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Development of Multi Wire Stripper with Line-shaped Magnetron Plasmas
同軸マグネトロンプラズマを用いたマルチワイヤストリッパー装置の開発

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To remove brass plating on saw wire used for cutting down a silicon wafer, the new type of multiple line-shaped magnetron plasma developed. This new-type plasma was characterized. The plasma has a typical characteristic to magnetron plasma; the character of discharge current density was proposed to B^2, $V^{3/2}$ and P^2.

1. Introduction

Silicon wafer used as a substrate of crystal silicon solar cells is carved out from the silicon ingot by fine wire. Figure 1 showed cross section of fine wire. The fine wire is covered with brass (Cu: 65%, Zn: 35%) plating to need in wire drawing process. The copper diffused in the silicon wafer during cutting process is caused to be contamination. So the electric conductivity changes, and there is a possibility of cause to decrease solar cell efficiency. Therefore Cu-free fine wire is strongly required.

Now, the wet electrochemical process by ammonia and hydrochloric acid has been used for removing the brass plating. The wet electrochemical process requires large currents. The processes also have high environmental loads, and high cost for waste liquid treatment. On the other hand, the dry processes have been low environmental loads and low cost.

The aim of this study is to remove brass plating on fine wires by the newly developed multiple line-shaped magnetron plasmas with the multiple electrode system.

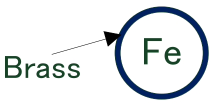

Fig.1 Cross Section of Fine Saw Wire

2. Experimental

At first, figure 2 shows the single unit for removing brass plating on wire. Many wires could be removed it with multiple unit systems. Figure 2 shows the multiple unit system for magnetron plasmas. Wire setting time could be made short by the simplification of electrode system.

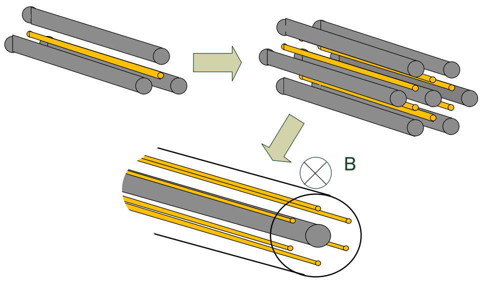

Fig.2 Multiple Electrode System

The electrode system of multiple plasma sources is shown in Fig.3. Plasma could be generated by applying negative DC voltage to the 6 wires against the grounded inner electrode and the outer electrode with axially applied magnetic field.

Six wires with 0.25mm in diameter were set, evenly-spaced apart from each other. The gap length from both electrodes was set to 11 mm. The surface of wire after plasma treatment was determined the mass percentage of residual copper by using EDS (Energy Dispersive X-ray Spectroscopy).

Table.1 Experimental Condition

SUS Tube Diameter [mm]	15
Wire Diameter [mm]	0.25
Gap Length [mm]	11
Gas	Argon
Gas Pressure [Pa]	0.3
Gas Flow Rate [sccm]	25
Discharge Voltage [V]	-600 ~ -800

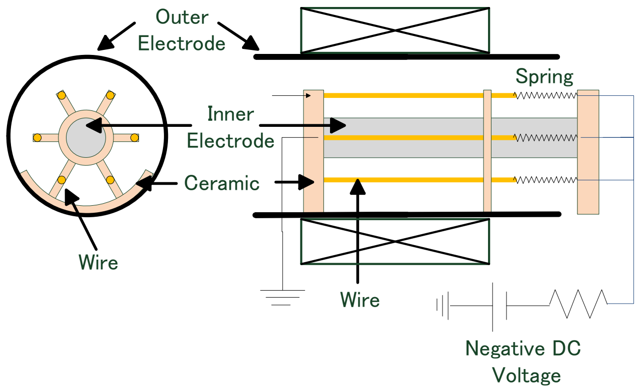

Fig.3 Electrode Systems

3. Experimental Results

Figures 4-6 show the dependences of magnetic flux density, discharge voltage and gas pressure on discharge current, respectively. The experimental conditions shown in Table 1. In magnetized discharge plasmas, the discharge current density can be applied to the following empirical formulas. [1]

$$J_a = A(aP^2 + bB^2)(V_d - V_0)^{3/2} \qquad [1]$$

Here, P, B, and V_d-V_0, indicate gas pressure, magnetic flux density, and discharge voltage, respectively. This formula showed the discharge current density increases, with $B^2, V^{3/2}, P^2$. The newly-developed multiple line-shaped plasma has the same characteristics. Then, the plasma can be a characteristic to magnetron plasmas.

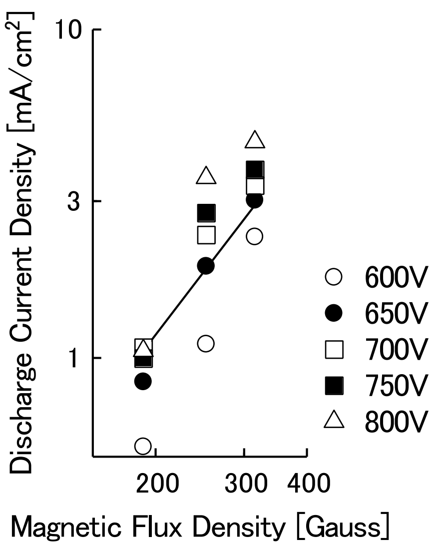

Fig. 4 Dependence of Magnetic Flux Density on Discharge Current Density

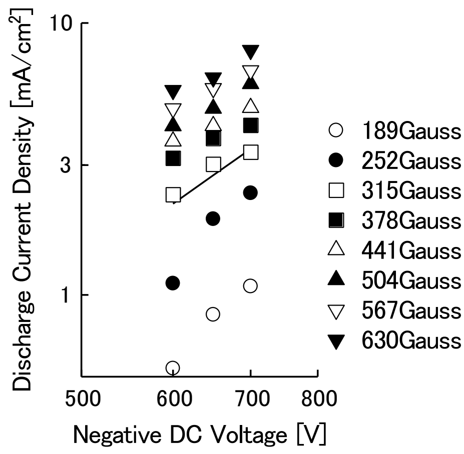

Fig. 5 Dependence of Discharge Voltage on Discharge Current Density

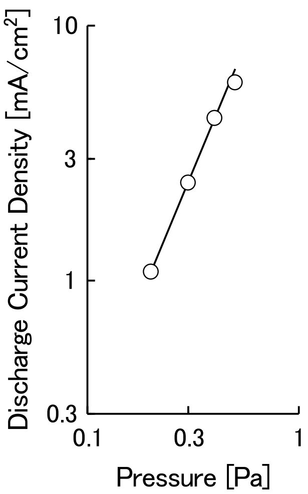

Fig. 6 Dependence of Gas Pressure on Discharge Current Density

4. Conclusion

Line-shaped multiple magnetron plasmas could be generated by new type of electrode system. The discharge current is proportional to magnetic flux density B^2, discharge voltage $V^{3/2}$ and gas pressure P^2, respectively. Stripping results of brass plating wire by the present plasma stripper will be reported.

Acknowledgments

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Reference

[1] K. Kuwahara and H. Fujiyama: IEEE Trans. on Plasma Science, Vol.22, No.4, pp.442-448 (1994).