Rapid Stripping of Brass-plating on Fine Saw Wire by Triangle-type Multiple Magnetron Plasmas

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ABSTRACT

To remove brass plating on fine saw wire, line-shaped magnetron plasma source has been newly developed. New type of multiple plasma sources has been developed by applying to multiple -triangle-type electrodes. The stripping effects were successfully established by using high density magnetron source with 20mm gap in an axially applied magnetic field. From the EDS analysis results of wire surface after plasma stripping during 30sec, it is clearly shown that Zn was removed after 10sec stripping and Cu after 30sec. (Fe:38.5%→97.7% , Cu:39.3%→2.43% , Zn:22.2%→ 0.03%)

Keywords: Metal sputter etching, Saw wire, Plasma stripping, Magnetron plasma

1. INTRODUCTION

Silicon wafer used crystal silicon solar cell is carved out from the silicon ingot by saw wire. Saw wire is covered with brass (Cu: 65%, Zn:35%) plated to need in wire drawing process. As a result basis of plating (especially copper) are diffused in the wafer as contamination. So the electric conductivity changes, and there is a possibility of cause to decrease solar cell efficiency. Therefore the saw wire with Cu free is strongly required.

Now, in the factory, various wet processes by ammonia, hydrochloric acid, sulfuric acid and oxygenated water have been used as a method for removing brass plating. The processes have some disadvantages that the environmental load is large and generally very expensive. In the present research, we propose to use plasma dry process for wire stripping. Dry process has some advantages that the waste liquid treatment is unnecessary, pollution policy of flue-gas treatment etc. is easy and high reaction rate is obtained at low temperature. We aim to remove brass plating on fine wire by the newly developed line-shaped magnetron plasma source. And also new type of multiple plasma sources has been developed by applying to multiple -triangle-type electrodes.

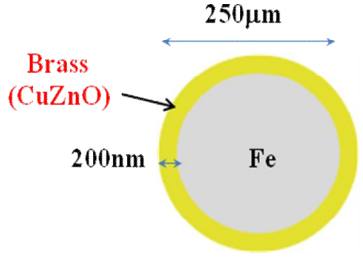

Fig.1 Brass Plating Saw Wire

2. EXPERIMENTAL

At first, it has been investigated on the electrode configuration to profit line-shaped plasma sputtering process to long and fine wire continuously. At the result, triangle-type electrode system shown in Fig.2 has been developed because of easy multination of the stripping process.

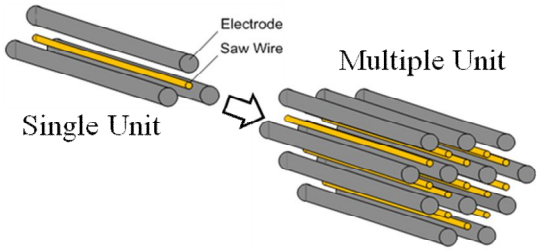

Fig.2 Easy multination of sputter etching process by the triangle-type electrode system

3. RESULTS AND DISCUSSION

3.1 Discharge Characteristics

In a magnetron discharge plasma[1], ion current density to a cathode is proportional to the magnetic flux density B^2, the gas pressure P^2 and the discharge voltage $V_d^{3/2}$:

$$J_d = A(aP^2 + bB^2)(V_d - V_0)^{3/2} \quad (1).$$

Table 1 shows the typical experimental conditions to investigate on the discharge characteristics in the single unit triangle type magnetron plasma.

Table 1 Experimental conditions

Gas	Argon
Gas Pressure [Pa]	1
Gas Flow Rate [sccm]	0.1
Gap Length [mm]	20
Wire Diameter [μm]	250

It is shown in Fig.3 that the dependence of the externally applied magnetic flux density on the discharge current into the fine wire as a cathode. The current was rapidly increased by the magnetron effect from a certain magnetic field.

The fine wire was strongly heated when the current density was more than a few mA/cm².

