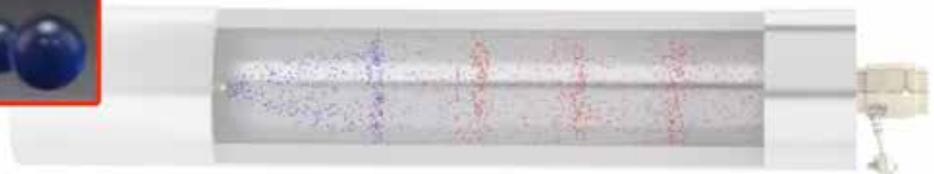


## **PRODUCTION OF HIGH-PERFORMANCE POWDERS**

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**SYNTHESIZED IN A PULSATING GAS STREAM**



## FOR YOUR NEXT GENERATION POWDER MATERIALS

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Globally increasing demands on the functionality and service life of products pose new challenges for material development in all industries including advanced powder production. Our solution is called Glatt Powder Synthesis.

Glatt Powder Synthesis is based on the principles of spray pyrolysis, spray drying and spray calcination. Depending on the choice of process parameters, materials are generated, optimized or functionalized in one of these ways. To accomplish this, a pulsating gas flow is used instead of a laminar flow. This leads to a high degree of turbulence in the reaction chamber and special thermodynamic conditions. These parameters enable customization of the powder.

As a plant manufacturer, Glatt offers the design and construction of specialized plants tailored to customer requirements. Glatt's experts work hand in hand with customers from initial testing and design through to plant delivery and startup.

Laboratory pulsation reactors of various designs are available for trials and process development at our Weimar technical center. Use the wide range of process parameters to design your material to your exact requirements. The ProAPP® 300 synthesis reactor is our pilot and production plant for scale-up trials and contract manufacturing. The annual capacity is several hundred tons and supports you entry in to the market while a customized machine is being built for you.

*Take advantage of our technology expertise for your innovative particle design!*

- » **Continuous, reliably scalable process**
- » **Drying, coating and calcination in one step**  
to create unique powders or core-shell structures
- » **Nanometer-scale homogeneous powders can be produced**  
through secondary atomization in a pulsating hot gas stream
- » **Precise particle design**  
with particularly narrow particle size distribution and adaptable surface properties
- » **Defined coatings and core-shell particles**  
with individually adjustable coating thickness, porosity and activity
- » **Precisely definable chemical composition**  
with multiple possibilities of (un)doped or complex oxides
- » **Prevention of hard aggregates**  
due to uniform distribution of particles in the pulsating gas flow
- » **No thermal hotspots in the reactor**  
due to turbulent flow yielding homogeneous thermal treatment of the material
- » **Highest flexibility in process control**  
from room temperature up to 1300°C
- » **Very high heat and mass transfer rates**  
by preventing the formation of boundary layers

## Glatt POWDER SYNTHESIS – APPLICATIONS

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### *Battery Materials*

#### **Active materials and solid electrolytes for solid-state batteries and fuel cells**

Generate your high-quality anode materials such as C/Si composites, cathode materials such as LNMO or solid electrolytes such as LLZO with complex compositions or doping and calcination in a single process step.



### *Ceramic powder materials*

#### **Innovative high-performance ceramics**

Create your high-quality ceramic base material with high sintering activity and precisely defined chemical or mineralogical composition, consisting of materials such as mixed oxides like spinel, perovskite, titanate and many others.



### *Catalytic powder materials*

#### **Future materials for catalysts with exceptional activity**

Produce highly active catalysts by optimizing the chemical composition, size, structure and surface area of the particles. Reduce material usage in catalytically active powders through innovative core-shell structures.



