THE SYNTHESIS OF TiAlN COMPOSITES BY CONDENSATION OF THE DIFFERENT ARC PLASMA FLOWS

V.S. Taran [1], *V.I. Tereshin* [1], *A.I. Timoshenko* [1], *O.G. Chechel'nitskij* [1], *A.P. Kryshtal'* [2]

[1] *IPP NSC KIPT, Akademicheskaya St.1, 61108 Kharkov,Ukraine;*

[2] *Kharkov National University, Kharkov, Ukraine*

Some properties of the arc-vapour deposited TiAlN films, obtained both – by condensation of the different and combined titanium and aluminium plasma flows, have been investigated. The different flows was provided by two arc evaporators with titanium and aluminium cathodes, at that, the aluminium plasma was passed through the curvilinear plasma filter. The combined titanium-aluminium plasma was generated by single evaporator with the alloyed TiAl cathodes, which have a volumetric content of aluminium 50 %. The growth rates, surface morphology and the Vickers hardness of the TiAlN films, obtained under the various conditions, have been analyzed. The comparative cutting tool trials with the cemented carbide drills, covered by TiN, TiCN and TiAlN were conducted. It is shown, that the TiAlN film compositions, condensed from different plasma flows with the filtering aluminium plasma, are more profitable and has much higher characteristics, than films, obtained from alloyed TiAl cathodes.

PACS: 52.77.-j

1. INTRODUCTION

Among the much variety of coatings, used for the tools hardening, TiAlN composites attract the special attention due to their valuable properties [1]. By such parameters, us resistance to temperature oxidation, "hot" hardness, friction coefficient and flexibility, they exceed the widely used TiN, TiC, CrN and Mo_2N coatings [2]. These properties were attributed to a stable aluminum oxide layer formed at the working surface [3]. TiAlN-composites keep his characteristics up to 925ºC [4], what makes its irreplaceable during high-speed cutting of difficult-to-machine materials. TiN, for example, is stable only up to 550ºC [4]. The Al_2O_3 acts also as the dry lubrication, providing low friction in a contacting area. As a result, the impact and thermal loads tend to decrease, improving the wear resistance. The life-time of tool with the TiAlN coating increases by 2 – 4 times in comparison with TiC and TiCN ones. The rate of metal removing increases also by 2 – 4 times in comparison with TiN coating, and relatively to the coatless tool it runs up to 10 times [5].

However, the synthesis of such coatings by vacuum-arc methods has some difficulties. Aluminum is an easily melted metal and its plasma contains a great quantity of vapor phase and droplets. Its dimension may reach several tens of micrometers. Such droplets reduce the hardness and smoothness of the films. The alloyed TiAl-cathodes with 20-60 vol. % of Al are commonly used for the synthesis of such coatings. The melting point of this alloy is higher then of pure aluminum, and, respectively, the amount of droplets and vapors contained in plasma are decreased. At the same time, the alloyed cathodes are much more expensive then pure Al or Ti ones. This, in turn, adversely affects the profitability of the resulting product. In addition, the amount of droplets in coatings continues to be high. Therefore, the advantage of the TiAlN composites does not exhibits completely.

The performance of such coatings may be improved by eliminating of the macro-particles from a plasma flow. In present work we have compared some properties of TiAlN-composites, obtained by two methods in a framework of vacuum-arc deposition technology.

2. EXPERIMENT

The experiments were carried out on a "Bulat-9" plant, equipped with a plasma filter (Fig.1). The sources of Al-plasma, containing cathode units (1), (9) with an Al-cathode, stabilizing coil (2) and a focusing coil (3), is fixed on a cubic plasma guide (4). The deflecting coil (6) with the coils (3) and (7) form the curvilinear magnetic field with the strength up to 150 Gauss. In this field the Al plasma deviates on 90º and condenses onto a tool

