Using Boron Doped Diamond Foils for Fabrication of Micro Cavities with EDM

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Abstract

High precision cavities come into action for micro injection and micro embossing tools in the field of tool making and are mainly used for small batch or mass production of micro parts.

To fabricate a large quantity of parts, wear resistant tool materials are required. Having a high hardness and a high Young´s Modulus, the materials used are often heavy or even impossible to machine by conventional fabrication processes. Being independent of the work piece's mechanical properties Micro Electrical Discharge Machining (µEDM) is predestined in this case.

Besides the adjustment of the electrical parameters, the µEDM-process is also determined by the tool electrode`s material having a big influence on the machining time, the result, and the electrode´s wear behaviour [1]. To assure an efficient process, short production time and a low tool wear are demanded. Therefore, electrodes with an excellent electrical and thermal conductivity as well as a high mechanical strength have to be used.

1 Introduction

The investigations described in this article show experimental results concerning the usage of two diamond foils with different boron dopings. Besides the examination of their removal rate and the wear behaviour, the paper gives information about a fabrication method concerning the manufacture of the foils.

2 Manufacturing of Diamond Foils by Hot-Filament Chemical Vapour Deposition (HF-CVD)

For the manufacturing of diamond foils by HF-CVD a 3-step process is used, which is described in detail by Lodes et al. [2]. Prior to diamond deposition the 6” silicon wafers, which are used as substrate material, were seeded with a suspension of 4 nm diamond powder and ethanol (1st step), which ensures a homogenous and fast diamond growth directly from the beginning of the deposition process. The diamond deposition (2nd step) was performed in a Cemecon CC800/Dia-9 HF-CVD plant in hydrogen atmosphere containing 3.6 % methane in the gas flow at gas pressures of 6-8 mbar. To obtain electrically conductive boron doped diamond foils, 0.5-1.5 % trimethylborate was added as boron precursor gas in the gas flow. For HF-CVD-diamond deposition tungsten filaments, which are electrically heated to 2.200 °C, are used to enable the chemical reactions for diamond deposition and to heat the substrate to 850 °C. The grain size of the diamond foils can either be adjusted by variation of the gas pressure or by variation of the methane and boron contents in the gas phase. The freestanding (i.e. substrate free) diamond foils were obtained by laser cutting and an ultrasonic delamination treatment (3rd step) of the coated wafers. The boron content of the boron doped diamond foils was measured by Glow Discharge Optical Emission Spectroscopy (GDOES).

3 Process behaviour

For first experiments, boron doped diamond foils with a thickness of t = 30 µm were used. Herewith micro cavities of a depth of d_c = 150 µm and a width of w_c = 50 µm were fabricated in 5 mm probes made of 90 MnCrV 8 by µEDM. A no-load voltage of u_0 = 100 V at a discharge current of i_e = 2.4 A was applied. Figure 1 shows the machined cavity and a boron doped diamond foil after its use in the dielectric oil IME 63. In general, the boron doped diamond foils showed a levelling of the B-CVD diamond crystal on the contact area of the electrode.

Due to a high electrical field and a high thermal exposure during µEDM the B-CVD diamond foils also showed an edge rounding. The machined cavities had straight even side walls and an arithmetical mean deviation of the roughness profile of around Ra = 0.3 µm at the cavity bottom. As a consequence it can be stated that B-CVD-diamond foils were generally applicable as tool electrode material for µEDM.

Process:
Micro die sinking (µEDM) with stationary tool electrode

Work piece electrode:
90MnCrV8 probe with b_w = 5 mm

Tool electrode:
BCVD-Diamond foil with b_w = 30 µm

Working fluid:
Dielectric oil IME 63

Generator:
Static Pulse Generator
i_e = 2.4 A
u_0 = 100.0 V
t_0 = 10.0 µs

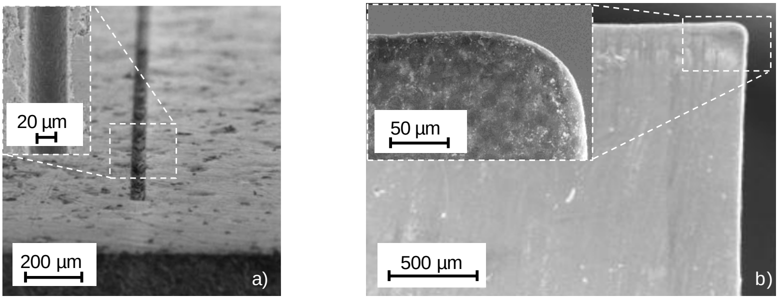

Figure 1: a) Top view of a micro cavity and b) side view of a boron doped diamond foil after machining

4 Removal rate and relative frontal wear

Further investigations focused on the analysis of the removal rate and the relative frontal wear of B-CVD diamond foils having two different boron dopings, such as 0.23 at% and 0.3 at% (Figure 2). For experiments, probes made from 90MnCrV8 came into action. A static pulse generator was applied providing discharge currents of i_e = 2.4 A and i_e = 3.2 A. Due to an increasing electrical conductivity, diamond foils with a bigger boron content showed a higher removal rate then diamond foils with lower boron content. Also, the resulting higher current flow caused an increase of the relative wear. Therefore, an increase of the discharge current resulted in a growing removal rate and a growing relative frontal wear for both foil electrode types.

5 Conclusion

First experimental investigations on the process and wear behaviour of B-CVD diamond foils being used as tool electrodes for the µEDM process were presented. The foil electrodes showed a general applicability when using static discharge pulses. Within this paper, machining results when using different discharge currents and diamond foils of different boron dopings were described.

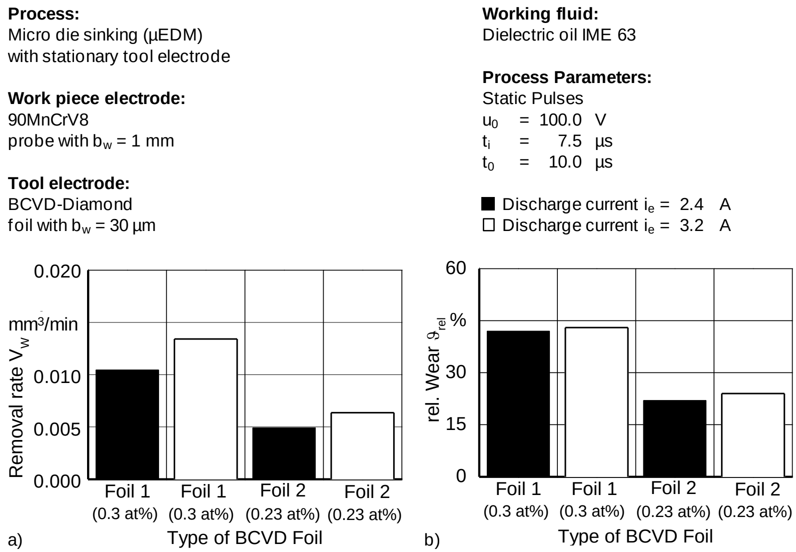

Figure 2: a) Removal rate V_W and b) relative Wear ϑ_{rel} of diamond foils with different boron dopings

Further investigations will focus on the optimisation of the B-CVD diamond foils. For this purpose, further experiments describing the influence of the boron concentration within the diamond foils on the process behaviour need to be carried out.

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