極薄 PVD-Co(W)膜の銅拡散バリア特性評価に適用したタイムラグ法の改良

Improvement of time-lag method applied on Cu diffusion barrier properties evaluation of ultra-thin PVD-Co(W)

○鄧 玉斌[1]、出浦　桃子[1]、百瀬 健[1]、松尾 明[2]、山口 述夫[2]、霜垣 幸浩[1]

(1. 東大院工、2. キヤノンアネルバ株式会社)

○Yubin Deng[1], Momoko Deura[1], Takeshi Momose[1], Akira Matsuo[2], Nobuo Yamaguchi[2], and Yukihiro Shimogaki[1]

(1. The Univ. of Tokyo, 2. CANON ANELVA CORPORATION)

E-mail: dybbuas@dpe.mm.t.u-tokyo.ac.jp

Introduction

With ongoing downsizing of ultra large scale integration (ULSI), currently 5-nm node [1], Cu interconnects require a liner/barrier layer with lower resistance, better barrier properties, and higher adhesion to Cu than current Ta/TaN bilayer to address the electromigration (EM), stress-induced voiding (SIV), and resistance-capacitive (RC) signal delay. Recently, many alloys have been evaluated as alternative materials as a single-layer barrier/liner that functions as both layers, such as WN, RuTa, MoS_2, CoMo, CoTi, Cu(Mn), etc. Previously, we screened Co(W) is a promising candidate material as a single barrier/liner layer with good performance as mentioned above [2]. As for barrier properties, it is normally evaluated by some qualitative method, like resistance variation test, Cu silicide formation test, Cu diffusion distribution (depth-profiling) measurement and etch-pit test, etc. However, the barrier property of such ultra-thin barrier layer against Cu diffusion, represented by Cu diffusivity (D) in it, has hardly been quantitatively evaluated due to lack of measurement technology. Therefore, we previously proposed the time-lag method to evaluate D of Cu in 5~11-nm-thick PVD-Co(W) film [3]. Here, the time-lag method was modified to improved accuracy on D evaluation, and which was successfully applied to evaluate D of Cu in 1-nm-thick PVD-Co(W) film.

Experimental

All samples with 1-11nm thick Co(W) thin film having W compositions of 14.5±1.5 at. % were deposited by a dual target plasma sputtering apparatus. The sample structure was PVD-Cu 100 nm / PVD-Co(W) 1-11 nm / PVD-SiO_2 1000 nm / PVD-Ti 100 nm / PVD-Co(W) 150 nm / thermal SiO_2 100 nm / Si substrate. These samples were heated under a temperature of 780-855 ℃ with different annealing time. After that, two-steps etching process was applied on the samples, i.e., removal of Cu/Co(W) layer and dissolution of remaining layers except for Si. The Cu concentration in the solution for second etching was measured by inductively coupled plasma optical emission spectrometer (ICP-OES), which was then plotted against the annealing time as shown in Fig. 1a. According to the annealing time obtained and the diffusion equation of Cu, D of Cu in Co(W) film is obtained from two different ways i.e. $D_{X\text{-}intercept}=L^2/6t_{Lag}$ and $D_{Slope}=k_{slope}*L/C_0$ using x-intercept and slope in Fig. 1a, respectively, where L is thickness of barrier layer, t_{Lag} is the lag time, k_{slope} is the slope, and C_0 is solubility of Cu in Co(W) [3].

Results and discussion

Cu diffusivity (@780 C) in Co(W) with different thickness was obtained and summarized in Fig. 1b. Note that $D_{X\text{-}intercept}$ and D_{Slope} agreed well except for thinner Co(W) (≤ 5 nm). The deviation for thinner Co(W) was caused by a relatively lower accuracy of $D_{X\text{-}intercept}$ in which the lag time was critically smaller and suffered from error of measurement. Meanwhile, from comparative study (data not shown), $D_{X\text{-}intercept}$ is more sensitive to error of measurement than D_{Slope}, and D of thinner film is susceptible to actual thickness (as a main factor affecting the accuracy). In general, D_{Slope} was more reliable than $D_{X\text{-}intercept}$ (especially ≤ 5 nm).

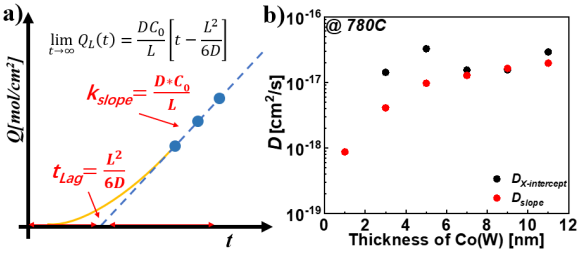

Fig 1. a) Schematic illustration of time-lag method and b) $D_{X\text{-}intercept}$ and D_{Slope} of Cu in Co(W) with different thickness at 780 ℃.

References

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