Promethean Particles design, develop and manufacture inorganic nanoparticle dispersions to our customer’s specifications.

We cover many industry needs such as printed electronics (enabling flexible circuitry, 3D printing etc.), nanocomposites, catalysts, MOFs, healthcare etc. In addition, we work with customers on feasibility studies to tailor a custom made solution for specific requirements.

We use continuous hydrothermal synthesis to make the optimum product for each application and back this up with large scale manufacturing capability, now up to 1000 tons a year in our new premises.

Promethean Particles has the world's LARGEST continuous multi-material nanoparticle manufacturing plant.

The list of dispersions below is non-exhaustive, please get in touch for any specific requirement.
1. Metals
   a. Copper
   b. Silver
2. Metal oxides
   a. Titanium dioxide
   b. Mixed metal oxides
   c. Indium
   d. Zirconium
   e. Cerium
   f. Silicon dioxide / Silica
   g. Barium titanate
   h. Iron oxide (Fe$_2$O$_3$, Fe$_3$O$_4$)
   i. Zinc oxide
3. MOFs
   a. ZIF-8
   b. MIL-53(Al)
   c. HKUST-1
4. Phosphates
5. Precious metals
   a. Gold
   b. Platinum
   c. Palladium
6. Feasibility studies
1. Metals
   a. Copper

   The image above an x-ray diffraction pattern showing the copper structure without any oxide impurity.

   Product Name: Copper nano-dispersion  
   CAS #: 7440-50-8  
   Composition: Copper with oxidative stabiliser  
   Preparation: Nano-dispersion in isopropanol (other media are available)  
   Appearance: dark red  
   Particle size: < 100nm  
   Morphology: Spherical particles  
   Dispersion loading: 50 – 70 wt. %  
   Solvent choice: Material can be readily dispersed into a range of solvents, please contact for more information.

   **Applications:** Printed electronics, conductive inks, antimicrobial applications.
1. Metals
   b. Silver nano-dispersion

<table>
<thead>
<tr>
<th>Product Name:</th>
<th>Silver nano-dispersion</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAS #:</td>
<td>7440-22-4</td>
</tr>
<tr>
<td>Composition:</td>
<td>Silver particles in water</td>
</tr>
<tr>
<td>Preparation:</td>
<td>Nano-dispersion in water (other media are available)</td>
</tr>
<tr>
<td>Appearance:</td>
<td>Grey dispersion</td>
</tr>
<tr>
<td>Morphology:</td>
<td>Spherical particles</td>
</tr>
<tr>
<td>Dispersion loading:</td>
<td>50 – 60 wt. %</td>
</tr>
<tr>
<td>Solvent choice:</td>
<td>Material can be readily dispersed into a range of solvents, please contact for more information.</td>
</tr>
</tbody>
</table>

Applications: Printed electronics, conductive inks, antimicrobial applications.
2. Metal oxides
   
a. Titanium (IV) Oxide Nano-Dispersion

Product Name: Titanium(IV) oxide nano-dispersion
Synonyms: Titanium dioxide, titania
Composition: TiO₂
CAS #: 13463-67-7
Preparation: Aqueous slurry
Appearance: White suspension
Crystal structure: Anatase
Particle size: 5 - 10 nm (by TEM)
Morphology: Spherical particles
Dispersion loading: Up to 10 wt %
Dispersion pH: 1-2

Applications: Cosmetics, solar cells, medical applications, paints and pigments.
2. Metal oxides
b. Zirconium(IV) oxide nano-dispersion

Product Name: Zirconium(IV) oxide nano-dispersion
Synonyms: Zirconium dioxide, zirconia
Composition: ZrO$_2$
CAS #: 1314-23-4
Molecular weight: 123.22
Preparation: Aqueous nano-dispersion
Appearance: Clear/hazy suspension (concentration dependent)
Particle size: 3-5 nm (by TEM)
Morphology: Spherical particles
Dispersion loading: up to 10 wt %
Dispersion pH: 2-4

Applications: Optical polymer modifier, oxygen sensors, solid oxide fuel cells, bioceramics, implant devices, thermal barrier coatings.
2. Metal oxides
   c. Cerium(IV) oxide nano-dispersion

| Product Name: | Cerium(IV) oxide nano-dispersion |
| Composition:  | CeO₂                              |
| CAS #:       | 1306-38-3                         |
| Preparation: | Aqueous slurry                     |
| Appearance:  | Pale yellow/white suspension       |
| Particle size: | 5 - 10 nm (by TEM)                |
|              | 40-50 nm (Z-average, DLS, uncoated particles) |
| Morphology:  | Spherical particles                |
| Dispersion loading: | Up to 10 wt %              |
| Dispersion pH: | 2-4                          |