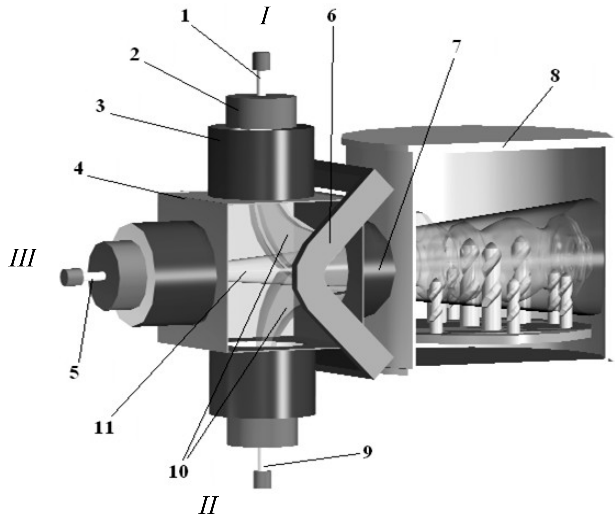


Fig. 1. Experimental plant. I, II -The plasma sources with the Al-cathodes; 1, 9 - cathodic units; 2 - stabilizing coil; 3 - focusing coil; 4 - plasma guide. III - The plasma source with the Ti-cathode; 5 - cathodic unit; 6 - deflecting coil; 7 - output coil; 8 - chamber; 10 - Al-plasma; 11 - Ti-plasma

surface free from macro-particles and vapor phase. The similar plasma source (5) with a titanium cathode is placed on the plasma guide (4) opposite to the entrance to the chamber. Such configuration allows obtaining just composite coatings, but no multi-layer ones, as in a case, when the plasma flows reach the surface of condensation from various directions. By changing the arc current in titanium evaporator from 40 to 160A as well as the magnetic field of solenoids (3) from 0 to 40 Gauss, one can change the deposition rate of Ti-layer in a range 2 – 14 μm/h. The same procedure allowed varying the grows of Al-condensate from 1.5 to 10 μm/h. It makes possible to obtain TiAl-composition with a wide range of relative percentage Ti and Al in the coating during the simultaneous working of three evaporators.

This films was compared with the coatings, obtained from a direct (non-filtered) and filtered plasma flows, generated by alloyed TiAl cathodes with 50 vol. % Al.

The coatings were deposited onto the polished stainless steel plates 20 ¿ 20Ч2 мм^3 and on the surface of the cemented carbide drills, made by Mitsubishi Carbide. The surface topography was analyzed by scanning electron microscopy. The hardness was measured by PMT-3 hardness-analyzer. The comparative cutting toll tests have been carried out with use the industrial equipment in Drogobych chisel plant.

