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Multi-wire EDM slicing of semiconductors with group power supplying method

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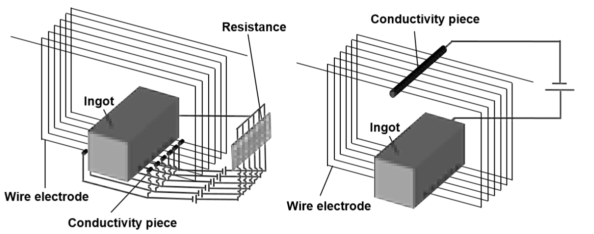
Abstract
Multi-wire EDM slicing method have been developed to overcome problems of multi-wire saw method, and high-efficient and high-accurate slicing could be expected compared with a single-wire EDM technologies. However, a multi-wire EDM slicing equipment becomes very complex in the case of an individual power supplying method with multiple power units and conductivity piece sets. This traditional method leads to difficulties in the preparation and a heavy load on the maintenance for a multi-wire EDM slicing equipment. Therefore, a group power supplying method was newly proposed to satisfy both processing efficiency and simplification of slicing equipment, since it can supply sufficient energy to multiple processing wire electrodes only using one conductivity piece set with one EDM power unit. When monocrystalline silicon ingot was sliced by using steel wire electrode of 120 µm with the group power supplying method, discharge current per wire ideally changed with number of processing wire electrodes. However, kerf width was approximately constant at almost constant cutting speed regardless of number of processing wire electrodes. In addition, diameter of crater caused by electrical discharge pulse was dependent on the peak discharge current per wire rather than the total peak discharge current. These results indicate that input energies were almost constant at each processing wire electrode, and electrical discharge pulses could be homogeneously distributed to each processing wire electrode without the breakage even by using only one conductivity piece set in the group power supplying method.

wire EDM, multi-wire, semiconductor, slicing, group power supplying method, silicon

1. Introduction

Monocrystalline and polycrystalline silicon have been used as materials for semiconductors and solar cells. Production amount of these materials have been increasing, and it is required to slice these materials efficiently. A multi-wire saw method is applied to slicing of these ingots. However, this method has some problems such as large cracks and a large kerf loss. On the other hand, a multi-wire EDM (Electrical Discharge Machining) slicing method has a possibly to decrease cracks and kerf loss, owing to its small machining force. This multi-wire EDM slicing method was developed to overcome problems of multi-wire saw method, and high-efficient and high-accurate slicing could be expected compared with a single-wire EDM technologies [1]. In former study, it was clarified that multi-wire EDM slicing of monocrystalline and polycrystalline silicon ingots could be performed efficiently by using the multi-wire EDM slicing equipment [2, 3], and it was reported that a multi-wire EDM slicing method was applied for the manufacturing process of silicon carbide [4-6]. In addition, the reduction of kerf loss was discussed by usage of the wire electrode with a track-shaped section in thin wire [7].

However, an equipment of multi-wire EDM slicing method becomes very complex in the case of individual power supplying method shown in Fig. 1 (a). Because, it is necessary to increase the number of conductivity piece and EDM power unit with increasing the number of processing wire electrodes o keep the processing efficiency. This method leads to difficulties in the preparation and a heavy load on the maintenance for a multi-wire EDM slicing equipment. Therefore, a group power supplying method shown in Fig. 1 (b) was proposed in order to satisfy both processing efficiency and simplification of slicing equipment, since it can supply sufficient energy to multiple processing wire electrodes only using one conductivity piece with one EDM power unit. In this method, a resistance of processing wire electrodes between a conductivity piece and a processing point could play as a limiting resistance of EDM power supplying unit. Therefore, it is desired that this resistance becomes the dominant factor to control the discharge current, and the controllability of multi-wire EDM slicing with the group power supplying method was investigated.



(a) Individual type (b) Group type

Figure 1. Power supplying methods of multi-wire EDM slicing equipment

2. Experimental method

Figure 2 schematically shows the wire driving part of the multi-wire EDM slicing equipment. A brass coated steel wire electrode of 120 µm in diameter was used as a wire electrode, which was wound spirally on wire guides approximately 30 times along the wire guide pitch. The wire electrode was fed reciprocally by reversing the feed direction, when the wire electrode came to the end of set travel length. Slicing experiments were carried out by moving the workpiece toward the running wires between the wire sub guides, which were prepared at the nearest side to the workpiece in order to stabilize the wire position. Low-resistance monocrystalline Si (LR-Si) with specific resistance of 0.01 Ω・cm was used as a workpiece, and the cutting width was 80 mm. Conductivity pieces were set at outer positions of lower wire guides to keep a sufficient length of wire electrode. A multi-EDM power supply unit can generate lower and longer discharge pulse compared with the normal commercial wire EDM equipment. Also, this electric discharge power supply has a high voltage circuit to start the electrical discharge and a low voltage circuits to generate the electrical discharge. These no-load voltages are expressed as u_{iH} and u_{iL}, respectively. Deionized water was used as a working fluid, and its specific resistance was set to 2.5×10^4 Ω・cm.

