrides are a class of very fine-grained, dense-structured, cubic metal nitride-based hard coatings, according to Rainer Cremer, corporate technology manager for CemeCon AG, Würselen, Germany.

The coating material is produced with the company's High Ionization Pulse process, which Cremer said is based on the dual-cathode, bipolar, pulsed-magnetron sputtering principle. "The extremely dense plasma generated by the pulse process is guided directly to the tools, leading to high ion bombardment of the growing film and, consequently, an improved coating quality," he said.

He noted that the H.I.P. process operates with either a DC or pulsed bias, depending on the film's electrical conductivity. "Electrically nonconductive coatings can be deposited by H.I.P., because the bipolar process allows an efficient periodical discharging of the tool surface and the cathode."

Cremer said the AlTiN coating's hardness increases as the aluminum content increases, but research is ongoing as to whether an 80 percent aluminum-nitride content optimizes cutting performance.

Question of Hardness

Although coatings with more than 50 percent aluminum are sometimes called titanium aluminum nitride, others distinguish AlTiN from TiAlN. For instance, Melin Tool Co., Cleveland, discontinued the use of TiAlN as a standard coating last July, recommending AlTiN for TiAlN applications since its AlTiN coating has a hardness of up to 4,500 HV vs. 2,600 HV for TiAlN.

Opinion is not unanimous regarding the hardness of AlTiN, since aluminum content is not the only element influencing hardness. Wolfgang Kalss, manager of research and development for Balzers AG, Liechtenstein, does not believe a coating's hardness increases as

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IonBond LLC
(864) 433-9450
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Isoflux Inc.
(585) 334-3230
www.isofluxinc.com

Melin Tool Co.
(216) 362-4200
www.endmill.com

Metallurgical Processing Inc.
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Teeter Marketing Services LLC
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aluminum content rises. “Aluminum contents higher than 65 percent are possible,” he said. “However, the hardness of the coatings decreases because at high-aluminum contents, softer AlN phases are formed.” He added that Balzers has collected data that shows maximum hardness can be found when the ratio of aluminum to titanium is 1:1.

Although the hardness of an AlTiN coating while in the cut is debatable, there’s no argument that oxidation of the coated surface creates a desirable Al_2O_3 layer. “As the oxide layer forms during the cut, the hardness increases

CemeCon

The CC800/9 H.I.P. furnace provides a pulsed etching stage at high voltages to clean tools prior to coating. This is especially beneficial when coating the intricate geometries of hobs and complex endmills.

along with the brittle coating’s heat resistance,” said Kris Lang, sales manager for Metallurgical Processing Inc. (MPI), New Britain, Conn.

He added that the AlTiN coating is ideal for tools running at a cutting speed of 600 to 800 sfm, a spindle speed of 20,000 to 40,000 rpm or higher, and a shallow DOC. This increases productivity, puts less stress on the spindle, imparts a finer finish and produces smaller chips that carry heat effectively. The downside is the coating won’t last as long at the slower speeds needed to effectively machine nickel-base alloys, which can have machinability ratings as low as 7 or 8 percent.

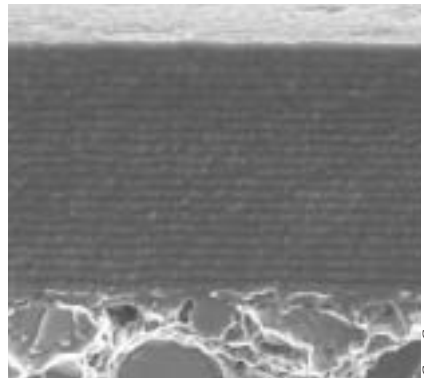
However, carbon can be added to the AlTiN coating mix to increase toughness when cutting nickel alloys, Lang explained. In addition, he said tests are being conducted on adding silicon as a binder, which strengthens the coating’s microstructure and may help coating performance.

As more shops purchase high-speed machining centers, the application of AlTiN-coated tools increases. Lang noted that about 40 percent of MPI’s coatings are AlTiN, up 40 percent from 2 years ago. Nonetheless, one AlTiN coating can perform differently from another, and the coating is not cost-effective—or the best choice—for every application.

“There are many variations of aluminum-based coatings, and it would be tough to take a standard catalog coating and expect maximum performance levels for a specific application,” Lang said. “Coating compositions are application-specific, and we have the ability to custom-design coatings based on the microstructure, element composition, layer arrangement such as monolayer, multilayer or gradient layers, and layer thickness.” He added that the coating should be considered a component of the tool, just like the substrate and geometry, that can be adjusted to optimize performance.

Research Continues

Regardless of the coating’s composition, end users seek higher productivity and better performance. “We are working on various possibilities to increase the oxidation resistance of our coatings,” Kalss said. “Aluminum content is one way. Improving composition and the coating’s structure are further possibilities.” These include adding metallic and/or nonmetallic elements to the coating to improve performance when dry machining at a high cutting speed.



CemeCon

A micrograph of a multilayer Supernitride AlTiN coating.

While AlTiN coatings are deposited on a growing number of tools, research continues into the development of an economical 100 percent PVD aluminum-oxide coating.

“PVD aluminum oxide is a hot topic,” said Kalss. “All major insert manufacturers are looking for a solution.”

However, when that PVD Al_2O_3 solution will be available remains uncertain. (CVD Al_2O_3 coatings are common, but lack the benefits provided by lower-deposition-temperature PVD coatings.)

In the meantime, companies making titanium alloy and nickel-base superalloy parts—especially for the aerospace, nuclear and medical industries—will continue to seek cutting tools whose substrate, geometry and coating have been optimized collectively to meet their application-specific needs.

“These AlTiN coatings are so new that that kind of optimization is still taking place,” said Isoflux’ Glocker.