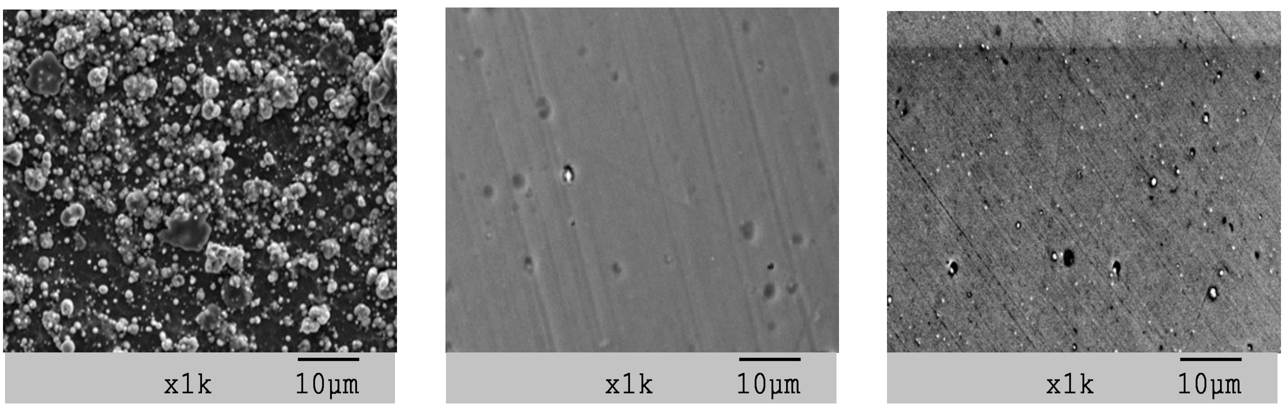
3. RESULTS

Fig. 2 shows the SEM micrographs of surfaces of TiAlN coatings deposited: a) – from a direct (non-filtered) TiAl-plasma flow (alloyed TiAl-cathode); b) – from a filtered TiAl-plasma flow (alloyed TiAl-cathode); c) – from two: direct titanium and filtered aluminum plasma flows (Fig. 1). The thickness of coatings was 10 μm.

The comparison of figs. 2a) and 2b) shows the efficiency of the plasma filter, and the figs. 2a) and 2c) demonstrate the difference in a content of droplets in a plasmas generated by TiAl- and Ti-cathodes. The hardness of TiAlN-coating on fig. 2a) does not exceed 2700 HV, whereas the films, obtained by condensation of fully (2b) or partially (2c) filtered plasma, has the hardness up to 4300 HV.

The performance of TiAlN coatings 2a) and 2c), and TiN and TiCN, condensed from non-filtered titanium plasma, were estimated during comparative tests of cemented carbide drills, made by Mitsubishi Carbide. The drills were coated after its re-sharpening. The maximum quantity of holes, perforated in tempered steel with a RHC of 52, was served as a criterion for wear resistance of drills with a various coatings. As shown in Fig. 3, the uncoated drills make 4 – 5 holes until failure. The TiN coated drills perform 6 – 7 holes. The TiAlN obtained from the alloyed cathode allowed to drill near 15 holes, and drills, coated by TiAlN, deposited from separated flows with the filtering Al-plasma perform up to 20 holes.

The last result, evidently, was obtained due to a much more perfect structure of the coatings, which not contain the Al-droplets. Besides, the high smoothness of the surface reduces in the friction coefficient and,



a b c

Fig. 2. SEM micrographs showing the topography of TiAlN surfaces condensed a) from non-filtered TiAl-plasma flow (alloyed TiAl-cathode); b) from a filtered TiAl-plasma flow (alloyed TiAl-cathode); c) from two: non-filtered titanium and filtered aluminum plasma flows. The thickness is 10 μm

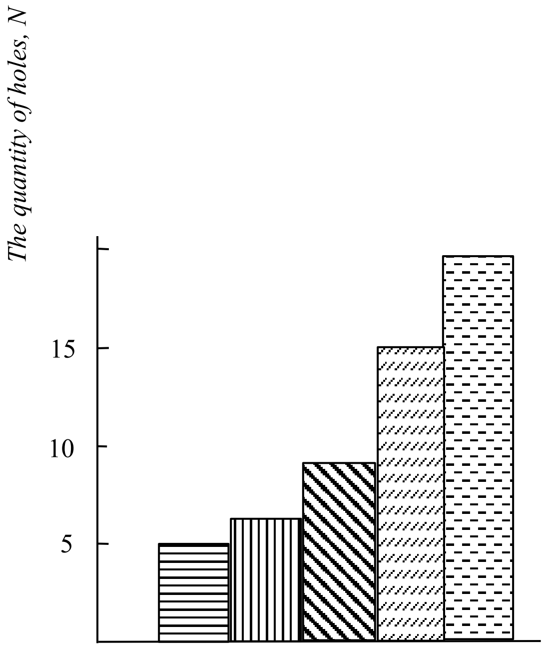


Fig. 3. The quantity of holes, perforated in tempered steel (HRC 52) with a drills of Mitsubishi Carbide:

– uncoated *–TiN-coated*

–TiCN *–TiAlN non- filtering*

–TiAlN with Al-plasma filtering

respectively, in dynamics and thermal load, applied to the cutting edge.

Notwithstanding the fact that hardness of TiAlN-coatings, obtained from alloyed cathodes, and TiN ones is almost identical, the wear-resistance of TiN coated drills were noticeably lower. Evidently, in this case the much higher flexibility and thermo-stability of TiAlN coatings have exhibited as compared to the TiN.