### *Paint and varnish pigments*

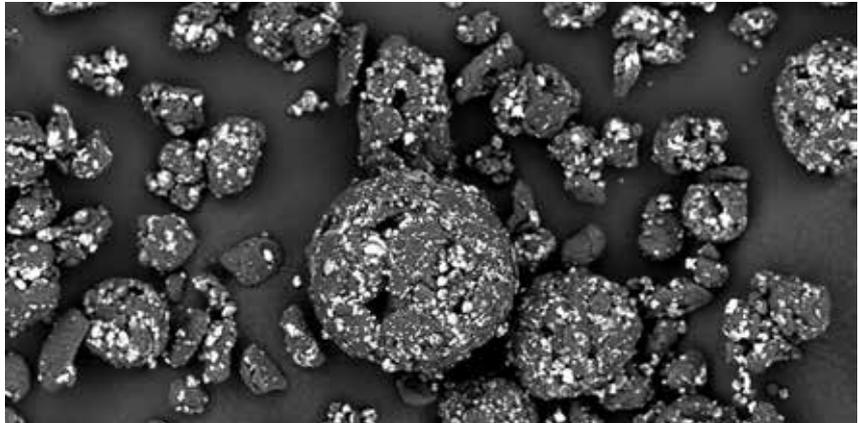
#### **Special pigments with completely new effects and functions.**

Create functionalized pigments, complex mixed oxides or doped materials for use in paints or coatings, for example with self-cleaning properties and/or catalytic activity.

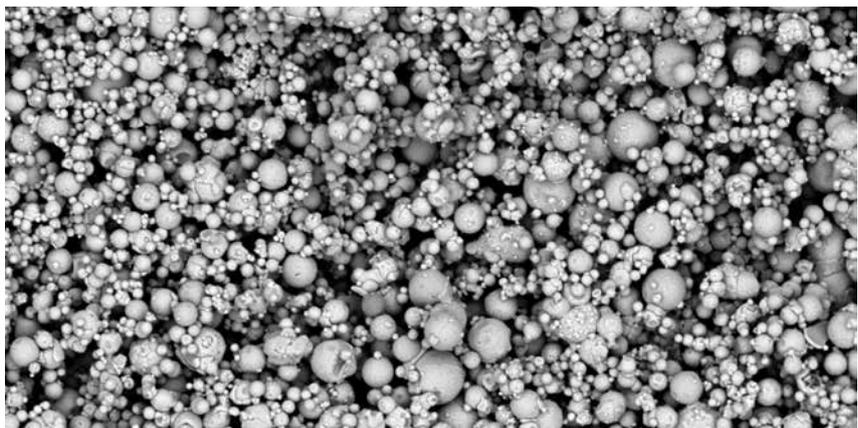
Open new fields of application with Glatt. Define physical properties such as particle structure, composition, surface properties, bulk density, solubility, compressibility or pour ability of your materials. Focus on additional functions such as catalytic activity, controlled release or protection against external influences. With Glatt Powder Synthesis a wide range of options are available. This revolutionary process can be used in all industrial sectors where innovative particle systems are required for high-performance applications.

Generate active materials as the basis for novel battery concepts. Create your raw material for electron and/or ion conducting ceramics or amorphous silicate powders as matting agents.

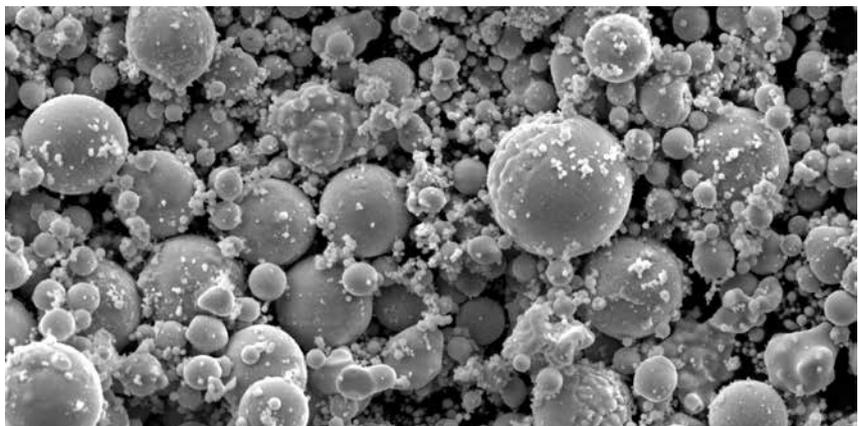
Specialized high-performance materials are the products of the future. Today, powders or granules with specifically adapted properties are used in almost all industries. As a unique technology, Glatt Powder Synthesis generates tailor-made products with precise specifications for countless applications.



