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Effect of Hydrogen Addition on Copper Film Deposition Using Atmospheric Pressure Plasma Jet
大気圧プラズマジェットを用いた銅薄膜堆積における水素添加の効果

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Copper thin films were deposited by using atmospheric pressure plasma jet in air. To prevent the oxidation of deposited film, the effect of H_2 addition as a plasma-gas was studied. The plasma jet was driven by radio frequency (RF, 13.56 MHz), and ignited by applying RF power of 300 W to the coil after plasma-gas introduction (Ar:1000 sccm, H_2:10 sccm). The characterization of copper films was curried out with scanning electron microscopy and X-ray spectrometry.

1. Introduction

Atmospheric plasma process has a great advantage for the treatment of the heat sensitive substrates under pump-free condition or the selective treatments and modifications for complex plasma treatment of three-dimensional work. Another demand of atmospheric pressure material processing is to realize fine-structured processing of electronic device fabrication [1]. Up to now, in the fabrication of the most of ultra-fine electronic devices, the dry plasma processing at low pressure has been widely used. However, the plasma processing in air is still restricted to a small number of applications that the oxidation does not adversely affect. The deposition process using atmospheric pressure plasma can be attained by feeding plasma gas containing a source gas for deposition [2,3]. One of important issue in plasma processing, such as metal film depositions, is the oxidation of the material and the film surface during the process in atmospheric air [4,5]. To apply atmospheric pressure plasma technique to metal film deposition for electronic devices, the decrease in oxidation of deposited material is important. In this study, the copper (Cu) thin films were deposited by using atmospheric pressure plasma jet in air. To prevent the oxidation of deposited film, the effect of H_2 addition as a plasma-gas was studied.

2. Experimental setup

Figure 1 shows the schematic drawing of experimental setup for Cu film deposition using atmospheric pressure plasma jet. The plasma jet was driven by radio frequency (RF, 13.56 MHz) and jetted out from a quartz nozzle (3 mm outer diameter). The nozzle was connected to Ar and H_2 gas feed line for plasma-gas introduction. A Cu wire 1 mm in diameter was employed as a source for the deposition and inserted into the quartz nozzle. A 4-turns solenoid coil 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 (Ar:1000 sccm, H_2:10 sccm). The inserted Cu wire was heated and evaporated by plasma, and then Cu film was deposited on a substrate which was set from the nozzle tip of 1 mm.

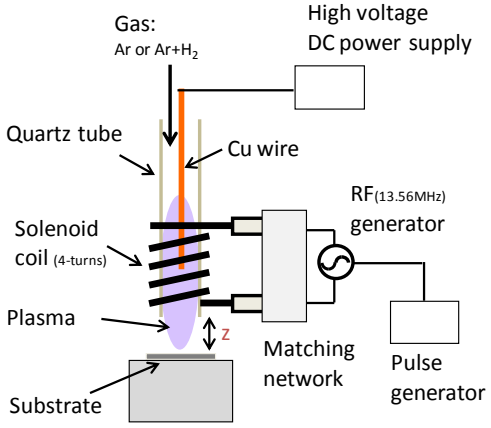

Fig. 1. Schematic drawing of experimental setup for copper film deposition using atmospheric pressure plasma jet.

The effects of H_2 adding on plasma process were evaluated from optical emission spectroscopy (OES). The film characterization was also observed with XPS. The analyzed depth of XPS analysis is expected to be roughly a few nanometers from the surface.

3. Results and discussion

Figure 2 shows the emission spectra at the quartz nozzle tip measured in the visible ranges. Though no optical emission from Cu atom was detected in the visible range shown in Fig.2(a), the Cu emission at 324.8 nm was obviously observed after installing a Cu wire on the central axis. Moreover, the Cu emission intensity increased by adding a small amount of H_2 to Ar, and the peak intensity of atmospheric gases such as N_2 and O_2 decreased. The emission intensity of Ar slightly decreased by adding of H_2. The decrease in the emission intensity of Ar corresponds to the decrease in the length of plasma jet.

