Atomic Layer Deposition of Cobalt at Low Temperatures

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The conformal deposition of cobalt is still an ongoing topic of research. Applications are manyfold and include interconnects[1], seed layers for electroplating[2], magnetic sensor systems[3], and antibacterial coatings[4]. The thermal budget during film deposition is a crucial parameter which has to be taken into account. Here we present the development of a low temperature Atomic Layer Deposition (ALD) process for the formation of metallic cobalt thin films.

The professorship of Inorganic Chemistry at the Chemnitz University of Technology developed a set of cobalt precursors on the base of dicobalt-hexacarbonyl-alkynes as $[Co_2(CO)_6(RC{\equiv}CR')]$.[5] We evaluated a set of these precursors for chemical deposition methos using density functional theory (DFT) calculations. According to these calculations the precursor $[Co_2(CO)_6((CH_3)_3SiC{\equiv}CSi(CH_3)_3)]$ is the most favourable precursor for Chemical Vapour Deposition (CVD) as it thermally decomposes completely on the substrate surface. In contrast, precursor $[Co_2(CO)_6(HC{\equiv}CC_5H_{11})]$ was identified as the most favourable precursor for deposition via ALD as it adsorbs with adjected $(HC{\equiv}CC_5H_{11})$ group which can be easily removed by use of mobile hydrogen. A simplified scheme for the surface reaction and release of the hydrocarbon group is shown in Figure 1.

We developed an ALD process based on the DFT results by use of $[Co_2(CO)_6(HC{\equiv}CC_5H_{11})]$ as the cobalt precursor and hydrogen plasma.[6] The process development was done on a *scia Atol 200* reactor, which was designed and fabricated by *scia systems GmbH* in cooperation with *Fraunhofer ENAS* and the *Chemnitz University of Technology*. The processes took place on standardised 200 mm Si wafers with a preliminary SiO_2 layer of 100 nm thickness. The precursor was evaporated via bubbling method. A full ALD cycle consists of cobalt precursor pulse, Ar purge, H_2 plasma pulse, and a second Ar purge.

The deposited cobalt films were analysed by *in-vacuo* ellipsometry to determine in-line the film growth rates. Figure 2 shows the deposition rates in the temperature range from 35 °C to 125 °C showing the ALD window for this process within the range of 50 °C to 110 °C. *Ex-situ* measurements with spectroscopic ellipsometry were done to determine the thin film homogeneity on wafer level using a spiral measurement pattern with 5 mm edge exclusion. The optimised process had a film thickness deviation of about 1.5% relative standard deviation.
Additional measurements with X-ray photoelectron spectroscopy confirmed that the deposited films consist of cobalt in metallic state. Sole contaminations were identified as oxygen and carbon which are expected as the wafers were measured *ex situ* and may oxidise during transport.

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References

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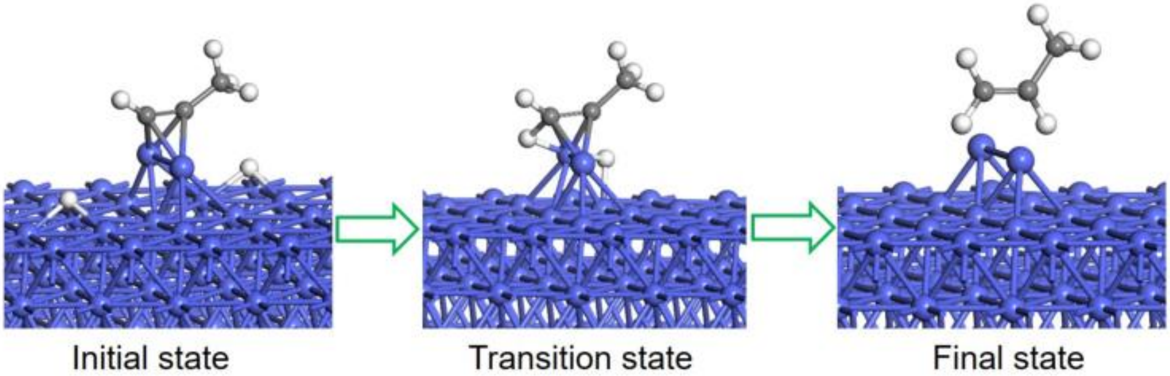

Figure 1: density functional theory simulations showing the surface reactions between hydrocarbon ligand and hydrogen.

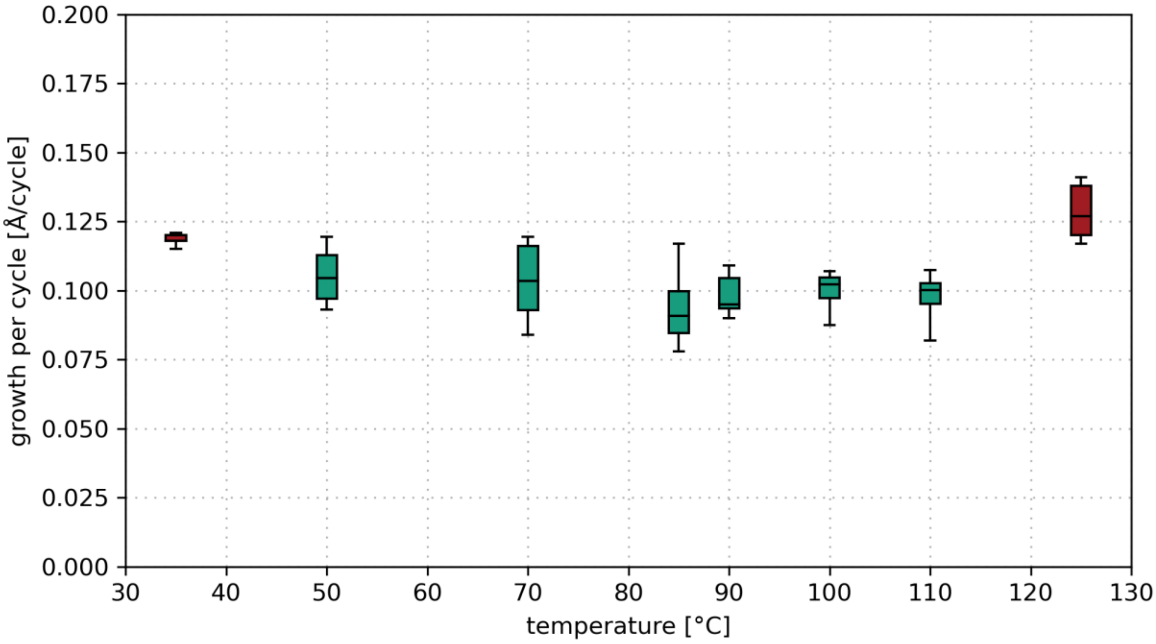

Figure 2: Temperature dependence of growth rate.