euspen's 16th International Conference & Exhibition, Nottingham, UK, May 2016
www.euspen.eu

Proposal of partially conductive diamond abrasives for an electroplated diamond wire

Yu Zhang [1], Yasuhiro Tani[1], Okiharu Kirino[2]

[1]*Ritsumeikan University,* [2]*Crystal Optics Inc.*

Email: zhangyu@fc.ritsumei.ac.jp

Abstract
Electroplated diamond wires are used for slicing hard and brittle materials because of its low wear resistance and high slicing rate. The electroplating process delivers a homogeneous layer with diamonds embedded in nickel alloy at high speed. The adhesion of abrasives depends on the electrically-conductive nickel membrane. The shape cutting edges of diamond abrasives are hidden in the nickel membrane, which causes some problems such as high grinding force. What's more, the nickel membrane dissolves in the electroplating solution at a low pH. A passive state film attaches on the surface of base nickel membrane in the case of high pH. The dissolution of nickel membrane or the passive state film shortens the service lifetime of abrasive in electroplating process and leads to high production cost of diamond tools.
In this paper, for improving the grinding characteristic of diamond tool, authors analysed the deposition mechanism of metal-coated abrasive in detail and developed partially conductive diamond abrasives. The conductive property of a new abrasive varies with the direction of abrasive. The high-conductive side of abrasive is easy to adhere to the base material of tool. Another side of abrasive has low electrical conductivity, so the other abrasives are difficult to adhere on the deposited abrasives and the abrasive aggregation can be prevented, too. It is confirmed that the grinding force of the tool used the partially conductive abrasives is smaller than fully conductive abrasive and the lifetime of tool is long than that of tools fabricated with non-conductive or fully conductive diamond abrasives. The partially conductive abrasive coated with TiN is developed to improve the lifetime of Ni-coated abrasive in the electroplating solution, because the TiN membrane does not deteriorate.

Keywords: Diamond wire tool, Abrasive, Conductivity, Electroplating

1. Introduction

Diamond grinding tools are the most popular for machining hard and brittle materials, such as silicon, glasses, ceramics, etc. A diamond grinding tool with fine grains and superior wear resistance is adopted for finishing process of free-formed dies or molds. The diamond grinding tool could be produced by electroplating process at low cost, thus it has been in the mainstream of fabricating tools [1]. To improve the shape accuracy and the grinding performance of the tool, a single layer of diamond abrasives is electroplated on the tool body. The electroplating process delivers a homogeneous layer with diamond abrasive embedded in nickel alloy at high speed. In order to facilitate the adhesion of diamond abrasives, the diamond abrasives are coated with nickel membrane in the process for manufacturing diamond wire tools, generically. Therefore, the sharp cutting edges of the abrasive are buried in the nickel membrane, the cutting performance of a diamond wire decreases, definitely. Moreover, a phenomenon of abrasive aggregation generates usually and leads to a bad distribution of abrasives, because of the conductive nickel membrane.

In this paper, authors developed a partially conductive diamond abrasive which is produced from the fully Ni-coated diamond abrasive. The cutting characteristics of partially conductive abrasive are discussed. A partially conductive diamond abrasive coated with TiN (Titanium nitride) membrane is produced by ion plating method, too.

2. Growth of electrodeposited layer around diamond abrasives

The growth of electro-deposited layer around abrasives and the gripping force of the abrasives coated with metal membrane or the non-coated abrasives have been discussed [2]. As shown in Fig.1(a), the sharp cutting edges of fully conductive diamond abrasives are covered and hidden under the metal membrane. Therefore, the fully conductive abrasives are gripped strongly on the tool body. In the composite electroplating process, some fully conductive abrasives continually deposit on the abrasives deposited previously. That leads to the abrasive aggregation on the tool body. Fig.1(b) shows the image of using non-conductive abrasives. Because there is not any metal membrane on the non-coated abrasives, the cutting edges or the abrasive distribution is better than that of the fully conductive abrasives, but the gripping force is weaker. In case of the abrasive have both merits of the non-conductive abrasive and the fully conductive one, the diamond tool that has sharp cutting edges and high gripping force can be produced as shown in Fig.1(c). Authors attempted to produce a partially conductive diamond abrasive for manufacturing diamond tool. The low gripping force of the non- conductive abrasive and the problem of abrasive aggregation can be improved with using the partially conductive diamond abrasives.

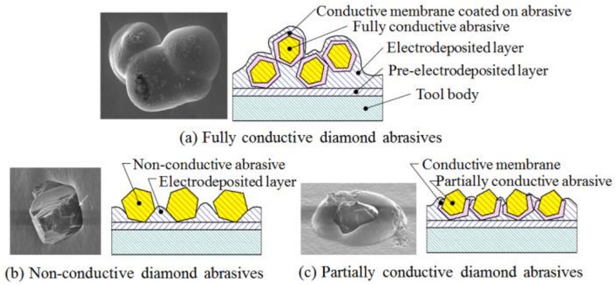

Figure 1. Effect of conductive membrane coated on abrasives on growth of electrodeposited layer

