TEM Investigation of the Oxidation of Copper

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Due to the good properties of the thermal and electrical conductivity, copper (Cu) is widely used in electronic and electrical industry, such as interconnect materials [1-3]. Unfortunately, Cu has a very poor oxidation resistance even at room temperature, and the oxidation rate will significantly increase with the temperature rising. Therefore, study of the oxidation of Cu is very important not only for academic researches but also for its industry applications.

For decades, studies on the oxidation of Cu have been extensively carried out and many results have been obtained. However, most of these studies are focused on the oxidation of poly-crystal Cu, efforts on the study of oxidation of Cu single crystal are not enough. Up to now, the researches about the oxidation of Cu single crystal are mainly based on dynamic calculations [4], experimental investigations therefore become more desirable. In this study, we try to investigate the oxidation behaviors of Cu single crystal with different exposure planes by using transmission electron microscopy (TEM). At the first step, we focus on the oxidation of (100) plane because it is the most basic and important plane.

We got commercial single-crystalline Cu substrate for oxidation investigation. Firstly, the Cu (100) substrate was annealed at 573 K in air for 30 min to get the oxidized surface. And then the precursor was used to prepare the cross-section TEM sample. The TEM samples were prepared by the standard ion-milling technique. SAED pattern, TEM and HRTEM images were taken by using JEOL-2010F TEM.

Bright-field TEM image shows the morphology of the oxide scale of the oxidation of Cu (100) for 30 min at 573 K in air. From Cu substrate to vacuum, Cu_2O layer is first formed on the surface of Cu substrate. After that, CuO layer is formed on top of the Cu_2O layer. The oxide scales are composed of ploycrystalline Cu_2O and CuO. Between the Cu_2O and CuO layers, many holes are formed. SAED pattern shows the orientation of Cu substrate. According to the results, we proposed that the Cu_2O emerged during the starting oxidation stage. With the oxidation proceeding, the C_2O film was grown on the surface of the Cu. And then the film was immediately transformed to CuO with the oxidation temperature increasing. HRTEM image shows the Cu_2O/Cu interface. The interface shows coherent characteristics

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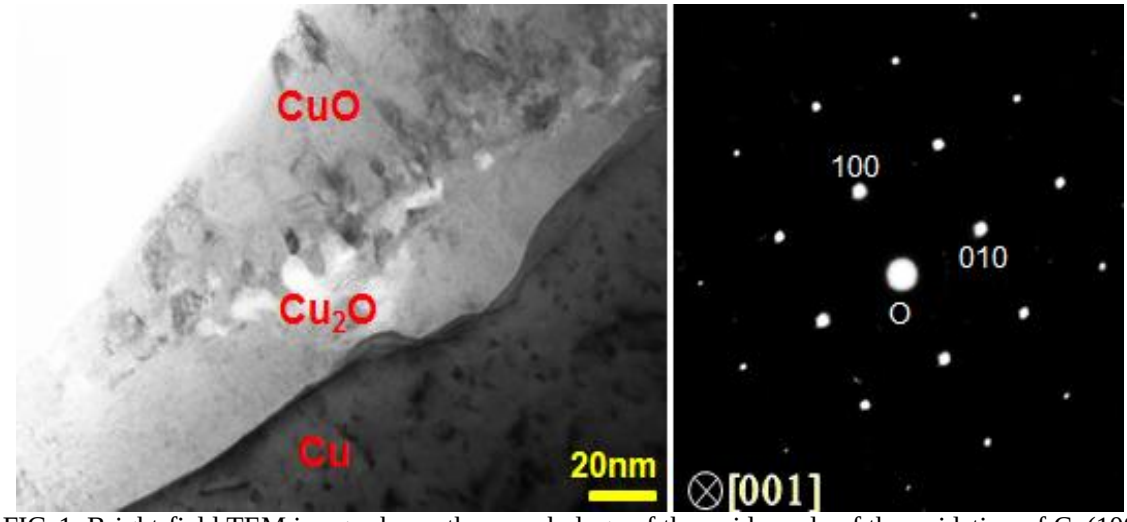

FIG. 1. Bright-field TEM image shows the morphology of the oxide scale of the oxidation of Cu(100) for 30 min at 573 K in air. And the SAED pattern shows the orientation of Cu substrate.

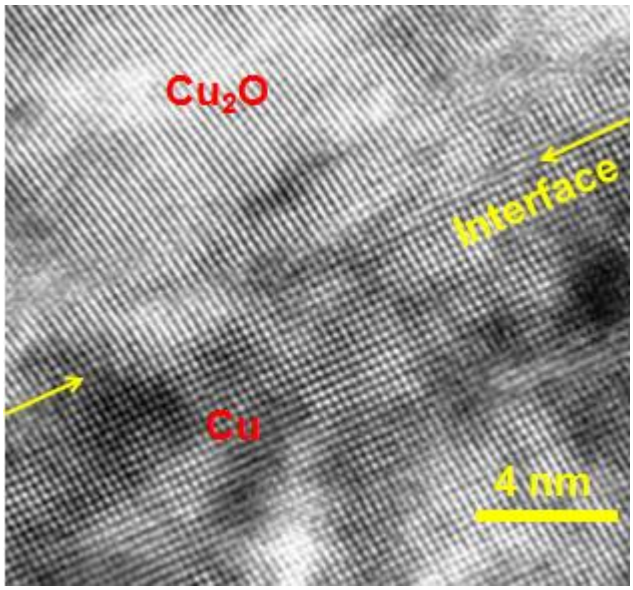

FIG. 2. HRTEM image shows the interface of Cu_2O/Cu. The interface shows coherent characteristics.