Al-rich Ti_{1-x}Al_{x}N – a new CVD layer

Today, modern cutting tools made of hardmetal are mainly coated with ceramic wear resistant layers. These thin layers with thicknesses between 1 μm and 20 μm allow a significant performance enhancement in machining metallic workpiece materials.

Chemical vapor deposition (CVD) and physical vapor deposition (PVD) are established methods in industrial production. The development of new and more efficient wear resistant layers is motivated by increasing demands on cutting tools which result from the increase of high-speed and dry cutting processes as well as the cutting of high-strength and hard materials. Such materials include, for example, high-strength steel and cast materials, high-strength alloys for automotive and aircraft engineering as well as metal matrix composites (MMC). At high cutting speeds, temperatures of more than 1000°C are obtained on the cutting edge and particularly on the rake face. That is why modern wear resistant layers must have – aside from high hardness – a good oxidation resistance and must be chemically inert against the workpiece material.

Over the last both decades, Ti_{1-x}Al_{x}N with cubic structure has become an important standard layer for wear resistant applications. So far, it could only be produced using coating methods that work at comparatively low temperatures as it is a metastable material. That is why TiAlN is only produced by PVD methods on industrial scale. But PVD methods only allow the
deposition of Ti$_{1-x}$Al$_x$N coatings with an aluminum content limited to $x = 0.65$ and thus oxidation resistance is also limited. By means of a new CVD process, which was developed at Fraunhofer Institute for Ceramic Technologies and Systems IKTS, it is now possible to produce cubic Ti$_{1-x}$Al$_x$N layers with significantly higher aluminum contents of $x = 0.8$ to $x = 0.9$. The CVD process works in the so-called moderate temperature range between 700°C and 900°C and at process pressures below 10 kPa.

Aluminum and titanium chlorides AlCl$_3$ and TiCl$_4$ as well as ammonia and hydrogen are used as starting materials. The cubic Ti$_{1-x}$Al$_x$N phase, however, can only be produced in a certain process window, that means below 900°C and using certain ratios of AlCl$_3$/TiCl$_4$. In case of a ratio that is too low, titanium nitride is additionally deposited. In case of ratios that are too high, AlN is deposited in the wurtzite structure. At temperatures above 850°C, TiN and AlN are co-deposited. High contents of these secondary phases are unwanted, as hardness and oxidation resistance of the wear resistant layer are reduced.

The figure below shows the result of an X-ray analysis of a Ti$_{0.1}$Al$_{0.9}$N layer with a high aluminum content of $x = 0.9$, which almost solely consists of the cubic phase fcc-TiAlN. The layers show high hardness values of approx. 3000 HV at room temperature, moderate residual compressive stress up to -1 GPa and an oxidation resistance up to 900°C. Hot hardness, which is relevant for this application, is also very high with approx. 1000 HV [0.2] at 800°C and is significantly higher than that of TiN, TiC and TiCN layers. High adhesion strength on the hardmetal tool is obtained by means of a layer structure that is shown in the cross section in the figure above.

The TiN layer provides good adhesion to the hardmetal tool. A second fine crystalline adhesion layer guarantees a continuous increase of the fcc-Ti$_{1-x}$Al$_x$N phase and hardness resulting in a very good adhesion to the TiAlN top layer. Aluminum rich Ti$_{1-x}$Al$_x$N with $x > 0.85$ shows a coarse-grained columnar growth.

The new aluminum rich CVD-TiAlN layers have outstanding wear resistant properties which result from their high hardness, the intrinsic residual compressive stresses and the good oxidation resistance. In various wear tests, such as reaming and milling of steel and cast materials, the layers show a lifetime that is up to 100% higher than that of commercially available PVD and CVD layers. The high performance potential is proved by a wear test depicted in the figure on the right. It shows that the new CVD layer is significantly better than a PVD TiAlN layer representing the state of the art.

Austrian tool manufacturer Boehlerit scaled up the CVD process within the last years and launched the new CVD-TiAlN layer under the name “TERAspeed” in 2011 (please see success story at page 3).
**SUCCESS STORIES**

**TERASPEED – THE CUTTING GRADE OF THE FUTURE**

Boehlerit, the Austrian expert for hardmetal tools, is the first company to succeed in depositing a new AlTiN carbide layer in serial production on carbide indexable inserts by means of a chemical vapor deposition (CVD) process. So, the milling performance was significantly increased as compared to standard AlTiN layers which were produced by physical vapor deposition. This brings a major efficiency boost with the milling performance on cast materials by up to 200%.

While AlTiN layers deposited by means of physical vapor deposition (PVD) have a maximum Al content of < 70%, the new AlTiN layer of Boehlerit has an aluminum content of more than 90%, and thus a hardness of HV 3500. It ensures significantly improved thermal stability, oxidation resistance and layer adhesion. The new AlTiN layer, which is available under the name TERAspeed, owes its distinct advantage to its high aluminum content and its benefits are particularly noticeable in dry machining at cutting speeds of + 250 m/min.

Cubic AlTiN layers with an aluminum content of more than 90% were deposited by CVD on laboratory scale already some years ago. Now, the great challenge was to upscale that process. Complex instrumental adjustments of a standard MT-CVD coater were necessary to reproducibly deposit AlTiN layers with regard to layer thickness and composition.

