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Atomic Layer Deposition of Niobium Nitride Thin Film with $NbCl_5$ and NH_3

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Due to some problems of Cu metal interconnect such as Cu diffusion into Si substrate and poor adhesion on SiO_2 substrate, the role of diffusion barrier materials is very important in nano scale process. Accordingly, the transition metal nitride such as TiN_x, TaN_x, MoN_x, WN_x and NbN_x have been widely studied to solve these problems. Among them, NbN_x is one of promising materials because of chemical insensitivity, good thermal stability and mechanical characteristics. Another important point for diffusion barrier is whether it can be conformally deposited on deep trench pattern. ALD method can make a uniform film at a relatively low temperature through self-limiting reaction, even at a trench or hole pattern where the aspect ratio is high.

In this study, we have performed the atomic layer deposition of NbN_x thin film with $NbCl_5$ and NH_3 at deposition temperature from 300 to 500°C. ALD saturation characteristics, ALD window and linearity of NbN_x were investigated on various substrates such as Si, SiO_2, Al_2O_3 and TiN. The thickness and resistivity were measured with XRF and 4-point probe, respectively. To confirm a chemical composition of NbNx film, RBS and SIMS were analyzed. The films have also been characterized with XRD and XRR for crystallinity and film density, respectively. The step coverage was identified with deep trench pattern of high aspect ratio (A/R = 15 ~ 18) by TEM.

The ALD window of NbN_x film was observed from 400 to 450°C. The resistivity of NbN_x film decreased gradually as the deposition temperature increases. It was ~ 1,900 μohm-cm at 350°C whereas at 500°C, it was only ~ 700 μohm-cm. The chemical composition was formed Nb_4N_5 at all conditions on Si substrate. Interestingly, Nb:N= 1:1 composition was shown on SiO_2 substrate. The Cl impurities decreased from ~7 to 0 at % as the deposition temperature increases from 350 to 500°C. Clear NbN peaks were observed in XRD analysis. These main peaks were well matched with c-Nb_4N_5 reference, and with SIMS and RBS data. The film density was increased from 6.63, 7.16, and 7.31, at 350, 450 and 500°C, respectively. The step coverage became worse slightly as the temperature increased, and 10Torr chamber pressure showed better step coverage than 20 and 30Torr. More than 95% step coverages at middle and bottom were achieved in deep trench pattern with A/R of 17.