Atmospheric Pressure Spatial ALD onto Powders with Conventional Powder Handling Equipment

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The manufacturability of ALD coatings on commodity particle substrates requires the development of cost effective ALD processing for industrial scales. We have developed a fully continuous spatial particle ALD system based on conventional powder handling equipment capable of multi-ton per day throughput. We demonstrate the feasibility of atmospheric pressure spatial ALD onto powders at hundreds of grams per minute. The high throughput of a continuous atmospheric pressure spatial ALD system will enable a broad range of commodity applications, including Li-ion battery materials.

Al_2O_3 ALD coatings were deposited using a continuous vibrating fluidized bed using a typical spatial ALD arrangement of TMA and water precursors. The vibrating bed is a large scale commercial piece of equipment in the powder handling industry, typically used for drying applications. The vibration is used to supply most of the fluidization energy and transport the particles, while gas carries purge and precursor species. A metal powder substrate was delivered through the 5 cm wide lab scale system at a rate of 12 kg/hr. This system operates at atmospheric pressure, and samples are compared against typical thermal ALD samples created in a vacuum rotary reactor. Thermogravimetric analysis is used to compare the oxidation resistance of the samples as an indicator of the uniformity and thickness of the deposited ALD film.

Powder handling is a non-trivial aspect of particle ALD scale-up; implementing the ALD process in commercial powder handling equipment is more feasible than implementing powder handling in conventional ALD reactors. Adapting the ALD process to an existing piece of scalable equipment means that production of multiple tons per day are almost immediately achievable

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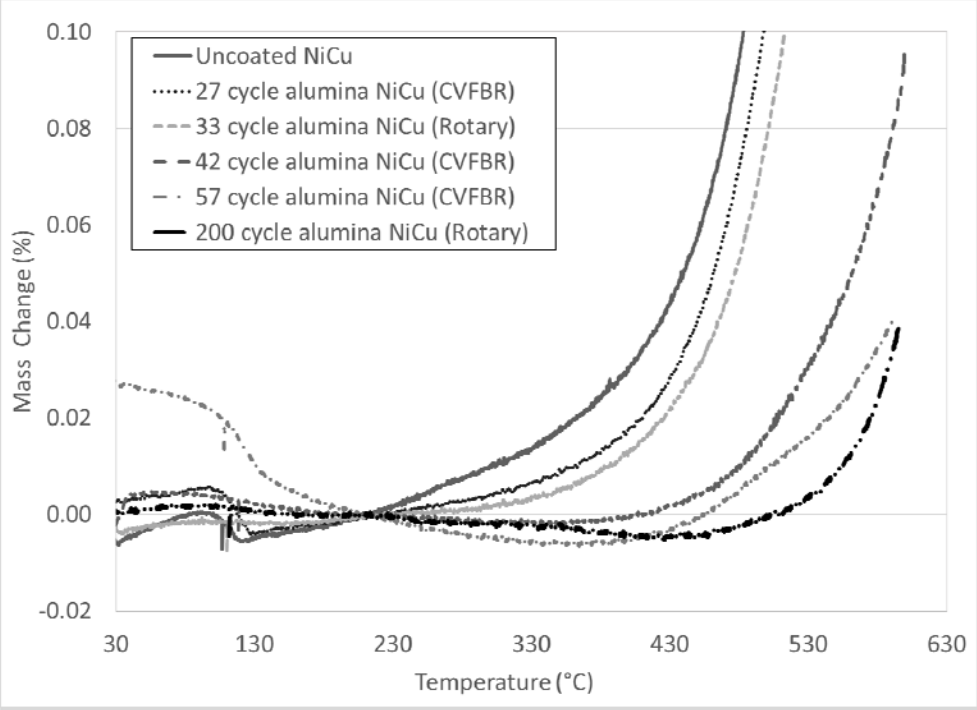

Figure 1 Thermogravimetric analysis of ALD alumina coating on NiCu showing a shift of oxidation to higher temperatures corresponding to thicker ALD coatings in continuous and batch ALD systems.