

DEVELOPMENT OF AN ELECTROMAGNETIC ACCELERATION PLASMA GENERATOR FOR ZIRCONIA AND TITANIUM NITRIDE COATINGS

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Abstract

Electromagnetic acceleration plasma generators, which are called Magneto-Plasma-Dynamic (MPD) arcjet generators, can produce higher-velocity, higher-temperature and higher-density plasmas than those of conventional thermal plasma torches, because MPD arcjet plasma is efficiently accelerated by electromagnetic body forces in MW-class input power operation. These properties are effective for deposition of rigid coatings adhering strongly to substrate surfaces.

In the present study, we newly developed two types of MPD arcjet generators for ceramics spray coatings. The one is for calcia stabilized zirconia (CSZ) ceramics which is usually used for thermal barrier coatings. The other is for a reactive spray process of titanium nitride film deposition. These ceramics coatings were deposited onto steel substrates by means of the MPD arcjet generators. The phase structure and the composition of the coatings were analyzed by means of scanning electron microscopy (SEM) and X-ray diffraction (XRD), and their Vickers hardness were measured. These analyses showed that the MPD spray process could successfully form dense and uniform ceramics coatings. In titanium nitride coatings by means of MPD arcjet generators, the properties of the coating were highly sensitive to the titanium cathode diameter and discharge current.

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Introduction

Plasma spraying process is widely used as a various material coating technique for many fields of modern manufacturing industries. And now, the plasma spraying becomes a key technology for enhancing the surface functionality of mechanical equipment. However, because of the improvement of industrial machines, the performance of the coatings is required much higher, such as strong adhesion, more corrosion resistance, higher hardness and so on. In recent held international conference and workshop, many research and development efforts devoted to the improvement of the coating quality.

An electromagnetic acceleration plasma generator, which is called Magneto-Plasma-Dynamic (MPD) arcjet generator, has a coaxial electrode structure similar to those of conventional thermal arcjet generators. However, their acceleration mechanisms are different; that is, in MPD arcjet generators, plasmas are accelerated by the electromagnetic interaction between the discharge current and the magnetic field induced by it in MW-class input power operations during the discharge, as in Fig. 1, although in thermal arcjet generators the working gas is

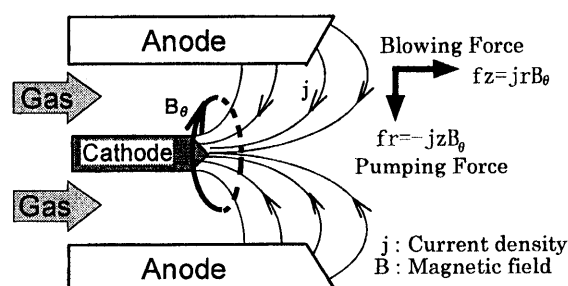


Fig. 1 Patterns of current, magnetic field and Lorentz force in MPD arcjet generator.

accelerated aerodynamically through a straight or convergent-divergent nozzle. As a result, the MPD arcjet generator can produce higher-velocity, higher-temperature, higher-energy-density, and larger-area plasmas than those of other conventional plasma torches can.¹⁻³ They are effective for deposition of rigid films adhering strongly to substrate surfaces.⁴⁻⁷

In order to apply MPD arcjet generators to ceramic spray coatings, we newly developed two types of MPD arcjet generators. The one is for calcia stabilized zirconia (CSZ) ceramics spray coating, and the other is for titanium nitride reactive spray coating. The CSZ ceramics are usually used as thermal barrier coatings, in high-temperature turbine blade applications for example. Titanium nitride has good wear resistance, corrosion resistance and heat resistance, therefore titanium nitride has many industrial applications such as wear resistant coating of cutting tools, heat resistant coating and corrosion resistant coating. However, ordinary titanium nitride forming methods are low deposition rate, and the coating is poor thickness.

In this study, CSZ ceramics coatings and titanium nitride coatings are formed onto the substrates by means of the newly developed MPD arcjet generators, and the property of the coatings are studied. The coating properties are examined by several diagnostic techniques. The cross sections of the coatings are observed with a scanning electron microscope (SEM), and their surface structures are analyzed by means of X-ray diffraction (XRD). The Vickers hardness of the coatings are also measured.

Experimental Apparatus

Figure 2 shows the cross sectional diagrams of the MPD arcjet generators for CSZ coating and titanium nitride coating used in the present study. Both the MPD arcjet generators are equipped with a rod cathode and a cylindrical copper anode. The anode nozzle is 48 mm in exit diameter with a 20 degree half-angle and has 4 gas ports in its sidewall. Figure 2(a) shows an ablation type MPD arcjet generator for CSZ spray coating. The cathode made of ThO₂-W is covered with a tube-shape CSZ ceramic material, and working gas is Ar. The end of the ceramic material is set up at the same axial position as that of the upstream

end of the discharge chamber, and the cathode end is placed 5 mm upstream of the ceramic material end. The ceramic material is supplied by turning the screw at the end of the MPD generator body. Figure 3 shows the schematic diagram of an ablation type MPD arcjet generator for CSZ spray coating. A high current arc

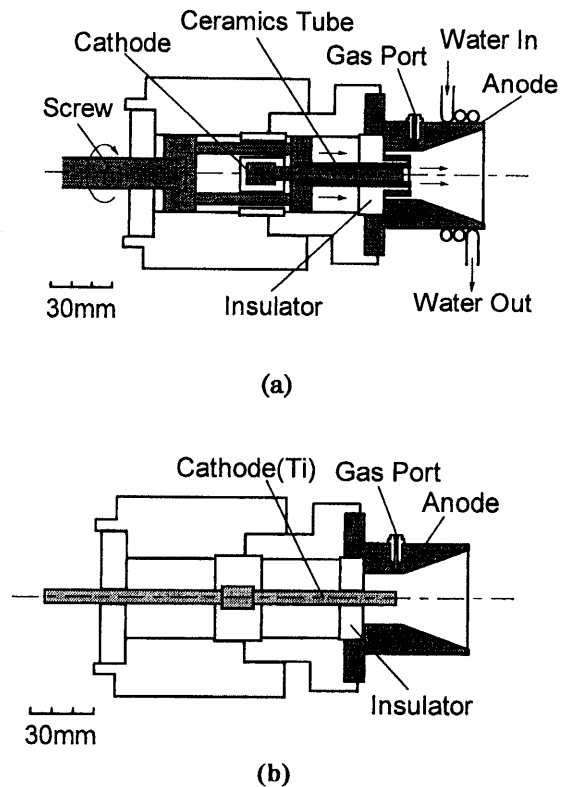


Fig.2 Cross sections of ablation-type MPD arcjet generators.
 (a) For CSZ coating
 (b) For titanium nitride coating

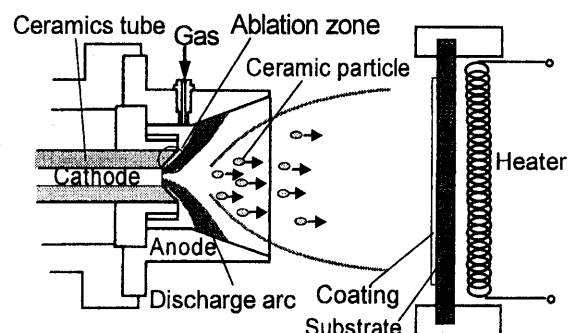


Fig.3 Illustration of ceramics spraying using ablation-type MPD arcjet generator.

