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An Experimental Investigation on the Effect of Nanopowder for Micro-Wire Electro Discharge Machining of Gold Coated Silicon

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Abstract

Micro Wire Electro Discharge Machining (μ-WEDM) is a type of electro-discharge machining (EDM) process where the wire is used instead of a rigid tool. It is a reliable and precise machining process, which is commonly used to produce various complex structural shapes for a wide range of industrial applications. However, to machine a semiconductor material of high resistivity like silicon (Si) requires more advanced processing to produce larger electrical sparks during the μ-WEDM operation. Current (μ-WEDM) technology is not enough to realize a stable machining environment for Si. In this research, a new type of μ-WEDM process for Si machining was investigated. At first, Si was temporarily coated with gold and then nanopowder mixed dielectric medium was used for the WEDMing process. The main purpose of this work is to investigate the effects of different nanopowder concentrations on two important response factors such as material removal rate (MRR) and spark gap (SG). In this regard, the μ-WEDMing of gold coated silicon was carried out in pure dielectric EDM oil and also in three different concentrations (0.1g/L,1g/L,2g/L) of nanopowder mixed dielectric oil to conduct an initial study with the aim to achieve better machining accuracy and stability. Based on the experimental investigations, the MRR were found to be increased on average minimum ~ 1% to maximum ~ 33% respectively for different carbon concentrations, as compared to machining in the pure dielectric medium. The spark gap was also observed to be increased by a significant margin on average of ~ 2% to up to ~ 159% than without using any nanopowder concentration, correspondingly.

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1. Introduction

In recent years, micro electrical discharge machining (μ-EDM) and microwire electrical discharge machining (μ-WEDM) have been considered as promising manufacturing processes to meet various industrial and diverse engineering requirements. The material eroding process of EDM and WEDM are identical. However, their processing setups are different. In μ-WEDM electrical discharges are generated between a flexible metallic wire and workpiece without any physical contact to erode material from the work-piece[1]. As the wire approaches the workpiece material, the electrical discharge produced nearby the wire erodes material from the targeted work-piece[2]. WEDM/ μ-WEDM process is widely used to machine electrically conductive materials. However, machining of semiconductor materials like Si by μ-WEDM also has a high demand due to its ability to produce complex shaped micro parts. Polished silicon mirrors have large demands in sensors and optical industries as well. To fabricate complex shape 3D silicon mirrors, WEDM could be an effective way. Takino et al. first introduced this technology[3, 4]. However, machining of silicon by μ-WEDM is very challenging because of its high surface resistance than bulk body resistance. Many researchers tried out several means to machine Silicon work-piece by WEDM process[4-10]. Recently, Saleh et al.[11] experimented the influences of temporary Gold (Au) coating on a silicon wafer for micro-EDM and micro-WEDM treatment. It was found that at a very low discharge energy (~<451.25 nJ), the micro-WEDM of silicon was impossible without gold coating. Further, the machining stability was significantly improved by this temporary gold coating process. The nanopowder mixed EDM is another approach to achieve the EDM stability and accuracy. Jahan et al. tested micro-EDM of SKH-51 tool steel in the presence of graphite mixed dielectric medium. Recently, Jahan et al.[12, 13] also showed that by using different concentrations of graphite nanopowder into dielectric oil it is possible to achieve surface roughness in nano metric value by μ-EDM process. However no attempt has been made so far to machine gold-coated Si wafer by μ-WEDM process. In this article, we investigated how nanopowder mixed dielectric fluid will influence machining characteristics of gold-coated Si wafer.

Nomenclature

μ-WEDM	Micro-wire electro discharge machining
EDM	electro discharge machining
MRR	Material removal rate
SG	Spark gap
R_a	Surface roughness

2. Experimental approaches and Methodology

2.1 Materials and Machine tool

In this study, an n-type pre-polished (mirror quality) silicon wafer of 500 μm thickness (resistivity, 1-100 Ωcm) was used as a workpiece material. Before the μ-WEDM process, the silicon wafer was coated both sides by conductive gold (Au) material using ion sputtering machine. The coating process was performed for 10 minutes on both sides of the silicon wafer, which produced approximately 320 nm thickness of gold.

For the μ-WEDMing process, the gold coated silicon was used as a cathode and zinc coated brass wire was used as an anode. The diameter of the anode wire was 70 μm. The commercially available dielectric fluid "Total FINA ELF EDM 3" oil was used as a dielectric medium. Carbon powder of average size of 50 nm (By US Research Nanomaterials, Inc.) was used in this research to carry out the μ-WEDM operation. Three different concentrations of carbon nanopowder mixed dielectric oil was used. Finally, for actual μ-WEDM operation, a multipurpose computer numerical machine was used which is available in International Islamic University, Malaysia. This machine