*Carbon-silicon anode material*



*Metal oxide powder for catalytic applications*

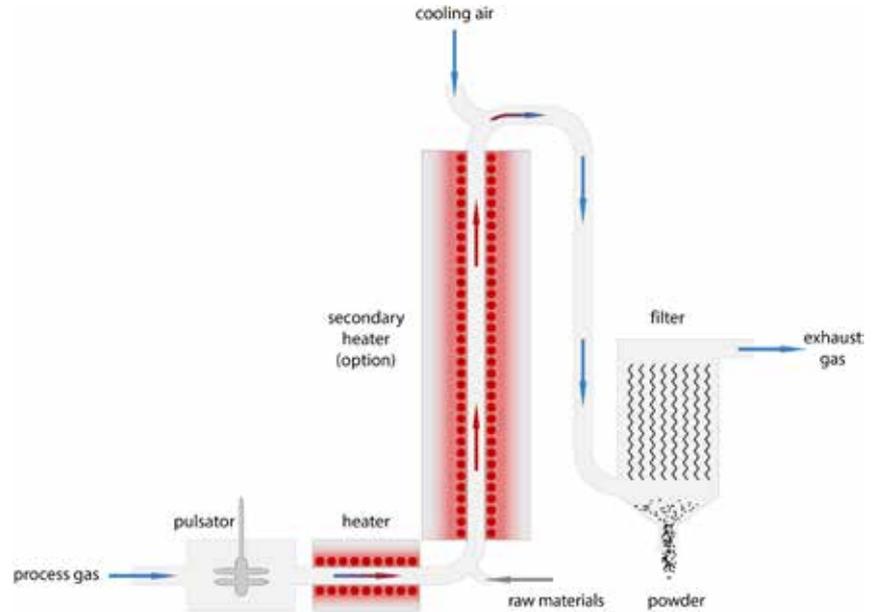


*Barium-strontium-cobalt-iron oxide powder for oxygen membranes and for hydrogen synthesis*

## Glatt POWDER SYNTHESIS – HOW IT WORKS

### *Continuous operation for maximum efficiency*

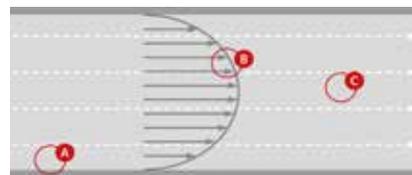
Glatt Powder Synthesis is a process for producing, modifying or coating powder particles in the nanometer and micrometer range. The process runs in a continuously operated pulsating gas stream. Solutions, suspensions or powders are sprayed into this. Depending on the objective, these materials are dried, coated or thermally treated and finally quenched. The entire process takes less than a second.



*Prinzipieller Prozessaufbau der Glatt Pulversynthese zur Erzeugung homogener Mikro- und Nanopulver mit definierbaren Partikeleigenschaften*

### *Pulsating gas flow has a clear advantage*

Pulsation within the reactor has a serious influence on product synthesis. In laminar tube flows, especially close to the walls, well defined gradients in gas temperature and velocity are formed resulting in an inconsistent final product. The high degree of turbulence in Glatt Powder Synthesis homogenizes the conditions across the reactor cross-section. At the same time, the pulsation causes the sprayed droplets to break down into ultrafine droplets, which dry very quickly due to their high specific surface area. Here, too, pulsation proves to be advantageous: the alternating gas velocity prevents the formation of boundary layers, which can hinder material and heat transfer.

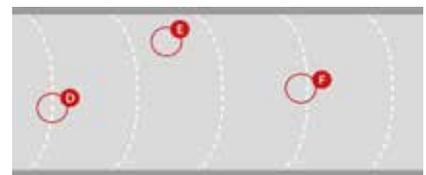


*Laminar flow without pulsation*

(A) Temperature gradients result in different heat treatment depending on position

(B) Velocity gradients result in different residence times of the particles

(C) Low relative velocity between gas flow and particles lead to boundary layers. This results in reduced mass and heat transfer



*Pulsating flow*

(D) The pulses produce superfine droplets by secondary atomization

(E) Equalization of temperature and velocity in the gas flow due to turbulence. Particles are mixed, the residence time homogenized