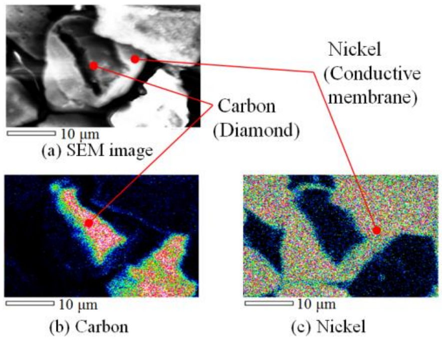

Figure 2. Image of partially conductive diamond abrasives

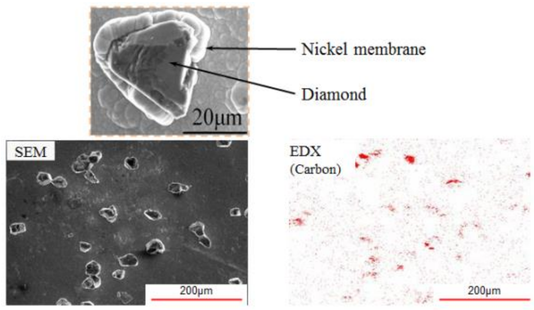

Figure 3. Orientation of partially conductive diamond abrasives and EDS analysis of carbon on tool

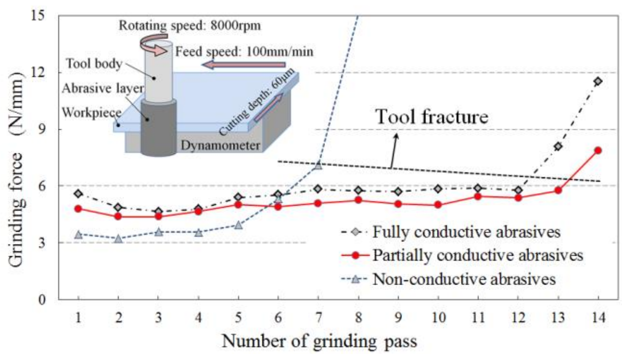

Figure 4. Variations of grinding force using tools deposited various diamond abrasives according to the number of grinding pass

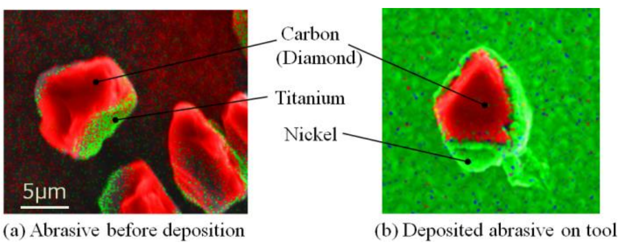

Figure 5. Partially conductive diamond abrasives coated with TiN membrane

3. Production of partially conductive diamond abrasive and grindability of tool used partially conductive abrasive

The partially conductive abrasives are formed by stripping off a portion of nickel membrane on the fully Ni-coated abrasives. At first, paint wax thinly on the surface of a stainless steel plate and next bury the half grain-size of the fully Ni-coated diamond abrasives into the wax. Secondly, soak the stainless plate with buried abrasives into a nickel stripping solution. The partial nickel membrane which is not buried into the wax is stripped off from the surface of abrasives. Finally, put the stainless plate into the toluene solution bath in order to dissolve the wax. The produced partially conductive diamond abrasives are collected after filtering from the toluene bath. Fig.2 shows the state of the surface elemental analysis of the partially conductive abrasives by EDS. It can be confirmed that a partial of diamond (carbon) exposed from the nickel membrane and sharp cutting edges are exposed.

The efficiency of partially conductive diamond abrasives was evaluated with diamond tools. The electroplating process of fabricating diamond tools is carried out with 3 steps, pre-plating, complex plating and post-plating. A nickel sulfamate bath is used and pH level is controlled to about 4.0. Fig.3 shows the orientation of partially conductive abrasives and EDS analysis of carbon on tool. The aggregated abrasives are few, and the abrasive distribution is uniform. It is confirmed that the portion of diamond (carbon) is not embedded in the electrodeposited layer and deposits on the tool surface outwardly.

To investigate the grinding ability of tool electroplated with the partially conductive abrasives, the grinding experiments are carried out on a soda-lime-glass of 30mm×50mm× 8mm. Fig.4 shows the schematic diagram of grinding and the grinding force using various tools according to the number of grinding pass. The grinding force is measured by a dynamometer. The normal grinding force is used to evaluate the grinding ability of each tool. The grinding force increases rapidly after tool fracture. When the grinding force exceeded the value of 6 N/mm, the tool life is judged to have been arrived. The tool life of using the partially conductive abrasives is better than that of using the fully conductive abrasives. The tool life of using the non-coated abrasives was the shortest, because the grip force of abrasives is the lowest.

It is known that the TiN membrane has low electrical resistance and high corrosion resistance. A partially conductive diamond abrasive coated with TiN membrane is made by ion plating method, as shown in Fig.5. The partially conductive abrasives coated with TiN have the same orientation as the abrasives coated with partially nickel membrane.

4. Conclusions

In this study, with the aim of improving the grinding ability of diamond tool, a partially conductive diamond abrasive is developed. The abrasive aggregation on tool used the partially conductive abrasives almost occurs. The portion without metal membrane of abrasive adheres on the tool surface outwardly. The grinding force of the tool used the partially conductive abrasives is small. The partially conductive diamond abrasive is suitable to manufacturing diamond tool.

References

[1] Semba T and Sato H 2000 CIRP Annals - Manu. Technol. (C), **49** 1, 157-160

[2] Sato K, Yokoyama T and Suzuki K 1995 Japan. J. Surf. Fin. Soc. **46** 4 371-374 (in Japanese)