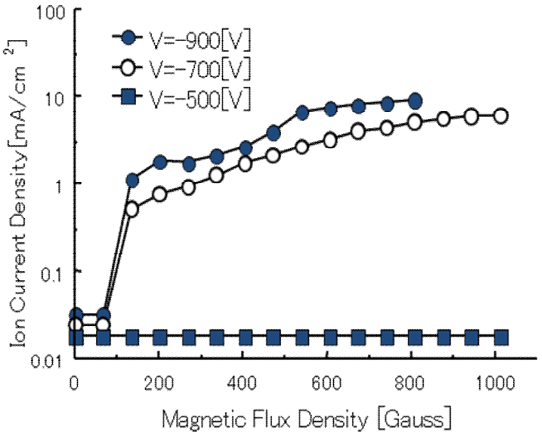

Fig.3 Discharge characteristics in single-unit coaxial magnetron plasma

3.2 Stripping Effect

The experimental results of stripping effects were successfully established by using high density magnetron plasma source with 20mm gap in an axially applied magnetic field.

Figure 4 shows the EDS analysis results of wire surface after plasma stripping during 30sec. Here, the discharge voltage was -730V, the constant discharge current density 1.5mA/cm^2 and the discharge gap length 20mm, respectively. In this figure, it is clearly shown that Zn was removed after 10sec stripping and Cu after 30sec. (Fe:38.5%→97.7% , Cu:39.3%→2.43% , Zn: 22.2%→ 0.03%)

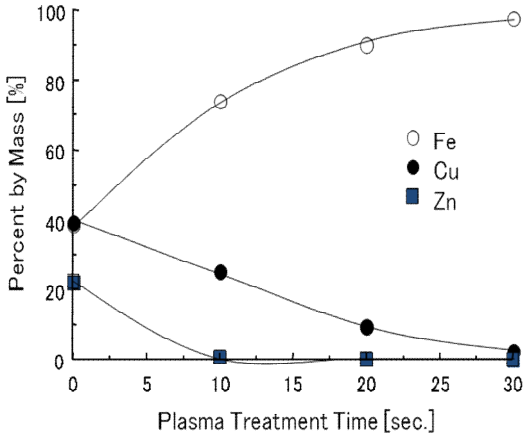

Fig.4 EDS analysis result of stripped wire

Let us estimate the required running speed for perfect removal of the brass plating. When the discharge current density was 1.5[mA/cm^2], perfect removal could be established after 25sec stripping. Therefore the stripping rate was estimated as 8nm/sec=480nm/min. This means that the required running speed of wire is 4.8 [m/min] for full removal in 2m reactor.

From these results suggest that the rapid stripping of fine wire is possible by using the developed triangle type magnetron plasmas. For the higher target voltage and current density to the wire, more rapid stripping can be realized.

3.3 Wire Temperature

Wire heating during plasma stripping is a serious problem for keeping the wire quality. In

this stripping process, before wire heating up to 500℃, perfect removal must be finished. So, high speed but low temperature process is strongly required.

Figure 5 shows the temporal variation of wire temperature measured by the electric resistivity method for the current density 1.5mA/cm^2. When the higher magnetic field, that is, for the constant current density, the higher target voltage leads to the rapid heating of the wire. The heating mechanism seems to be both Joule heating and ion kinetic energy to the wire. So, the optimum condition should be investigated.

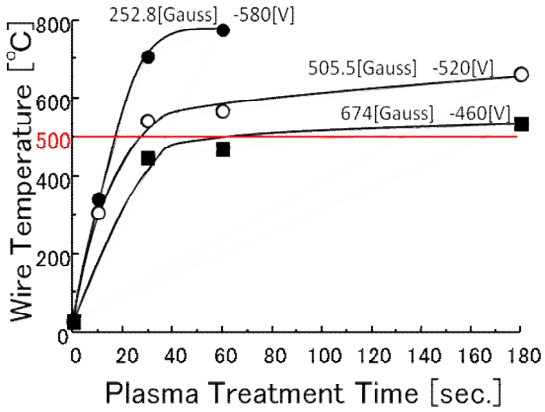

Fig.5 Wire heating during Stripping Process

3.4 Upscaling

～Idea for Multiple Unit Magnetron Plasmas～

For practical use of plasma stripper, we developed new electrode configuration for multiple wire stripping as shown in Fig.6.