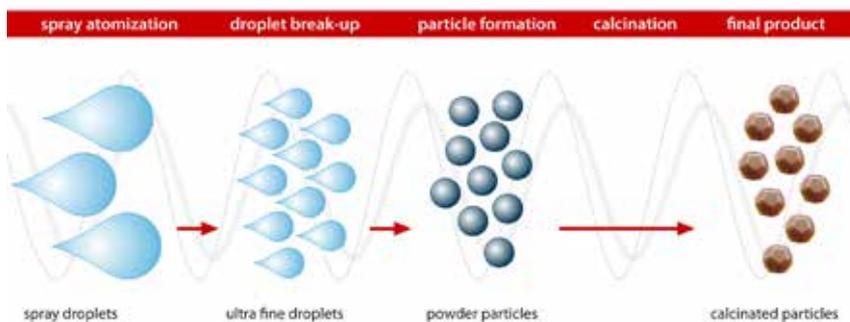
(F) High mass and heat transfer by breaking up the boundary layers.

### *Homogeneous particles with defined structure*

The range of applications for Glatt Powder Synthesis is diverse: homogeneous fine particles are produced from solutions. From suspensions, the generation and calcination of core-shell particles is possible in a sing-

leprocess step. Particle formation supported by pulsation enables the formation of unique structures. Rapid cooling of the powder at the end of the reactor can be used to generate metastable phases to produce highly reactive powders.

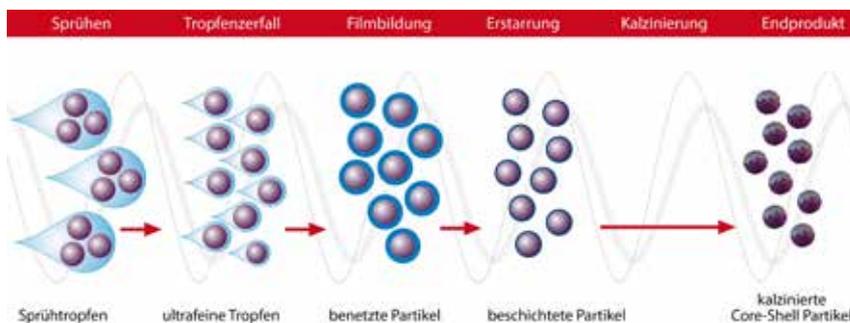
## Spray drying and calcination



In particle design with Glatt Powder Synthesis, the process steps of particle formation, drying, and calcination can be combined in a single step. All particles undergo the same thermal treatment.

- » Spraying a raw material solution into the gas stream creates small primary droplets
- » The interaction between primary droplets and pulsating gas produces even finer secondary droplets
- » The high heat and mass transfer rates cause the solvent to evaporate and powder particles to form in a very short time
- » Optionally, further thermal post-treatment (e. g. calcination) of the product can be carried out in the same process run

## Coating / Core Shell Coating



Glatt Powder Synthesis is also used as a process for coating nano- and micrometer-sized powders. To achieve this, suspensions are used as raw materials. Here, the coating material is dissolved in the liquid phase and is dried onto the core material. If necessary, further thermal post-treatment (e. g. calcination) can be carried out in the same process run. Glatt Powder Synthesis coating processes have the same advantages and thermodynamic conditions as already described.

- » Spraying a suspension into the gas stream produces small primary droplets
- » The pulsating gas flow breaks these up into even smaller droplets
- » Evaporation of the solvent causes the coating material to begin to deposit on the particle surface until all of the solvent has evaporated
- » Optionally, further thermal post-treatment (e. g. calcination) of the product can take place in the same process run

## Glatt POWDER SYNTHESIS – THE PROAPP®-REACTORS

*At the Glatt Technology Center Weimar, ProAPP® synthesis reactors are available in various plant sizes from the development and production of small batches up to industrial production on a ton scale.*



*Glatt synthesis reactor ProAPP® 80 HT*

*The Glatt ProAPP® reactors on the laboratory scale*

ProAPP® synthesis reactors are available for customer trials on a laboratory scale at our Glatt Technology Center in Weimar. Take advantage of the expertise of our process engineers for feasibility studies, the verification of material and/or process ideas and for the production of initial samples and test batches. These systems, with reactor diameters of 80 mm and 100 mm, allow the production of 100 to 500 grams of powder per hour, depending on the raw materials used, and are therefore also ideal for university and industrial research facilities that want to develop a large number of novel product variants in a short time.

