2nd International Conference on Recent Developments in Science, Humanities & Management
Mahratta Chamber of Commerce, Industries and Agriculture, Pune (India)
8th July 2018 www.conferenceworld.in ISBN : 978-93-87793-33-0

Conductive coating on insulating substrate for application in Wire Electric discharge machining

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ABSTRACT

Electric discharge machining uses phenomenon of erosive effect due to electric discharges from electrode to the work piece. Basic pre-requisite is that both electrode and work piece has to be conductive. But today many non conductive materials such as glass ,ceramics has applications where their machining requires precision and accuracy. Concept of assisting electrode has made it possible to machine non conductive material on EDM. In this study, various coating methods are applied on non conductive substrate so as to make its utilisation as assisting electrode and to use it for machining on WEDM. Properties such as adhesiveness and thermal stability has taken into consideration for coating method selection.

KeyWords—Assisting electrode, Physical vapour deposition (PVD),Chemical bath deposition(CBD).

I. INTRODUCTION

EDM technology is now increasingly used in tool, die and mould making industries, for machining of heat treated tool steels and advanced materials (super alloys, ceramics, and metal matrix composites) requiring high precision, complex shapes and high surface finish. The demand for precision, crack-free micro-structures made of hard, brittle materials has been increasing in a variety of applications. Micro-holes and micro-features can be fabricated on such materials by various non-traditional machining methods, including wire electric discharge machining (WEDM), laser machining, powder blasting, and ultrasonic machining. But Wire EDM is having various advantages over its competitive machining processes. Comparison between WEDM and Laser beam machining have been in constant debate. But both of them have their advantages in particular conditions. Laser beam

machining have tapering problem during machining which a WEDM cannot have as wire is all over the length of thickness. Also LBM has high melting Zone which can Increase the kerf width especially in micron level machining. Hence WEDM possesses advantages over its competitors. Lots of research have been carried out in fabrication of micro channels like laser machining ,focused ion machining. These micro channels are used in Various applications like MEMs, electronic cooling system, miniaturization and biochemistry.

Many non conductive parts such as glass and quartz has wide applications in MEMs. Machining them by WEDM is a challenge since basic requirement is that both electrode and workpiece must be electrically conductive. For this ,the concept of assisting electrode has came into existence. In this process, a conductive coating is applied on non conductive substrate which acts as assisting electrode. After this machining can be carried out by taking into consideration various process parameters.Investigation of the micro-EDM milling of zirconia in order to understand the mechanisms of ceramics machining is carried out recently [1]. Roughness and surface characteristics are analyzed and compared with the equivalent metal parts. [12] applied the WED-milling method to insulating ceramics. Machining was difficult under conventional machining conditions, and so a conductive layer on the ceramic surface to realize stable machining is applied. Study[9] has evaluated four coating techniques and several processing parameters in order to optimize nanoparticle coatings on gold- and platinum-coated quartz crystals.

Fig: Micro WEDM setup

II. COATING METHODOLOGY

For machining non conductive workpiece on WEDM it is required that it should act as conductive workpiece. For that purpose a conductive layer is to be applied on workpiece which can act as assisting electrode. Conductive layer can be formed by various coating processes but there are some parameters that has to be taken into consideration mainly adhesiveness, thermal stability and thickness of coated layer.

Firstly, adhesiveness has taken into consideration. Since working conditions in WEDM has higher temperature and also circuit completion depends upon stickness of conductive layer on non conductive workpiece. Then thermal stability plays important role because working temperature is near about 800^0C. So coated material should have melting point higher than 800^0C. So that it can sustain the temperature. Coating layer has to be uniform and around

all corners and edges. Uniformity becomes crucial issue as machining goes on. So thickness control is also have taken into consideration. Accordingly various methodology has been tried for coating on non conductive substrate.

1. Chemical bath deposition (CBD), is a coating approach that has been well developed to fabricate large-area in view of its several advantages:it does not require sophisticated instruments; the starting chemicals are commonly available and cheap; the preparation parameters are easily controlled. However, little work has been done to prepare dense and adherent TiO_2 films by CBD method. The TiO2 thin films were synthesized by room temperature CBD method. In the typical synthesis, equimolar (0.1 M) titanium trichloride ($TiCl_3$:15% HCl) and ammonium chloride (NH_4Cl) in double distilled water is taken. The Quartz substrate dipped vertically in the reaction bath. The depositions were carried out at predetermined time interval in between 15-35 h. In order to remove hydroxide from deposited film and to improve the crystallinity the films were heat treated at 673 K for 1 h. Fig.2 shows the schematic representation of CBD method for TiO_2 films at room temperature.

