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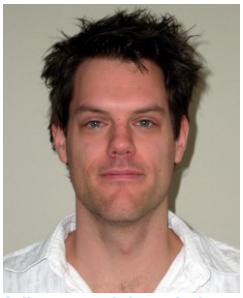
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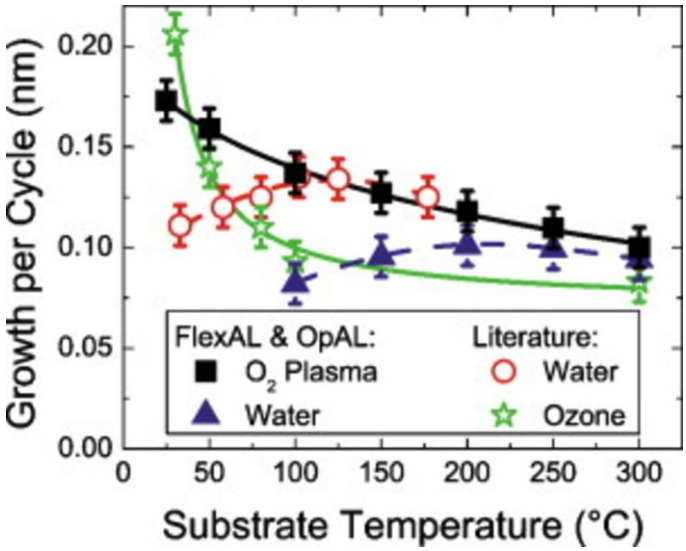
Low Temperature ALD: What's limiting?

Summary

It is desirable to carry out ALD at low temperatures (<150 °C) while maintaining the high material quality that is typically achieved with ALD at higher temperatures. The main incentive to move to low temperature ALD processes is to achieve a greater flexibility in depositing films onto temperature-sensitive structures, such as polymers or temperature-sensitive devices. Several low-temperature ALD processes have been developed; however, this development has so far been mainly trial and error. The details of what is limiting low-temperature ALD, in terms of viability of the processes and in terms of material quality, are largely unclear.



A comparison of growth per cycle for the ALD of Al_2O_3 from $Al(CH_3)_3$ for different co-reactants. All lines serve as a guide to the eye [Potts et al., J. Electrochem. Soc. 157, P66 (2010).]

In this session we try to identify which factors can be limiting low temperature ALD with an emphasis on ALD of metal-oxides. The basics of ALD and the most common ALD chemistries used for metal-oxide deposition will be reviewed. Plasma-enhanced and thermal ALD will be compared and the resulting differences in material quality at low temperature will be discussed. In a case study of low-temperature thermal ALD of Al_2O_3 it will be discussed what is limiting ALD in this specific case.

Outline of the overview presentation

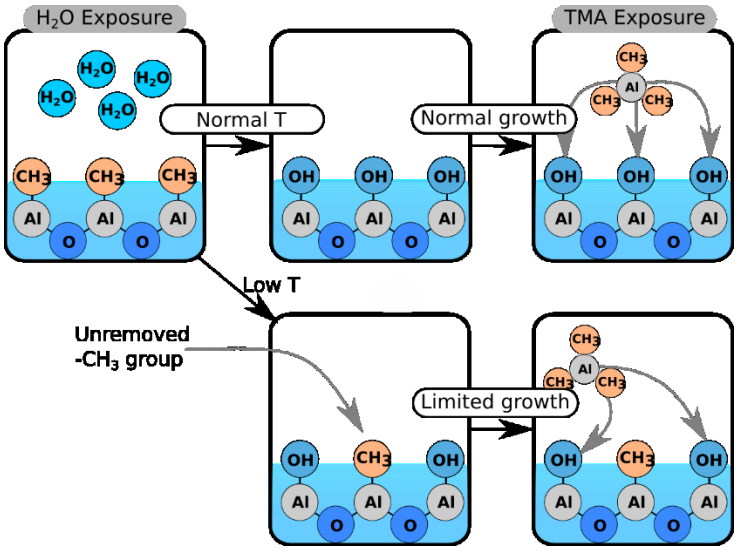
The following topics will be addressed:

- ALD growth mechanism of Al_2O_3 and TiO_2.
- ALD temperature window.
- Growth rate in nm/cycle or in atoms/(cycle nm^2).

- Why does ALD typically deposit less than a monolayer?
- Typical trends in film composition with deposition temperature.
- Metal precursor considerations for low-temperature ALD.
- The reactivity of the co-reactant.
- TMA v.s. DMAI, the influence of steric effects in precursors.
- Role of purge times in ALD.

Case Study

Thermal ALD of Al_2O_3 using $Al(CH_3)_3$ and H_2O as co-reactants is known to produce high-quality material even at low temperatures. However, a significant decrease in growth per cycle (GPC) is commonly observed at low temperatures (<150 °C). To understand the cause of this reduction in GPC, the ALD surface chemistry was studied using vibrational broadband sum-frequency generation (BB-SFG). BB-SFG is a laser-based spectroscopic technique that yields information about the type and number of surface groups present at the surface during growth. It was found that at low process temperatures, the limited reactivity of H_2O results in a significant number of unremoved CH_3-groups on the surface. This remaining $–CH_3$ limits the amount of TMA chemisorption and therefore the GPC.



At regular ALD temperatures, H_2O removes all of the $–CH_3$ groups on the surface, resulting in a fully –OH terminated surface. The decrease in GPC, observed at low temperatures, is caused by $–CH_3$ groups remaining on the surface and limiting the amount of $Al(CH_3)_3$ that can chemisorb. At these temperatures, H_2O is not reactive enough to removal all the $–CH_3$ groups.

How to participate?

You can participate actively in the session about low-temperature ALD by giving a short presentation or a pitch after the two presentations that are already scheduled. Please submit a short presentation clearly describing the **observation, issue or open question** that you would like to discuss to contact@nanomanufacturing.nl. We would like to receive your presentation **before the 29th of May**, which will allow sufficient time for us to evaluate your contribution. You might receive suggestions from the session coordinators to fit it in the session.

If your short-talk is accepted, you can chose to bring a poster in addition to giving the short talk. The poster will receive attention during the breaks and during lunch. The poster will allow you to present more background information and interesting findings which cannot be discussed during the sessions due to time constraints.