Since 1932, Boehlerit has been standing for permanent innovation in machining of metals. When the company was included in the Leitz group in 1991, it became a global leader in the production of carbide materials for tools for metal, wood and plastics machining. With approx. 500 employees in Kapfenberg/Austria, Boehlerit is one of the most important employers in Upper Styria.

**“JOINT TASKS“ – A SUCCESSFUL CONCEPT FOR RESEARCH COOPERATION**

In collaboration with the hardmetal working group of the powder metallurgy industry association, in which more than 20 hardmetal manufacturers and raw material suppliers are represented, the Fraunhofer Institute for Ceramic Technologies and Systems IKTS has been conducting joint research projects for many years. Within the framework of the regular working group meetings, Fraunhofer IKTS presents different research approaches and concepts, whereupon a so called joint task is derived with interested companies.

Then, a cooperation contract is concluded in which task, budget as well as the exploitation rights are determined. The project consortia works on the joint project over a period of two years. The project partners meet twice a year informing about and discussing the latest project results. Usually, the joint tasks result in further research cooperation.

The joint task “CVD deposition of hardmetals” is one successful example for this kind of joint research. Within the framework of this project results were obtained that Boehlerit successfully used for its product “TERAspeed” (please see article on the left). Another good example is the joint task “Flowability of ceramic granules for die pressing”. Here, suitable processes for characterizing the “flowability” were investigated as well as knowledge about the interactions between primary granule properties and resulting processing properties was acquired.

This kind of cooperation is a successful concept for industry consortia of associations, regions or other interested groups. As the joint projects are not publically funded, the partners are free to determine the conditions, time schedule and budget as well as formalism. In order to work on individual and confidential questions, the companies often use the opportunity to commission Fraunhofer IKTS to work on additional tasks.

---

**TERAspeed: The new CVD-AlTiN layer increases the milling performance of indexable inserts.**
IMPORTANT DATES

AdvanCer training courses
“Advanced ceramic materials”
• Part 1: Materials, technologies
  March 6 and 7, 2013 (Dresden)
• Part 2: Machining
  May 14 and 15, 2013 (Berlin)
• Part 3: Construction, testing
  November 7 and 8, 2013 (Freiburg)

Seminars and workshops at
Fraunhofer IKTS
• Workshop: Nano- and membrane-based systems for water treatment
  April 17 and 18, 2013
• Symposium: Thermoelectrics – From materials to systems
  April 17 and 18, 2013

For further information please see
www.advancer.fraunhofer.de

NEWS

OPENING OF BIOENERGY APPLICATION CENTER
The Fraunhofer Institute for Ceramic Technologies and Systems IKTS and Lehmann Maschinenbau GmbH will pool their skills in the field of biomass utilization. They opened a bioenergy application center in Pöhl/Saxony in mid-October. With the foundation of the bioenergy application center, the scientific competences of Fraunhofer IKTS are combined with extensive experiences and comprehensive skills of Lehmann Maschinenbau GmbH in the field of design and manufacture of equipment and systems for biogas technology. The installed pilot equipment comprises a three-stage pilot biogas plant, innovative process steps for substrate pretreatment, stirring fermenters for evaluating mixing processes, biogas purification and desulfurization reactors as well as equipment for fermentation treatment and dewatering. Lehmann Maschinenbau GmbH and Fraunhofer IKTS demonstrate solutions to use biomass for fuel cell operation. Thus, the application center serves to determine processes, to perform long-term tests and to upscale processes for making biogas production and use effective. What makes this so special is that the methods are always developed in connection with the appropriate equipment. In this way, the aimed market maturity and broad application can be achieved faster.

Aside from using and further optimizing the existing equipment, the application center is used to develop and study new ideas, e.g. in the field of bioalcohol production and gas purification with ceramic membranes and catalysts. The application center offers the unique opportunity to investigate the processes and research results under operational conditions.

EUROMOLD AWARD 2012
At the end of November, the EuroMold Award was given to three companies at the World Fair for Moldmaking and Tooling, Design and Application Development. The award goes to exhibiting companies for outstanding and exemplary novelties in the sector of manufacturing and services, such as for innovative products, trendsetting manufacturing processes, new market strategies as well as for corporate concepts.

Among this year’s winners are two companies which successfully use or produce advanced ceramics. The EuroMold Award Gold was given to Hans-Hermann Bosch GmbH, which uses galvanically coated ceramic electrodes to produce high-precision, geometrically complex parts made from metal by electro-chemical machining ECM. The EuroMold Award Silver was awarded to Lithoz GmbH for its LCM method (lithography based ceramic manufacturing) and the appropriate machine Cerafab 7500 by means of which ceramic components can be produced in the same density, strength and precision as by standard manufacturing methods.

EDITORIAL NOTES

A publication of:
Fraunhofer AdvanCer Alliance
Winterbergstrasse 28, 01277 Dresden, Germany
Phone +49 351 2553-7504
advancer@ikts.fraunhofer.de
www.advancer.fraunhofer.de

Editors: Susanne Freund, Andrea Gaal

All rights reserved. Reprints permitted only upon express authorization by Fraunhofer Alliance AdvanCer. Photo credits on request.