Applications: Fuel additive, fuel cells, catalysis.
2. Metal oxides
   d. Silicon dioxide

Product Name: Silicon(IV) oxide nano-dispersion
Synonyms: Silica
Composition: SiO₂
CAS #: 7631-86-9
Preparation: Aqueous slurry
Appearance: Clear/hazy suspension
Particle size: <50 nm
Morphology: Spherical particles
Dispersion loading: Up to 10 wt %

Applications: Catalysis, water treatment, ceramics
2. Metal oxides

e. Indium Zinc Oxide Nano-Dispersion
(Upon raw material availability from supplier)

Product Name: Indium zinc oxide
Synonyms: Zinc-doped indium oxide
Composition: $\text{In}_x\text{Zn}_{1-x}\text{O}_y$ (typical In:Zn ratio 14:3)
Preparation: Alcohol-based nano-dispersion, polyol stabilised
Appearance: Clear/hazy pale yellow suspension (concentration dependent)
Particle size: $<50$ nm (by TEM)
Morphology: Spherical particles
Dispersion loading: up to 4 wt %

Applications: Semiconductor pre-ink for thin-film applications, inkjet printable
2. Metal oxides
   f. Barium Titanate Nano-dispersion
      (material still under development)

The images above show a transmission electron micrograph of barium titanate particles and an x-ray diffraction pattern showing the BaTiO$_3$ structure.

<table>
<thead>
<tr>
<th>Product Name:</th>
<th>Barium titanate nano-dispersion</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAS #:</td>
<td>7440-50-8</td>
</tr>
<tr>
<td>Composition:</td>
<td>BaTiO$_3$</td>
</tr>
<tr>
<td>Preparation:</td>
<td>Nano-dispersion in water (other dispersion media are available)</td>
</tr>
<tr>
<td>Appearance:</td>
<td>White dispersion</td>
</tr>
<tr>
<td>Morphology:</td>
<td>Spherical particles</td>
</tr>
<tr>
<td>Dispersion loading:</td>
<td>15 – 25 wt. %</td>
</tr>
</tbody>
</table>

**Applications:** Dielectric material for thin-film applications (printed electronics)
2. Metal oxides

g. Iron oxides

**Product Name:** Iron(III) Oxide  
**Synonyms:** Hematite  
**Composition:** Fe₂O₃  
**CAS #:** 1309-37-1  
**Preparation:** Aqueous slurry  
**Appearance:** Red-brown suspension  
**Morphology:** Spheres or rods  
**Dispersion loading:** Up to 5 wt %

**Applications:** Cosmetics, coatings, paints and pigments, healthcare.

**Product Name:** Iron(II, III) Oxide  
**Synonyms:** Magnetite  
**Composition:** Fe₃O₄  
**CAS #:** 1317-61-9  
**Preparation:** Aqueous slurry  
**Appearance:** Black suspension  
**Morphology:** Spherical particles  
**Dispersion loading:** Up to 10 wt %

**Applications:** Superparamagnetic particles, medical imaging, pigments, healthcare.
3. Metal-Organic Frameworks (MOFs)
   a. ZIF-8

   **Product Name:** ZIF-8  
   **Synonyms:** 2-Methylimidazole zinc salt.  
   **Composition:** C₈H₁₀N₄Zn  
   **Preparation:** Powder  
   **Appearance:** White powder  
   **Surface area:** ~2000 m²/g (BET)

   **Applications:** Gas storage (e.g. H₂, CO₂), sensors, catalysis, gas/liquid separations
4. Metal-Organic Frameworks (MOFs)
   b. MIL-53(Al)

Product Name: MIL-53(Al)
Syonyms: Aluminum terephthalate.
Composition: C₈H₅AlO₅
Preparation: Powder
Appearance: White powder
Surface area: ~1100 m²/g (BET)

