Scalable Manufacturing of Nanopowders by Solution Combustion Processing

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ABSTRACT

nGimat LLC has scaled-up a proprietary solution combustion process, called NanoSpray ^{SM} Combustion, for the production of complex metal oxide nanopowders in high-volume. This process can also be used for the scalable manufacturing of complex metal phosphate and select metal nanopowders. In this presentation, we will discuss the benefits of the process, the challenges involved in its scale-up and the innovative approaches taken to address these challenges.

Keywords: nanomaterials, nanopowder, scale-up, production, manufacturing

1 PROCESS & SCALE-UP

For the past several decades, gas-phase combustion processing has been used to produce nanomaterials like titanium dioxide and carbon-black in tonnage. These processes are restricted to the production of simple, single-element or single-metal compositions, primarily because of the limited availability of gaseous precursors that lend themselves to combustion processing. Most processes that are currently capable of making complex multi-metal oxide nanopowder compounds rely on expensive, energy-intensive processes that start with large grain particles and reduce them down to smaller sizes – *a top down process* that leads to inhomogeneous particle sizes.

In this paper we will discuss the development and scale-up of a patented *bottom-up process* called NanoSpray Combustion^{SM} (Figure 1) to make complex metal-oxide (and select metal) nanopowders (Table 1) at through-puts close to 100kg/day (3Tonnes/month). To make these complex compositions a proprietary device called the Nanomiser® converts the metal-containing precursor solution into an ultrafine spray that can be combusted like a gas, thereby eliminating the need for gaseous precursors.[1] The NanoSpray Combustion process is less energy intensive than other nanopowder production processes since most of the energy required to form the nanoparticles are self-contained in the chemicals being combusted. In a conscious effort to further reduce cost and lower carbon-footprint, nGimat has been able to convert most of its metal precursor systems to low-cost, low or no-carbon compounds that are soluble in renewable, bio-derivable fuels.

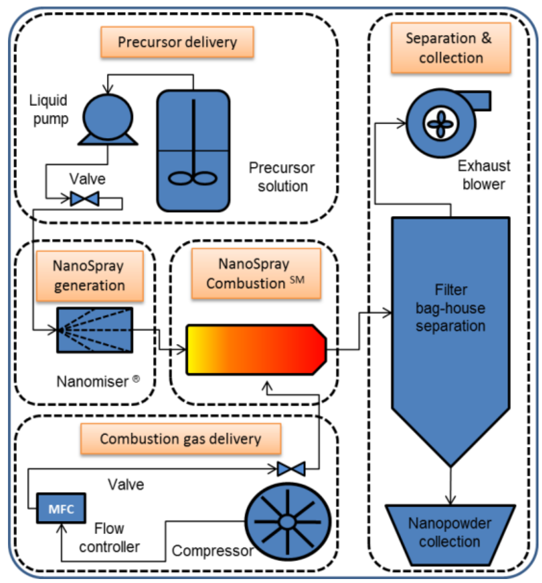

Figure 1: Process flow diagram for the NanoSpray Combustion process

Table 1: A representative list of nanopowders made using the NanoSpray Combustion process

Application	Candidate Materials	Benefits	nGimat materials
Lithium-ion batteries	Various Li metal oxides & phosphates, Tin Oxide	Higher power	$Li_4Ti_5O_{12}$ $LiMn_{1.5}$Ni0.5O4
Sorbents (Sulfur removal)	Zinc Oxide (ZnO) Copper Oxide (CuO)	Higher efficiency	ZnO CuO
Fuel cells	Yttrium Stabilized Zirconia (YSZ) Samarium Doped Ceria (SDC)	Easier fabrication (lower cost)	$(Y_2O_3)(ZrO_2)$ $(Sm_2O_3)(CeO_2)$
Catalysts	Various transition metal and rare-earth oxides, Precious metals	Higher efficiency Lower cost	NiO-$(Y_2O_3)(ZrO_2)$ Pt, Pd
Photovoltaic	Titanium dioxide, Zinc Oxide Silver , Tin Oxide	Easier fabrication (lower cost)	TiO_2 , ZnO, Ag, SnO_2
Ceramic Lasers	Yttrium Aluminum Garnet (YAG) Lutetium Oxide	Easier fabrication (lower cost)	Nd-$Y_3Al_5O_{12}$ Yb-Lu_2O_3
Wire coating insulation	Various nanocomposite	Superior thermal & electrical properties	Proprietary
Biomedical	Hydroxylapatite, Calcium Oxide & Phosphate	High surface area for tissue regeneration	CaO, $Ca_3(PO4)_2$ $Ca_5(PO4)_3OH$
Electrical/ Electronic	Barium Strontium Titanate, CCTO, Zinc Oxide	High-K dielectrics Semiconductors	$BaTiO_3.SrTiO_3$ $CaCu_3Ti_4O_{12}$

