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Plasma enhanced atomic layer deposition of copper: A comparison of precursors

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ABSTRACT

The growth of Cu films by atomic layer deposition using hydrogen plasma has been investigated. To obtain continuous films at sub 5 nm thicknesses the two dimensional coalescence of Cu nucleation sites formed at the start of the deposition process must be enhanced in preference to three dimensional island growth. Thermal energy reduction in the growth process is a key parameter. In this work hydrogen plasma is used to allow the reduction of the adsorbed precursor to metallic Cu at a range of low temperatures. Therefore, precursors can be compared at their low temperature limit, which is mainly determined by transport issues due to their relatively low vapor pressures. The structure of the deposited Cu films varies strongly with the substrate material used highlighting the importance of the nucleation mechanisms. On metallic substrates such as Ru and Pd continuous conductive thin films could be obtained, island formation and slow coalescence were observed on Si, TaN and CDO substrates even at temperatures low as 30 °C; therefore conductive films could only be obtained for relatively thick deposits.

1. Introduction

Atomic layer deposition (ALD) is a thin film deposition method which can provide highly conformal coating as it consists of saturated half-reactions on the sample surface. Therefore as long as precursor flux is in excess film growth is independent of precursor transport and complex structured such as trenches of high aspect ratio or even shadowed structures can be coated conformally. High quality ALD growth has been demonstrated for many metal oxides including high-k oxides for CMOS gate stacks such as alumina or hafnia. Their growth with ALD has already become a process relevant for the commercial fabrication of CMOS devices [1] as the film thickness can be precisely controlled.

ALD of elemental metals is more challenging as the reduction of the metal center usually requires temperatures which are not compatible with the thermal budget for the growth of thin metal films. Copper is a metal of high interest as it is widely used for CMOS interconnects, which are usually fabricated by electroplating of the metal into trenches and vias structured in dielectric layers. For this process a continuous Cu seed layer is necessary, which is currently produced by physical vapor deposition (PVD). As the critical dimensions will fall below 10 nm within this decade [2], the thickness required for this seed layer will be so small that ALD will become an economic option in spite of the small growth rate. The vast majority of publications report the use of metal–organic complexes as precursors due to the vapor pressure of Cu-halides being very low. Therefore, the number of publications where the latter are used for Cu ALD is quite limited [3–6]. The low vapor pressure of Cu halides was also the main reason that the damascene process had to be developed as it forbids the

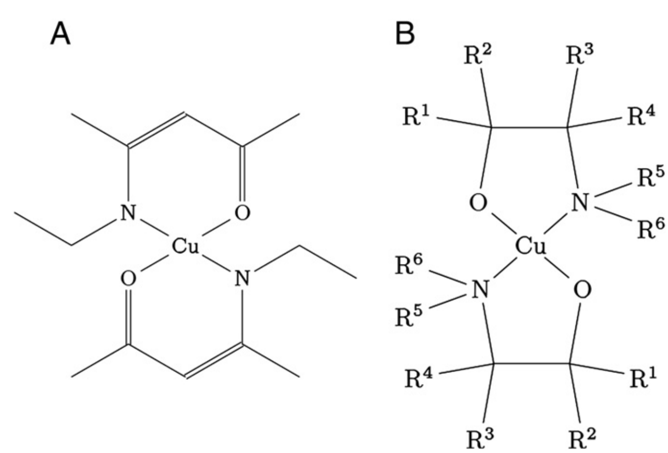

Fig. 1. Precursors: (A) AbaCus, (B) generic structure of a Cu-bis(aminoalkoxide) such as CTA1.

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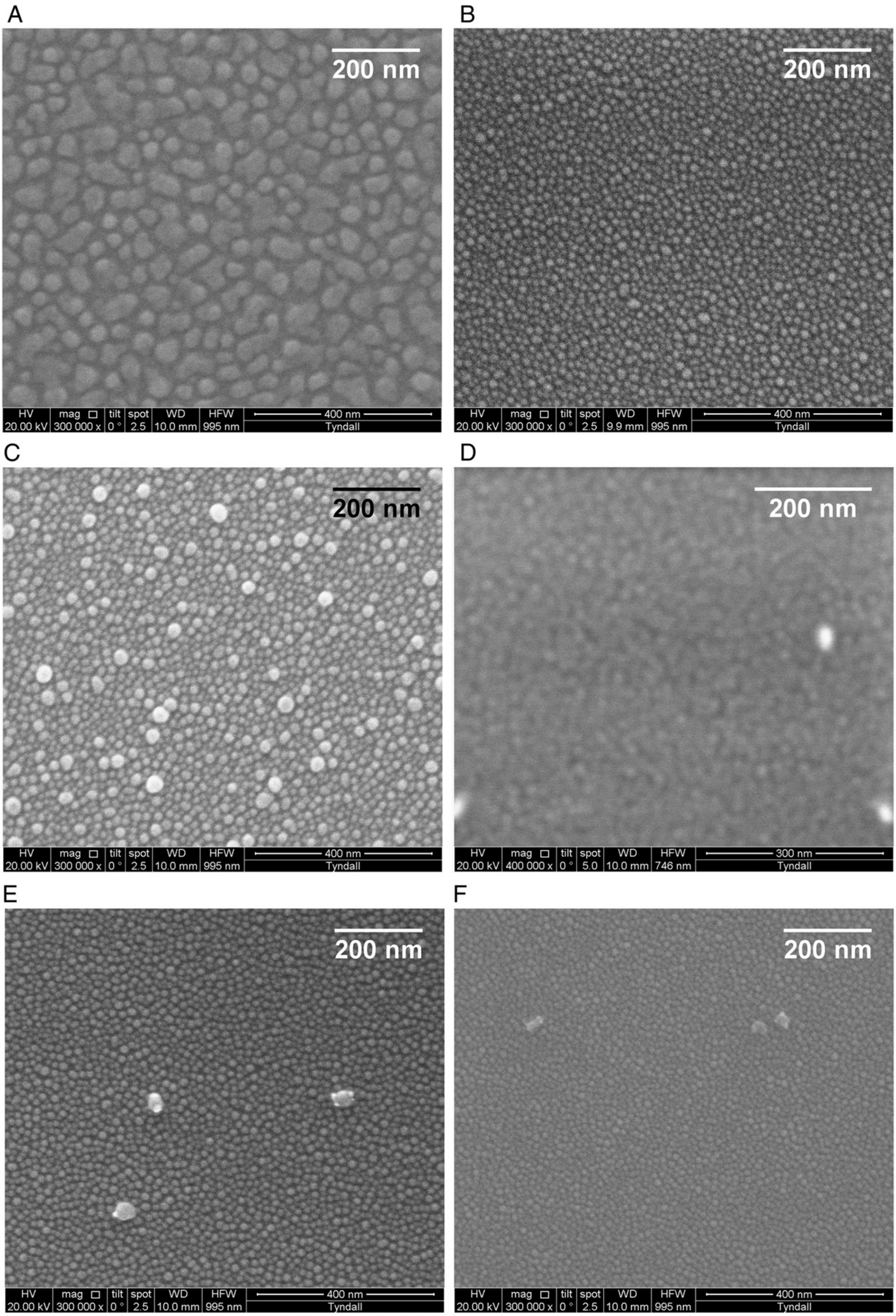

Fig. 2. SEM micrographs of Cu deposited with AbaCus on (A) Ru, (B) PVD TaN, (C) ALD TaN, (D) CDO, (E) Si, and (F) Al_2O_3.