From stamp to wafer - How complex ALD processes become exponentially harder to control on fab-friendly scale

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Electronic devices utilizing different order parameters for new switching mechanisms is important in the transition to neuromorphics and the ultra-low power paradigm. Leveraging these order parameters very often require materials with tunable functionality, typically found in complex materials systems with at least two metal cations. Examples are ferroelectricity in $BaTiO_3$ and $(Hf,Zr)O_2$, ferromagnetism in $(Ca,La)MnO_{3-\delta}$ and $(Co,Ni)Fe_2O_4$ or multiferroicity in $BiFeO_3$.

While the possibilities offered by such materials are well-known on the lab scale due to facile preparation by *e.g.* molecular beam epitaxy or pulsed laser deposition, it is difficult to harness the possibilities at larger scale due to the limitations (area, temperature, pressure) of said techniques.

Integration of complex materials needs to take place utilizing fab-friendly techniques. One possibility is ALD, which is already in widespread use due to the low thermal budget, the large area conformality and the high repeatability. Unfortunately, not all of these advantages are (necessarily) carried over from simple binary systems (like HfO_2) over to the more complex materials.

In this talk, I will present some of the challenges going from simple binary processes over to the more complex materials with ALD. I will spend time on discussing how these challenges can be overcome, and how I propose that ALD is utilized beyond the classic binary oxides and nitrides as we move to completely new device types.

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