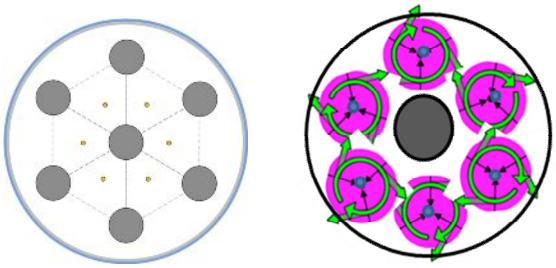

Fig.6 Concept of new electrode system (right) for multiple wire stripping:
Conventional (left), New (right)

The plasma can be generated between 6 wire cathodes and both a center rod and reactor wall as anodes. Easy maintenance and less abnormal discharge could be obtained. Photo 1 shows the cross-sectional view of magnetron plasmas for multiple unit wire stripper.

Photo 1 Cross-sectional view of plasmas for multiple units wire stripper.

Figures 7 ,8 and 9 show the dependence of magnetic flux density, Discharge voltage and gas pressure of the discharge current density in the newly developed multiple plasma stripper for the gas pressure P=0.2Pa and the gap length d=11mm. The discharge current clearly shows the magnetron property to proportional to B^2, $V^{3/2}$ and P, respectively. These results clearly shows that the newly-developed multiple line-shaped plasma has the same characteristics on the mentioned eq.(1).

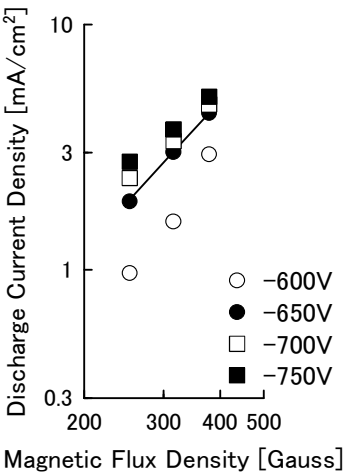

Fig.7 Dependence of magnetic flux density of the discharge current density

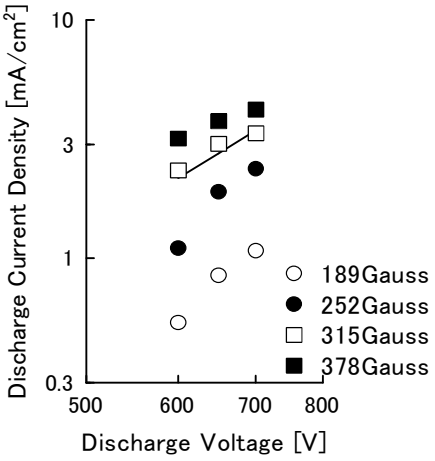

Fig.8 Dependence of discharge voltage of the discharge current density

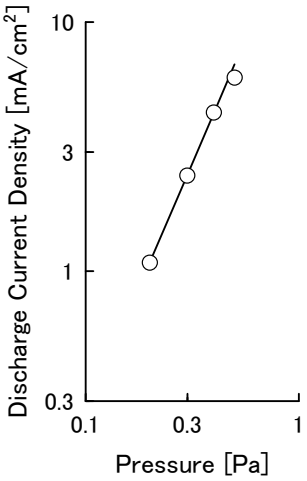

Fig.9 Dependence of gas pressure of the discharge current density

4. CONCLUSION

In order to remove brass plating on saw wire, we propose to use plasma dry process instead of wet process for wire stripping. Dry process has advantages that the waste liquid treatment is unnecessary and pollution policy of flue-gas treatment etc. become easy and high reaction rate should be obtained.

New type of line-shaped magnetron plasma source has been developed by applying magnetic field to triangle-type electrodes. For multiple wires stripping, the multiple unit magnetron plasma with new type of electrode system has been also developed.

The stripping effects were successfully established by using high density magnetron source with 10-30mm gap in an axially applied magnetic field.

Acknowledgments

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References

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