At the same time, the alloyed TiAl-cathodes are almost in order expensive of the Ti- or Al-ones. This fact, and high performance of TiAlN-composites, obtained by condensation of Ti- and filtering Al-plasmas, point out to advisability of the usage of plasma-filters in this technology.

4. CONCLUSIONS

The variant of the synthesis of TiAlN coatings from different Ti- and Al-plasma flows with the aluminium plasma filtering has been examined. This method allows to obtain such composites with a widely range of its Al content without reducing the growth rate.

These coatings are remarkable by its high hardness (4300 HV) and wear resistance (1.5 times higher as to coatings obtained from alloyed TiAl cathodes).

The application of plasma filter in this case not only improves the coatings performance but is also more profitable as compared to usage of the alloyed cathodes.

REFERENCES

[1] Knotek et al.// *Proc. of the 11th Int. Plansee Seminar (1).* 1985, pp. 677 – 691.

[2] B.F. Coll, P. Sathrum, R. Fontana // *Surf. Coat. Technol. (52*). 1992, pp. 57-64.

[3] Da-Yung Wang, Yen-Way Li, Chi-Long Chang, Wei-Yu Ho// *Surf. Coat. Technol. (114).* 1999, pp.109-113.

[4] E.J.Bienk, H.Reitz, N.J. Mikkelsen // *Surf. Coat. Technol. (76/77)*. 1995, p. 475.

[5] H. Jehn, S. Hofmann // *Thin Solid Films (153).* 1987, pp. 45-53.

СИНТЕЗ КОМПОЗИТОВ TiAlN ПУТЕМ КОНДЕНСАЦИИ РАЗЛИЧНЫХ ПОТОКОВ ВАКУУМНО-ДУГОВОЙ ПЛАЗМЫ

В.С. Таран, В.И. Терешин, А.И. Тимошенко, О.Г. Чечельницкий, А. П. Крышталь

Исследованы свойства композитов TiAlN полученных конденсацией раздельных и совмещенных потоков титановой и алюминиевой плазмы. Генерирование раздельных потоков обеспечивалось двумя вакуумнодуговыми испарителями с титановым и алюминиевым катодами, причем, алюминиевая плазма проходила через криволинейный плазменный фильтр, где очищалась от паров и макрочастиц. Совмещенный поток титан-алюминиевой плазмы создавался одним испарителем с использованием сплавных катодов TiAl с объемным содержанием алюминия 50%. Исследованы стойкостные характеристики твердосплавного инструмента, упрочненного покрытиями TiAlN. Показано, что композиты TiAlN, осажденные из раздельных потоков с сепарацией алюминиевой плазмы, более рентабельны и обладают более высокими характеристиками, чем покрытия, полученные с использованием сплавных катодов.

СИНТЕЗ КОМПОЗИТІВ TiAlN ШЛЯХОМ КОНДЕНСАЦІЇ РІЗНИХ ПОТОКІВ ВАКУУМНО-ДУГОВОЇ ПЛАЗМИ

В.С. Таран, В.І. Терешин, А.І. Тимошенко, О.Г. Чечельницкий, А. П. Кришталь

Досліджено властивості композитів TiAlN одержаних із окремих і сполучених потоків титанової та алюмінієвої плазми. Генерування окремих потоків забезпечувалося двома вакуумно-дуговими випаровувачами з титановим і алюмінієвим катодами, причому, алюмінієва плазма проходила через криволінійний плазмовий фільтр, де очищалася від парів і макрочасток. Сполучений потік титан-алюмінієвої плазми створювався одним випаровувачем з використанням сплавних катодів TiAl, що містили 50 об'ємних % алюмінію.

Визначено стійкістні характеристики твердосплавного інструменту, зміцненого покриттями TiAlN. Показано, що композити TiAlN, конденсовані з окремих потоків з фільтрацією алюмінієвої плазми, більш рентабельні і мають більш високі характеристики, ніж покриття, одержані з використанням сплавних катодів.