### **ProAPP® 80 HT synthesis reactor**

The reactor at the Glatt Technology Center in Weimar has a diameter of 80 mm. The pulsating gas flow is first pre-heated to up to 900 °C in the ProAPP® 80 HT reactor the gas can be heated via a secondary heater with individually

controllable heating segments over the entire length of the reactor. This makes it possible to keep the temperature constant despite evaporation or even to increase it further up to 1300 °C as required by the process.



Glatt synthesis reactor ProAPP® 100

### ProAPP® 100 synthesis reactor

This laboratory unit has a 100 mm reactor tube. Due to the use of a pulsator and an electric heater, process gas temperatures from room temperature up to 900 °C are possible. Short set-up and heating times make the system the ideal tool for synthesis and coating trials at process temperatures up to about 750 °C. The product separation is carried out via a filter. In addition,

small quantities of product can be extracted during operation using a sampler. The small amounts of product can be used for chemical or morphological analysis. Another benefit of this reactor is the modular design which allows customer-specific hardware setups e. g. for particle separation.

## *Pilot scale for safe scale-up / production scale for small and medium campaigns.*

The first tests of your new powders were successful, demand is increasing and now you need more? Not required volumes can be covered by lab scale equipment. The scalability of the process proves to be advantageous. By enlarging the reactor, the throughput can be adapted to your individual requirements. A corresponding pilot plant of the ProAPP® type is also available to you for this purpose at our Glatt Technology Center in Weimar.

High-quality powder materials are often only required in small quantities. For such special materials, a synthesis reactor of this size already represents the production benchmark.



Glatt synthesis reactor ProAPP® 300

### ProAPP® 300 synthesis reactor

Glatt has a ProAPP® reactor with a diameter of 300 mm available as a pilot and production plant. Unlike the laboratory-scale plants, the oldest pulsation reactor at the Weimar site is not heated electrically, but by a pulsating gas burner.

This allows process gas temperatures between 400 °C and 900 °C. For full flexibility, the plant has different systems for product separation, so that both hot as well as cold separation are possible.

The knowledge gained in laboratory tests can be used directly in pilot tests to design production plants. In addition to pilot trials, we also offer contract production on the ProAPP® 300. Up to 300 tons per year can be realized with that reactor.

## Glatt – PARTNER FOR INTEGRATED SOLUTIONS

*Glatt – your development partner for your competitive edge on the market*

The excellently equipped Glatt Technology Center in Weimar allows technical trials on a laboratory scale and the production of test batches for your future products. This is where the relevant process parameters are determined, or samples generated for application trials – up to a low-ton scale if required.



### **Our quality assurance laboratory**

An interdisciplinary team of process engineers, material scientists and chemists evaluate the analytical results and adjust parameters to develop your product.

In order to keep abreast of the latest trends Glatt is actively involved in various publicly funded research projects together with numerous university and industry partners.

*Glatt – your plant manufacturer for planning and execution of your ProAPP® synthesis reactor*

Would you like to implement our pioneering spray calcination process for powder synthesis in at your site?

We would be pleased to design and implement a Glatt Powder Synthesis reactor specifically tailored to your individual needs. Based on the preceding process evaluation, the Glatt Process & Plant Engineering team will design a unit tailored to your requirements and can go as far as engineering a turnkey production site. Worldwide.

Why wait for your own plant? We can produce on your behalf!

With capacity of up to 300 tons per year, the ProAPP® 300 has sufficient capacity for contract manufacturing. Whether for the synthesis of sample quantities or as part of an entire year's production.



*Profit along the entire process chain!*



We support your product idea from the early phase of product formulation to process development and scale-up to production scale. Glatt specializes in intelligent particle design for genera-

ting and functionalization of powders and granules with defined adjustable properties. As a pioneer for processes based on technologies such as fluid bed, spouted bed and Powder Synthe-

sis Glatt has the know-how to formulate and optimize particle properties and can - together with you - select the optimum process for your application.



Glatt Technology Center Weimar



[powdersynthesis.glatt.com](http://powdersynthesis.glatt.com)

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