Applications: Gas storage (e.g. H₂, CO₂), sensors, catalysis, gas/liquid separations
4. Metal-Organic Frameworks (MOFs)

c. HKUST-1

**Product Name:** HKUST-1

**Synonyms:** Copper benzene-1,3,5-tricarboxylate, Cu-BTC, Copper trimesate

**Composition:** C\textsubscript{18}H\textsubscript{6}Cu\textsubscript{3}O\textsubscript{12}

**Preparation:** Powder

**Appearance:** Blue powder

**Surface area:** ~2000 m\textsuperscript{2}/g (BET)

**Applications:** Gas storage (e.g. H\textsubscript{2}, CO\textsubscript{2}), sensors, catalysis, gas/liquid separations

We are able to offer a large variety of other MOFs such as Ni-74, CPO-27 and many others. Other metal-ligand combinations are also available. Please contact us for any specific requirement and we will be happy review your requirements.
4. Phosphates

a. Hydroxyapatite, rod morphology

Product Name: Hydroxyapatite, rod morphology
Synonyms: Calcium hydroxyphosphate, calcium phosphate tribasic, HA, HAp, hydroxylapatite
Composition: Ca₅(PO₄)₃OH
CAS #: 12167-74-7
Molecular weight: 502.31
Preparation: Aqueous slurry
Appearance: White suspension
Particle size: 30-50 nm diameter (by TEM)
Morphology: Rod
Dispersion loading: up to 15 wt %
Dispersion pH: 9-10

Applications: Bioceramic coatings, bone fillers, prosthetics, dental products
4. Phosphates

b. Hydroxyapatite, sheets

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Hydroxyapatite, sheets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synonyms</td>
<td>Calcium hydroxyphosphate, calcium phosphate tribasic, HAp, hydroxyapatite</td>
</tr>
<tr>
<td>Composition</td>
<td>( \text{Ca}_5(\text{PO}_4)_3\text{OH} )</td>
</tr>
<tr>
<td>CAS #</td>
<td>12167-74-7</td>
</tr>
<tr>
<td>Molecular weight</td>
<td>502.31</td>
</tr>
<tr>
<td>Preparation</td>
<td>Aqueous slurry</td>
</tr>
<tr>
<td>Appearance</td>
<td>Off-white suspension</td>
</tr>
<tr>
<td>Particle size</td>
<td>0.5 - 1 ( \mu \text{m} )</td>
</tr>
<tr>
<td>Morphology</td>
<td>Sheets</td>
</tr>
<tr>
<td>Dispersion loading</td>
<td>Up to 10 wt %</td>
</tr>
<tr>
<td>Dispersion pH</td>
<td>7-8</td>
</tr>
</tbody>
</table>

**Applications:** Bioceramic coatings, bone fillers, prosthetics, confectionery.
5. Precious metals
   a. Gold

- **Product Name:** Gold
- **Composition:** Au
- **CAS #:** 7440-57-5
- **Molecular weight:** 196.97
- **Preparation:** Aqueous dispersion
- **Appearance:** Various colours
- **Particle size:** 10-50 nm diameter (by DLS)
- **Morphology:** Spherical
- **Dispersion loading:** up to 5 wt %

**Applications:** Catalysis, diagnostics
6. Precious metals
   b. Platinum

Product Name: Platinum
Composition: Pt
CAS #: 7440—06-4
Molecular weight: 195.08
Preparation: Aqueous slurry
Appearance: Black dispersion
Particle size: 20-40 nm diameter (by TEM)
Morphology: Spherical
Dispersion loading: up to 10 wt %

Applications: Catalysis, diagnostics
6. Precious metals
   • Palladium

<table>
<thead>
<tr>
<th>Product Name:</th>
<th>Palladium nanodispersion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composition:</td>
<td>Pd</td>
</tr>
<tr>
<td>CAS #:</td>
<td>7440-05-3</td>
</tr>
<tr>
<td>Molecular weight:</td>
<td>106.42</td>
</tr>
<tr>
<td>Preparation:</td>
<td>Aqueous slurry</td>
</tr>
<tr>
<td>Appearance:</td>
<td>Black suspension</td>
</tr>
<tr>
<td>Particle size:</td>
<td>20-40 nm diameter (by TEM)</td>
</tr>
<tr>
<td>Morphology:</td>
<td>Spherical</td>
</tr>
<tr>
<td>Dispersion loading:</td>
<td>up to 10 wt %</td>
</tr>
</tbody>
</table>

**Applications**: Catalysis, diagnostics
FEASIBILITY STUDIES

Promethean Particles work with customers on feasibility studies to tailor a custom made solution for specific requirements. Please enquire for the cost of feasibility studies into alternative materials, such as investigation of other compositions, particle size, different morphologies, doping and/or surface coatings.

At the end of the feasibility study, the customer has the possibility to own foreground IP for the material in their application.

As the next step, the customer can:

- Manufacture the dispersion at their facilities (the customer’s)
- Have their dispersion manufactured by Promethean Particles
- Utilize one of Promethean Particles’ reactors under license

For more information on our reactor range, please consult our reactors brochure.