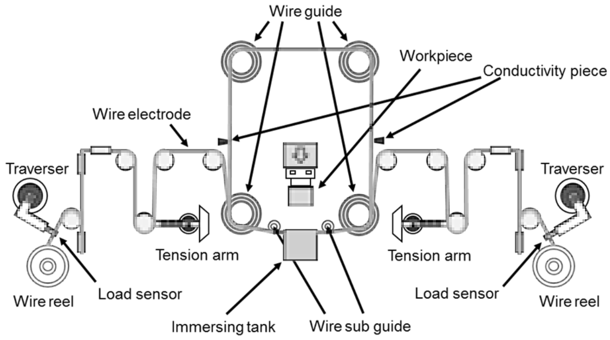


Figure 2. Schematic diagram of wire driving part in multi-wire EDM slicing

3. Results and discussion

Figure 3 shows variations of discharge current per wire and diameter of discharge crater for various numbers of processing wire electrodes. The total discharge current is the product of number of processing wire electrode and discharge current per wire. Diameter of crater generated by single discharge was determined by an average of 10 craters. The discharge current per wire was almost constant regardless of number of processing wire electrode, which indicated that the total discharge current proportionally increases with increasing the number of processing wire electrodes. There is a correlation between the discharge current per wire and the diameter of crater. Therefore, the diameter was dependent on the discharge current per wire rather than the total discharge current. This result clarified that input energies were almost constant at each processing wire electrode, and electrical discharge pulses could be homogeneously distributed to each processing wire electrode from one conductivity piece set in the group power supplying method.

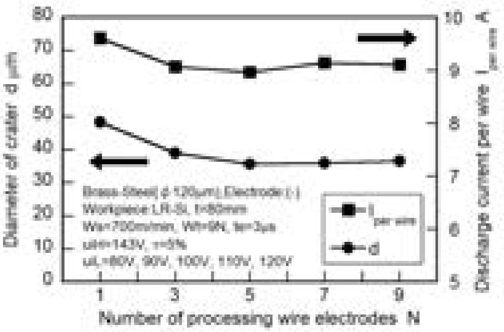


Figure 3. Peak discharge current per wire and diameter of crater for various numbers of processing wire electrodes

Figure 4 shows relationships between displacement of workpiece and machining time for various numbers of processing wire electrodes. Almost constant removal rate was obtained owing to realizing the ideal control of discharge current and limitation of maximum feeding speed. However, the removal rate with single wire electrode was slightly larger than other number of processing wire electrodes. This result indicates that machining control in single wire processing is superior to that in multi-wire processing.

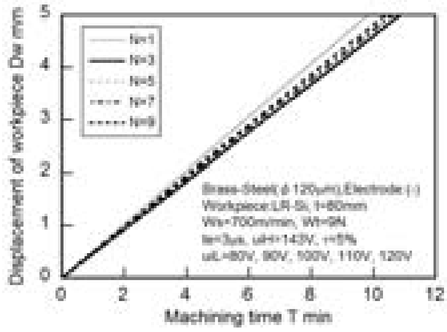


Figure 4. Relationships between displacement of workpiece and machining time for various numbers of processing wire electrodes

Figure 5 shows average kerf width for various numbers of processing wire electrodes. Average kerf width was approximately 150 μm regardless of the number of processing wire electrodes. In addition, a standard deviation of kerf width was small, even if the number of processing wire electrodes increased. Therefore, stable processing could be performed regardless of the number of processing wire electrodes by using newly proposed group power supplying method.

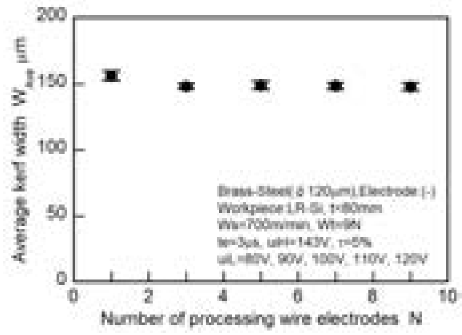


Figure 5. Average kerf width for various numbers of processing wire electrodes

4. Summary

A newly developed group power supplying method can distribute electrical discharge energy uniformly at each processing wire electrode only by using one conductivity piece set and one power unit, and simplification of multi-wire EDM equipment can be expected.

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