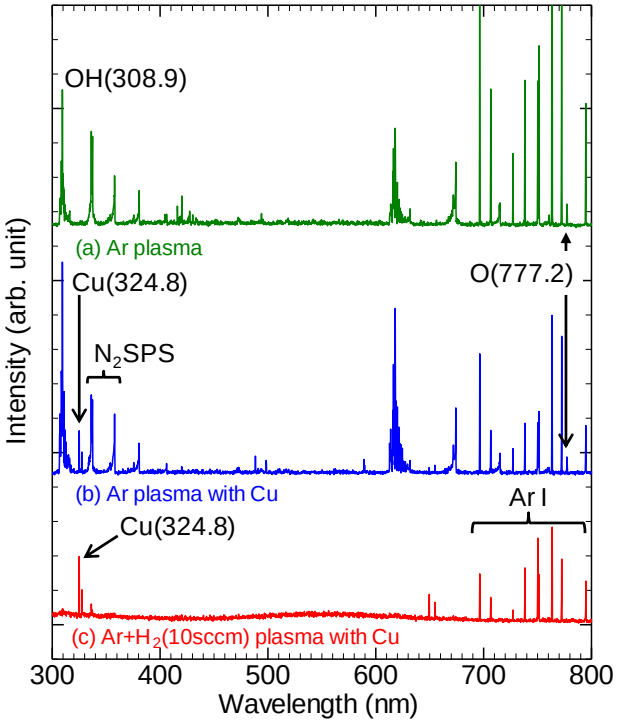

Fig. 2. Optical emission spectra obtained during deposition at the quartz nozzle tip. (a) Ar plasma without Cu wire, (b) Ar plasma with Cu wire on the tube axis, and (c) Ar and H_2 gas mixture plasma with Cu wire.

To obtain the surface information on the chemical composition, the deposited surfaces were analyzed with XPS. Typical XPS spectrum in Cu 2p3/2 of the film is shown in Fig. 3. The sharp Cu peak was obviously observed when small amount of H_2 gas was introduced in Ar. In the case of H_2 gas addition, a component was clearly detected at 933.1 eV corresponding to Cu and/or Cu_2O [6,7]. Moreover, another component around 935.2 eV which assigned to CuO and/or $Cu(OH)_2$ was decreased by H_2. The formation of Cu oxide is due to the oxidation reactions of Cu with O_2, excited oxygen and water vapor in air.

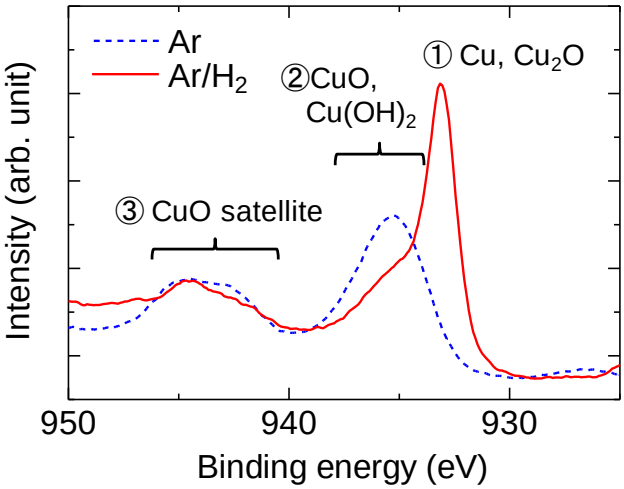

Fig. 3. XPS spectrum in Cu 2p3/2 regions of the surface deposited by Ar and Ar/H_2 atmospheric pressure plasma jet.

4. Conclusion

In this study, the experimental results of the Cu film deposition using atmospheric pressure plasma jet. The Cu film deposition was carried out on the substrate installed in air. According to OES measurement, the Cu emission intensity at 324.8 nm increased by adding of H_2, and the peak intensity of atmospheric gases decreased. According to XPS measurement, the oxidation of Cu film during deposition was prevented by H_2 addition in plasma. The obtained results show the possibility of atmospheric plasma processing for metal film deposition. The other results and detail discussion will be presented at the conference.

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