Public Abstract

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Title:DESIGNING, MODELING, MANUFACTURING, AND TESTING AN ATOMIC LAYER DEPOSITION SYSTEM

There are multiple techniques for depositing thin films in nanoelectronics and semiconductor industries. Each technique has its own advantage and disadvantage. Of the many techniques, chemical deposition is the most favorable since materials can be deposited in high aspect ratios and give full coverage across uneven surfaces. However the most conventional technique in chemical deposition, named chemical vapor deposition (CVD), has some limiting properties like high temperature and uncontrollable film growth. To have the advantage of chemical deposition and also being able to control film growth in monolayer resolution, a new technique has been introduced, named Atomic Layer Deposition (ALD). This technique gives a very good control on layer-by-layer film growth. It can work at low temperatures and high pressures. In manufacturing nanoantennas and MIM diodes there is a need, for having an ultra thin film with full coverage across select areas. ALD is a promising solution for ultra-thin film fabrication problems. In this work we designed, modeled, manufactured, and tested a novel ALD system. Our system is designed to do more exotic film depositions than the small-range accessible with industrially available ALDs.

A typical ALD process starts with entraining a precursor in a carrier gas that brings it inside the reactor where it adsorbs on the substrate’s surface. The second step is removing the extra precursor from the chamber by purging it. The third step is adding another precursor gas to the reactor. The two precursors will react with each other on the substrate’s surface. In the fourth step a purge is used to remove excessive precursors and by-products from the reactor chamber. A well-designed reactor for this process needs to have the ability to operate under high vacuum, high temperatures, and intense reactions. In the designed reactor within this project, a showerhead, a stage heater, a ceramic spacer, and stage holder were designed and manufactured. There are four gas inlets from a top flange that feed into showerhead, which helps better gas dispersion. Also in the showerhead each of the inlets can be used to bring different gases inside the reactor for CVD processes. The designed reactor is a cross reactor, which minimizes the gas entrapment. All the flanges were designed in a way to have good ability to control the system.

The tubing in this system is used to bring precursors inside the reactor. To have a good control on the flow rate of precursors, individual mass flow controllers, i.e. four ALD Solenoid Valves, are used to regulate the flow of each precursor. Bubblers are used to contain precursors at the entry point of the gas delivery line. Each bubbler has a dipping tube that extends the length of the bubbler container to give the carrier gas the ability to entrain precursors and bring them inside reactor. ALD Valve-4 is designed in a way that can switch the system from ALD to CVD. This gives us the ability to have multiple depositions in different techniques in a single run. ALD Valve-3 is designed for vacuum bubblers in case there is a precursor with very low volatility or very sensitive to high temperatures.

Controlling the entire system, all at the same time, is crucial to the success of ALD. The parameters that needed to be controlled are temperature, pressure, gas flow, and each of the ALD Valves. There are five parts in the designed system that have separate thermocouples and heaters. Each of bubblers, tubings, the reaction chamber’s body, and substrate stage can get to a separate temperature using PID controllers. Finally a box designed for all the PID controllers and relays to read all the temperatures side-by-side. In addition, there is a terminal box that connects all the tubings’ heaters and chamber heaters together. Low vacuum pressure can be read by either of the two thermocouple gauges installed on the system. One of the thermocouple gauges reads the pressure of the reaction chamber and the other reads the pressure inside turbopump. Also there is an ion gauge, which has the ability to read pressures less than 10-3 Torr. To

control gas flow and ALD Valves, a software program was developed that can send digital signals to DAQ cards and the cards can change it to analog signal and send to MFCs and Valves. A control box is designed that contains all the four DAQ cards and a circuit that gives us the ability to control the valves by low currents.

Finally the manufactured ALD was tested for process of depositing Al2O3 on top of silicon substrate. The test were performed in two batches, EDS test were performed to prove the deposition of Al2O3 also AFM test showed very flat films with 1.2 nm RMS were fabricated. The results of tests ensured the ability of the ALD to deposit films.