18PB-082

Deposition of Cu Thin Film Using RF-driven Atmospheric Pressure Plasma Jet in N_2 Atmosphere

窒素雰囲気下におけるRF駆動大気圧プラズマジェットを用いた銅薄膜堆積

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For depositing highly-conducting Cu thin films on substrate, an Ar/H_2 atmospheric pressure plasma jet (APPJ) driven by a 13.56 MHz RF power was developed. The oxidation of deposited films was inevitable when carrying out the experiment under atmospheric conditions. In order to protect the Cu thin films from oxidation we have replaced with nitrogen atmosphere. Then we have used quartz as a substrate, which can withstand the high temperature of APPJ. Here we are presenting the Cu thin films deposition under this modified conditions

1. Introduction

For fabrication of future flexible electronic devices, an Ar/H_2 atmospheric pressure plasma jet (APPJ) driven by a 13.56 MHz RF power is developed for depositing highly conducting Cu thin films on substrate. In previous studies, we found that by adding a fractional amount of H_2 gas into Ar APPJ, quality of Cu film was significantly improved. [1] But under atmospheric condition, the oxidization of deposited film is inevitable because of the presence of oxygen. In this study, we are focusing on the low temperature deposition of Cu thin films using APPJ in nitrogen atmosphere. [2, 3]

APPJ driven by RF power has many advantages. It produces non-thermal plasma in the atmospheric pressure so that it can release high ion/radicals at a relatively low excitation power. Since it does not use an electrode during discharging, this will eliminate the issues like electrode erosion and contamination. Finally, it is a simple, small-scale, damage-free, and economical method for the deposition of Cu thin films. [4]

2. Experimental setup

Plasma jet was introduced in the chamber under nitrogen atmosphere as shown in Fig.1. The plasma jet was jetted out from a quartz nozzle. A Cu wire 1 mm in diameter was employed as a source for the deposition and inserted into the quartz nozzle. A solenoid coil having 4 turns made of Cu tube was wound around the quartz tube. The plasma was ignited by applying RF power of 300 W to the coil after plasma-gas introduction. The inserted Cu wire was heated and evaporated by plasma, and then Cu film was deposited on quartz substrate from the nozzle tip of z=1 mm.

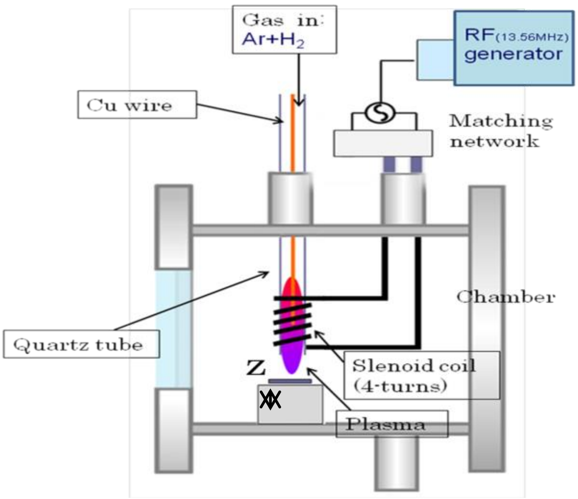
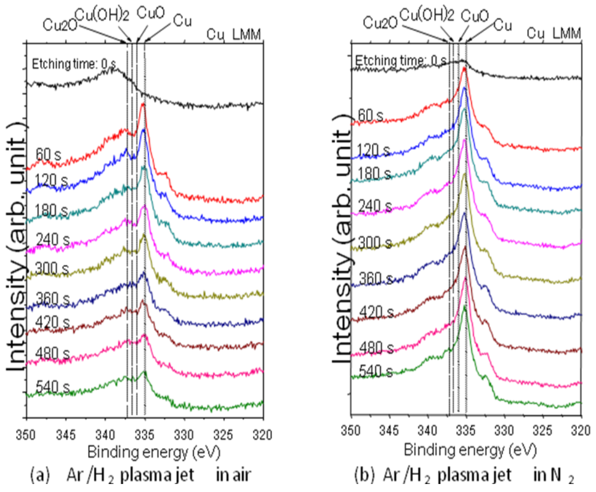


Fig.1 The RF-driven APPJ in chamber.

In this experiment, after vacuuming, the chamber is filled with nitrogen under atmospheric pressure. Then APPJ is made to addition Ar and H_2 gas. The flow rate of Ar is fixed to 1000 sccm and flow rate of H_2 is changed. The size of quartz substrate used is 1 cm^2.

3. Experimental results and discussions

Figure 2 shows the XPS spectra in Cu LMM region when in air and nitrogen atmosphere. From Fig. 2, by performing the experiment in nitrogen atmosphere, not only prevents the oxidation of copper, but also increased the deposition of copper films with high conductivity. By changing the amount of hydrogen added, there was an observable change in the conductivity of the film.



(a) Ar/H$_2$ plasma jet in air
(b) Ar/H$_2$ plasma jet in N$_2$

Figure.2 XPS spectra in Cu LMM region.

Figure 3 shows the relationship between the conductivity of copper thin film and hydrogen flow rate when using a polyimide substrate. The flow rate of hydrogen varied from 0sccm to 5sccm. Then, the conductivity was measured using a four-terminal method. In Fig. 3, indicated by dashed red line, is conductivity measurement of the copper thin film of commercially available, printed circuit board. The conductivity of the board that was created, is indicated by a blue dotted line. From Fig. 3, with the increase in the flow rate of hydrogen, the improvement in conductivity is confirmed, and it is close to the conductivity of the printed circuit board. From this result it is estimated that with increasing the flow rate of H_2, Cu thin films with higher conductivity can be produced. However it is observed that the temperature of the system is increasing when the flow rate of hydrogen is increased. This will in turn damage the substrate, and evaluation process will be difficult. The substrate is completely damaged when the hydrogen flow rate reached 10 sccm.

So we are hereby proposing to use quartz substrate, which can withstand high temperature. Thus, it becomes possible to perform the creation of the copper thin film having more high conductivity by varying the hydrogen flow.

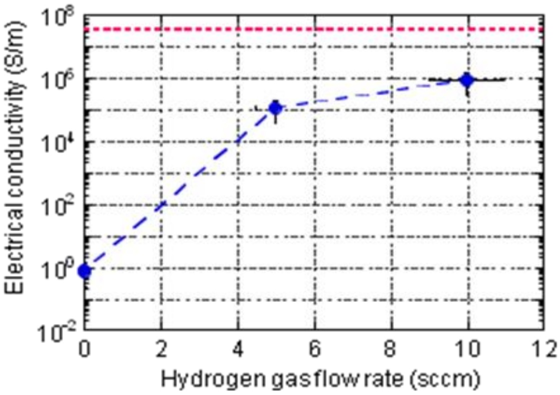


Fig.3 Electrical conductivities of the samples prepared by the Ar/H_2 APPJs as a function of H_2 gas flow rate

4. Conclusion

We have reported the experimental results on the low temperature deposition techniques of copper thin films using atmospheric pressure plasma jet. When carried out the experiment under nitrogen atmosphere, we are able to prevent the oxidation of the substrate and also able to increase the conductivity of the deposited Cu thin films. The obtained result is two order lower conductivity than the practical copper film, it has resulted in high conductivity is expected to effect the hydrogenation.

Acknowledgements

The authors would like to acknowledge the collaboration of Yazaki Corporation.

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