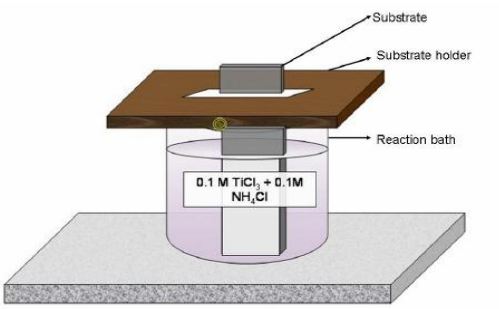

Fig. Chemical bath deposition setup

Further, pH value decreases again owing to the consumption of OH For deposition of TiO2 films, TiCl3:15% HCl was used as a source of titanium and ammonium chloride as a complexing agent. At the beginning of reaction,

$$NH_4Cl \rightarrow NH_4^+ + Cl^-$$
$$NH_4^+ + OH^- \leftrightarrow NH_3.H_2O$$

Ti^{3+} cations form amine complex of $Ti(NH3)n^{3+}$ (n = 1-4) with NH3 (aq) in solution as:

$$Ti^{3+} + nNH_3 \leftrightarrow Ti(NH_3)_n^{3+}$$

Here, initially the solution is acidic and the pH value is about 1 and then the pH of solution increases gradually and monotonically with time and the solution becomes alkalescent. On this alkalescent bath condition, the $Ti(NH3)n^{3+}$ is unstable and the following reactions occur,

$$Ti(NH_3)n^{3+} \leftrightarrow Ti^{3+} + nNH_3$$
$$Ti^{3+} + nH_2O \rightarrow Ti(OH)_3^+$$
$$Ti(OH)_3^+ + OH^- \rightarrow TiO_2 + 2H_2O$$

In the processing, ammonium chloride is introduced as a complexing agent and exerts itself to control the release velocity of Ti^{3+} ions for deposition of TiO2 thin film.

Thermal spraying techniques are coating processes in which melted (or heated) materials are sprayed onto a surface. Coating materials available for thermal spraying include metals, alloys, ceramics, plastics and composites. They are fed in wire form, heated to a molten or semi molten state and accelerated towards substrates in the form of micrometer-size particles. Combustion or electrical arc discharge is used as the source of energy for thermal spraying. Resulting coatings are made by the accumulation of numerous sprayed particles. The surface may not

heat up significantly, allowing the coating of flammable substances. Conductive layer of copper can be sprayed on non conductive material by thermal spraying. Only adhesiveness has to be taken into consideration.

Graphene is the thinnest and strongest material known to man. It is also an excellent electrical and heat conductor that has unique optical properties. Graphene layer is usually formed on substrate by CNT(Carbon nanotubes).But formation of graphene layer depends upon conditions applied during coating. Coating methodology used also affects the formation of graphene layer and its tough to attain in room temperature.

Procedure followed started with dipping the substrate in graphene conductive ink or applying it by paint brush. Making substrate dry by use of hot air furnace. Again all above steps are followed till a firm layer is formed(8-10 times).

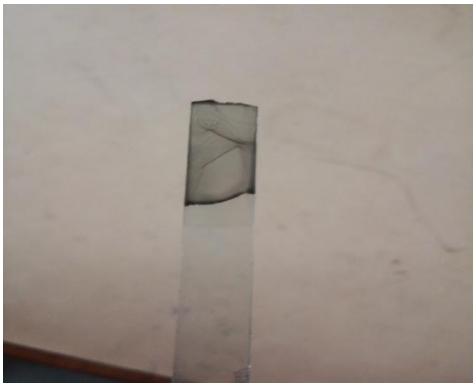

Fig. Graphene conductive ink layer on glass substrate

4.Physical Vapour Deposition (PVD) is a collective set of processes used to deposit thin layers of material, typically in the range of few nanometers to several micrometers. PVD processes are environmentally friendly vacuum deposition techniques consisting of three fundamental steps ,Vapourization of the material from a solid source assisted by high temperature vacuum or gaseous plasma, transportation of the vapour in vacuum or partial vacuum to the substrate surface and condensation onto the substrate to generate thin films.

Different PVD technologies utilize the same three fundamental steps but differ in the methods used to generate and deposit material. The two most common PVD processes are thermal evaporation and sputtering. Thermal evaporation is a deposition technique that relies on vaporization of source material by heating the material using appropriate methods in vacuum. Sputtering is a plasma-assisted technique that creates a vapor from the source target through bombardment with accelerated gaseous ions (typically Argon). In both evaporation and sputtering, the resulting vapor phase is subsequently deposited onto the desired substrate through a condensation mechanism.Titanium nitride (TiN) is selected for coating as The most common methods of TiN thin film creation are physical vapor deposition (PVD, usually sputter deposition, cathodic arc deposition or electron beam heating) and chemical vapor deposition (CVD).Layer thickness obtained is uniform and precise on non conductive substrate.

III. RESULTS AND DISCUSSION

Chemical bath deposition provides a firm adhesive layer ofTiO_2
.But conductivity of TiO_2 is very less. It acts as semiconductor on room temperature. So it can't be utilised for machining on WEDM. Thermal spray coating is done by feeding copper wire into a nozzle chamber which also melts the copper wire and then it is spread onto the substrate that is glass. But in this adhesion comes out as problem. Copper sticks but it also gets removed when simple disturbance is applied on it.
Graphene conductive ink emerged as possible option as it provides adhesiveness and also thermally stable. Conductivity is also very good than others. But uniformity is issue that came across while dipping it or even while applying it by paint brush. Hence for uniformity ,conductivity and thermal stability Physical vapour deposition(PVD) emerges as best method compared to all others. It provides uniform thickness of 5 microns. Also titanium nitride (TiN) is thermally stable so that it can withstand high temperature zone during wire electric discharge machining.

IV. CONCLUSIONS

The objective of the present work is to find the optimized coating method of conductive layer on non conductive substrate.

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