ULSI-Cu 配線の信頼性向上に向けた極薄 PVD-Co(W)単層バリア/ライナーの特性評価

Investigation of physical properties on ultra thin PVD-Co(W) barrier/liner layer to improve the reliability of ULSI intercconect

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Introduction

The current Cu wiring consists of Cu and a low dielectric material [1]. A barrier layer (TaN) to prevent diffusion of Cu into low dielectric materials and a liner layer (Ta) to improve adhesion surround the Cu line [2]. The continued miniaturization of Cu wiring enables electronic devices to achieve both high speed processing and low power consumption at the same time. This trend demands the barrier/liner layer of next generation Cu wiring getting thinner. Therefore, to meet such demand, barrier/liner layer will be 1-3nm in thickness. It however causes some crucial reliability issues that will be evident in near future, such as electromigration (EM), short circuit and RC (resistive-capacitive) signal delays. As these issues are originated from the barrier and liner, we proposed a single layer serving as both barrier and liner. We therefore screened Co(W) [3] and showed desirable physical properties (higher resistivity than Ta, higher barrier properties than TaN, higher adhesion than Ta) of a 20-nm-thick Co(W) film grown by plasma sputtering [4]. Here, we investigated the physical properties of Co(W) film with 1, 2, and 3 nm in thickness.

Experimental

The method for fabricating PVD-Co(W) single layer of 1, 2, and 3nm is basically the same as those of 20nm [4]. All samples were prepared by dual target plasma sputtering. The composition of the PVD-Co(W) thin film was measured by X-ray photoelectron spectroscopy (XPS). The sample structure to evaluate barrier property is PVD-Cu 200nm/PVD-Co(W) 1, 2, 3nm/thermal SiO_2 1nm / Si substrate. The barrier properties were evaluated from the RMS values of the surfaces measured by atomic force microscopy (AFM) after annealing. The surface RMS value of the Cu film increases when Cu diffuses into SiO_2 via Co(W) and thereby becoming discontinuous. Sheet-resistance was measured by 4-point probe.

Results and discussion

The W composition of PVD-Co(W) films with 1, 2, and 3 nm in thickness was first evaluated. Under the same deposition conditions, the W composition of the 3-nm-thick film was 13 at.% lower than that of the 20-nm-thick film that was reported previously [4]. This phenomenon is more significant for 1-nm-thick films. This implies that initial growth mechanism of Co(W) film i.e. Co(W) onto heterogeneous underlayer is different from that onto the homogeneous underlayer. At least, the sticking probability of W on SiO_2 would not be unity but lower than that on Co and W.

We then evaluated the barrier property of Co(W) films. In Fig.1, the barrier property was maximized at 19 at.%-W. Although 19 and 9 at.% showed the similar trend, the resistivity was 25% lower for 19 at.% (data not shown). Considering that the barrier property of 20-nm-thick Co(W) thin film was maximized at 43 at.%-W, anything other than W composition could affect the barrier property. The nanostructure of ultra-thin Co(W) film is likely to be different from that of 20-nm-thick. Barrier properties improved with increasing the film thickness from 1 to 3 nm, but the optimum W composition did not change significantly, suggesting that the nanostructure did not evolved in this thickness range.

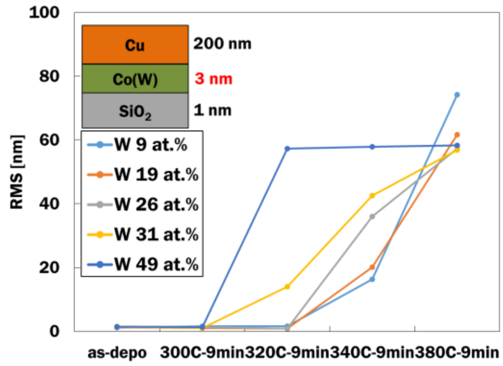

Fig. 1 RMS value of surface roughness with various W composition in 3-nm-thick Co(W) film.

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