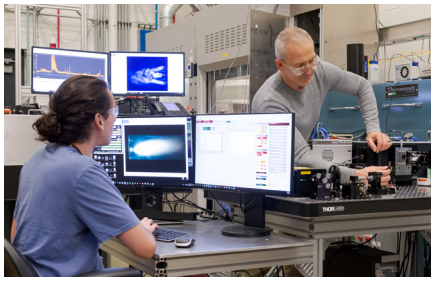
Argonne NATIONAL LABORATORY

ENABLING FLAME SPRAY PYROLYSIS FOR **MANUFACTURING COMPLEX MATERIALS IN HIGH VOLUMES**

New complex materials and predictive manufacturing processes to optimize quality control can be designed by leveraging Argonne National Laboratory's world-class in-situ diagnostics, computer modeling, scale-up technology and expertise.

Flame Spray Pyrolysis (FSP) technology simplifies the manufacturing of nanomaterials in high volume that are critical to produce numerous industrial materials. FSP process can produce samples at pre-pilot-scale one-day rates up to 500 grams per day for a single chemistry or permute over multiple chemistry or process variations up to six times per day. Compared to the wet chemistry processes typically used for synthesizing material such as silica, metallic, oxide and alloy powders, Argonne's FSP process can deliver cost savings due to faster production rates and reduced material waste — making FSP the technology of choice for commodity scale production when the process can be successfully optimized for any given material.

The FSP facility combines advanced diagnostics with a pre-pilot-scale powder production facility to enable the optimization of powder synthesis in a manner and scale relevant to transitioning to commercial scale systems. It provides combustion laser diagnostics (planar laser induced fluorescence and filtered Rayleigh scattering), optical emission flame spectroscopy, in-situ Raman spectroscopy and scanning mobility particle sizing in addition to a heavily instrumented process control and monitoring system.



FSP Operators Joseph Libera and Anthony Stark prepare for in-situ Raman spectroscopy.

COLLABORATE WITH US

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U.S. DEPARTMENT OF ENERGY
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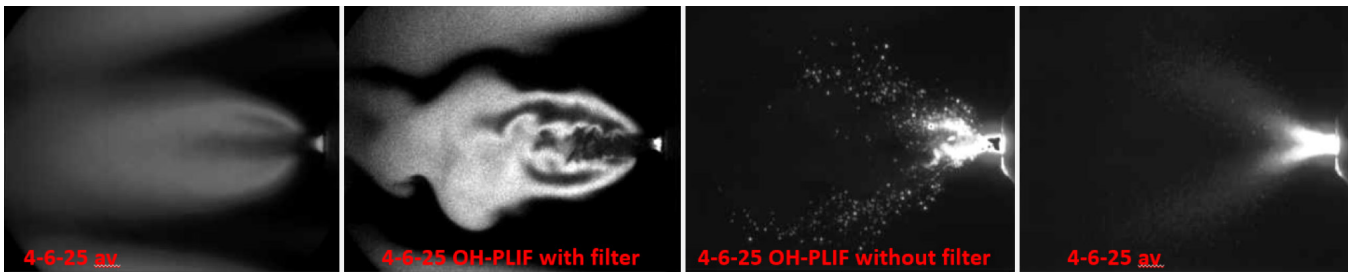
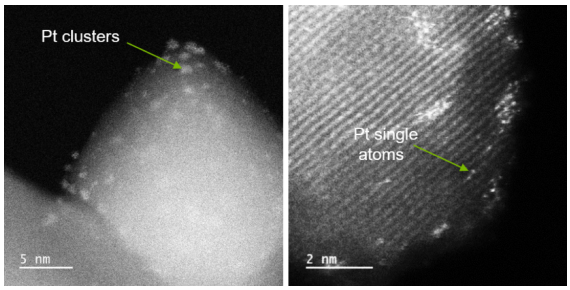
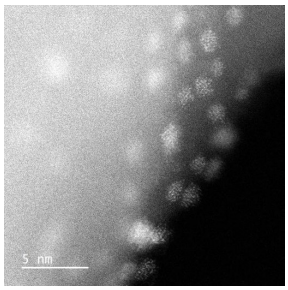
October 2019



Laser Diagnostic measurements of spray flames in the ANL FSP form left to right (a) average OH PLIF, (b) instantaneous OH PLIF (c) instantaneous light scatter, and (d) average light scatter



Pt/TiO2 catalyst manufactured in a single step using FSP. Fine dispersion of the active phase Pt is achieved including down to numerous single atom sites.



Titania supported platinum catalyst manufactured in a single step by FSP.

Solution blending and advanced burner controls provide the ability to rapidly screen the complex parameter space to achieve novel materials. Ongoing machine learning development will enable the navigation towards optimal solutions in the complex parameter space. Scientists and researchers will use real-time optimization to leverage the highly automated FSP facility and machine learning algorithms.

Major initiatives at Argonne's FSP facility include: development of low cobalt battery cathode powders, solid state electrolyte powder precursors and platinum/titania catalysts for biomass pyrolysis oil upgrading reactions. The facility is engaged with industrial partner Cabot Corporation to ensure we develop scalable strategies.

INDUSTRIAL BENEFITS OF FSP COMPARED TO WET CHEMISTRY-BASED PROCESSES

- Low-cost production
- Low precursor material cost (e.g. metal salts)
- Rapid, scaleable production of materials
  - Only way to produce materials with unique physicochemical properties
  - Fewer and less time-consuming production steps
  - Continuous process
  - Reproducible catalyst morphology
- Produces nanometer monolithic particles instead of porous micron-sized particles
- Unique material morphologies such as core-shell structures and nanorods are possible
- Suitable for the mass production of solid state electrolyte and cathode powders for advanced battery applications
- Enables the production of catalyst active material and support in one step

CUTTING-EDGE FLAME SPRAY PYROLYSIS RESEARCH AND DEVELOPMENT IN THE U.S.

Capabilities

- Suite of world-class laser in-situ and ex-situ diagnostics systems. (2018 build out)
  - 2d chemical species and flame temperature distribution
  - Real-time measurement of particle sizes from 5 nm to 1 µm
- Medium resolution spectrometer for flame emission spectroscopy with linear probe array along the flame axis
- In-situ UV Raman spectrometer with 266, 355, 512 and 630 nm excitation
- Ongoing machine learning effort for real-time optimization of combustion flames
- Catalysis characterization at Argonne's High Throughput Research Laboratory
- Fundamental combustion science expertise
- Modular design to easily deploy advanced burner concepts
- In-house suite of synthesized families of catalysts with unique morphologies for use in benchmark testing