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2 APPLICATIONS

Applications for the nanopowders are soon expected to be widespread in the energy, biomedical & electronics space. Typical examples of nanopowders made by NanoSpray Combustion include, Lithium Titanium Oxide (LTO) & Lithium Manganese Nickel Oxides (LMNO) for Lithium-ion batteries, hydroxylapatite (HAP) for biomedical tissue regeneration and silver (Ag) for electronic inks (Figure 2). For energy applications, the combination of small particle size and high surface area of nanopowders provide them with enhanced electrochemical, catalytic and photocatalytic characteristics. For Lithium-ion batteries this translates to significantly high-power capability compared to conventional systems. Figure 3 demonstrates the high-power charge (30C – 2 minutes) and discharge (50C – 1.2 minutes) capability of a 200mAh Lithium-ion battery with an nGimat LTO anode. Furthermore, nanopowders produced by this process are also used commercially to provide enhanced desulfurization of natural gas streams. The presentation will also discuss the challenges faced during the process scaling effort and solutions for the same, as well as the impact of scaling on the above mentioned applications.

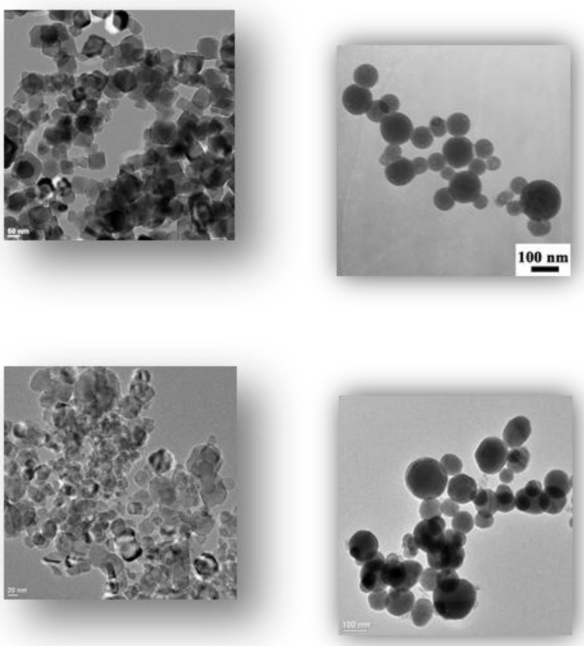

Figure 2: Transmission electron micrographs of LTO (top left), HAP (top right), LMNO (bottom left) and Ag (bottom right)

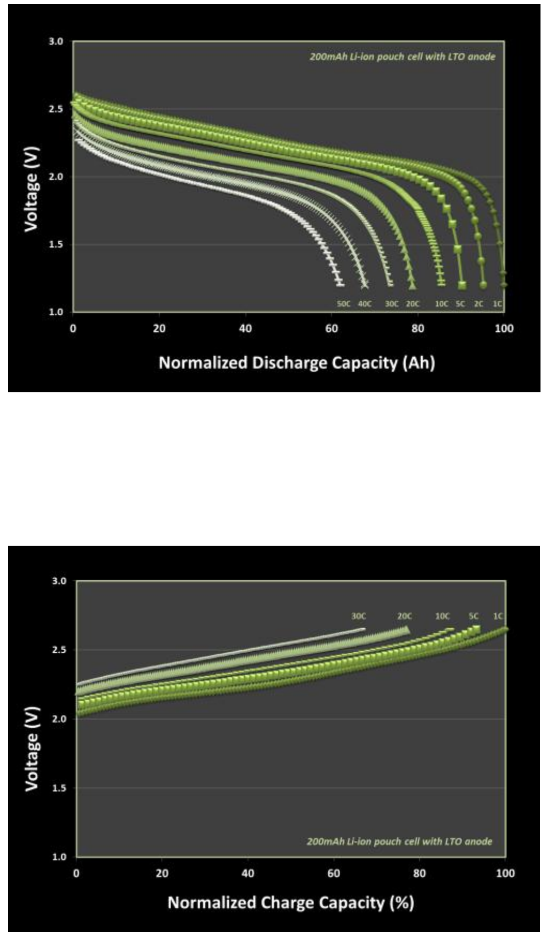

FIGURE 3: Disharge (top) and charge (bottom) curves for a high-power capable Lithium-ion battery based on LTO nanopowder anode

3 ACKNOWLEDGEMENTS

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REFERENCES

[1] G. Venugopal, A. Hunt, and F. Alamgir, *Materials Matters 5(2), 42,* **2010**.