BASF Temperature Sensing

catalysts.bASF.com/tempsensing
www.exactus.bASF.com
Temperature sensing
Delivering process insights to increase yields

- **What we do:** Accurate, precise measurement of mission critical temperatures

- **How we do it:**
  - Deep customer process knowledge in markets served
  - Products include precious metal (PM) thermocouples, IR optical pyrometers, thermocouple recycling services, calibration services
  - Global footprint and over 60+ years high temperature process experience

- **Markets we serve:**
  - Glass, semiconductor, heat treating, crystal growth, solar, gas turbine, and heat treating
  - Expanding into petrochemical and refinery
Expertise in high temperature applications
- Vast experience in applications from 1000 to 3000° C
- Experts in PM and Refractory TCs

Technical application assistance
- Provide technical assistance on specialized designs

Diversified Technology Platforms

Full service precious metal provider
- Refining, PM management

High quality standards – ISO 9001: 2015 certified
Full Precious Metal Provider

Global refining capabilities – BASF has refineries in the U.S. and Europe with the ability to provide full global refining services. Other suppliers do not have direct refining capabilities thus requiring them to go-to a 3rd party for their refining. This can add cost and time to the refining process.

- BASF also has the capability to refine unique items such as crucibles and large ceramic bottom blocks. We provide these services at no extra charge

Pool account management – BASF’s PM expertise provides full precious metal management services including the following benefits –

- PM buying and selling
- PM leasing
- Secured vault

Retentions – Because of our refining capabilities, BASF’s retentions are the lowest in the industry
## Temperature sensing

### Portfolio technologies & operations

<table>
<thead>
<tr>
<th>PM Thermocouple</th>
<th>Optical Pyrometry</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description</strong></td>
<td></td>
</tr>
<tr>
<td>Contact</td>
<td>Non-contact</td>
</tr>
<tr>
<td>Types R, S, B, P</td>
<td>Infrared</td>
</tr>
<tr>
<td>Consumable</td>
<td>Longer service life</td>
</tr>
<tr>
<td><strong>BASF’s Advantage</strong></td>
<td></td>
</tr>
<tr>
<td>Proprietary Fibro® technology</td>
<td>Accuracy, precision, speed</td>
</tr>
<tr>
<td>Longer life or reduced PM</td>
<td>Exactus® patented edge</td>
</tr>
<tr>
<td>ISO 9001:2017 Certified</td>
<td></td>
</tr>
<tr>
<td>ISO 17025:2017 Certified</td>
<td></td>
</tr>
<tr>
<td><strong>Production</strong></td>
<td></td>
</tr>
<tr>
<td>Fremont, CA</td>
<td>Portland, OR</td>
</tr>
<tr>
<td>Fremont, CA</td>
<td>Fremont, CA</td>
</tr>
<tr>
<td><strong>Hand assembly following Lean Manufacturing principles</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Made-to-order with lead times ranging 3 days to 8 weeks</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Precious metal recovery services</strong></td>
<td></td>
</tr>
<tr>
<td><strong>EH&amp;S</strong></td>
<td></td>
</tr>
<tr>
<td>Products are Articles, with no hazardous materials involved</td>
<td></td>
</tr>
<tr>
<td>Ergonomics and complacency are largest risks</td>
<td></td>
</tr>
<tr>
<td>Awards recognize success building interdependent culture</td>
<td></td>
</tr>
<tr>
<td>Received Safety Award of Excellence for a total of 12 years</td>
<td></td>
</tr>
<tr>
<td>Working towards &quot;zero waste&quot;</td>
<td></td>
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</tbody>
</table>
Temperature sensing
PM thermocouple technologies

- Precious metal thermocouples are used in higher operating temperatures and provide higher accuracy and lower drift vs traditional base metal TCs
- BASF Proprietary designs and materials create competitive advantage
  - Fibro® wire: Reduces cost by extending service life or reducing precious metal content
  - Enclad® designs offer diffusion barrier to reduce drift
  - Sheath materials specially selected to reduce drift via metal transport
PM expertise lead to Fibro®
How Fibro® benefit’s customers

- Failure mechanism of pure Pt wire
  - Time at temp grain growth
  - Grain growth leads to grain slippage – And open junctions

- BASF’s technical innovation
  - Fibro® developed
    - Fibrous grain structure
    - Oriented longitudinally
  - Testing confirms improved mechanical stability
How to take advantage of Fibro®
How Fibro® benefit’s all industries

- Constant diameter wire
  - Increased lifespan
  - Significantly reduced grain growth delays grain slippage
- Smaller diameter
  - Equivalent lifespan at lower PM content
  - Mechanical stability increase allows smaller gauge to match lifespan of pure Pt
Temperature sensing
Major industries we serve

- Petro Chemical
- Metal
- Glass
- Semiconductor
- Heat Treating
- Gas Turbine
Temperature sensing
Semiconductor industry
### Temperature sensing
#### Semiconductor industry

<table>
<thead>
<tr>
<th>Semi/Wafer Fab</th>
<th>Solar Wafer Fab</th>
<th>Exactus® Pyrometer &amp; Thermocouples</th>
<th>Exactus® Market expansion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Diffusion Processes</strong></td>
<td><strong>Diffusion Processes</strong></td>
<td><strong>Epitaxial Processes</strong></td>
<td><strong>Semiconductor</strong></td>
</tr>
<tr>
<td>- Profile – Spike TCs</td>
<td>- Profile – Spike TCs</td>
<td>- Epi TCs</td>
<td>- Backend</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Exactus®</td>
<td></td>
</tr>
</tbody>
</table>
Temperature sensing
Glass industry

- Served glass markets
  - Container
  - Float
  - Fiberglass
  - TV Glass, Lighting
  - Tableware
- Extensive experience
- Technology leader
- Global Presence
Temperature sensing
Glass industry

- More than 60 years experience in the High Temperature technology
- Our Technology gives solutions to improve your process and reduce your cost of ownership
BASF’s advanced designs
How BASF’s designs benefit glass industry

- **Reduced PM content and optimized TC life**
  - **Utilization of Fibro® wire** – Significantly reduce PM content while maintaining TC longevity
  - **Grain Stabilized Thimbles** – Eliminated Rh in Thimbles, TCs can be used in ALL glass chemistries (no sulfur attack from Amber Glass)
  - **Reduced wall thimbles** – Used in HWA design to minimize PM content and maximize life
  - **Advanced Alloy for Support Pipe** – Significantly reduces thimble length and provides better structural support than Alumina support designs. Can reduce PM content by 50%
# Temperature sensing

## BASF ENCLAD® Thermocouples

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ENCLAD® cable</strong></td>
<td>Mineral insulated precious metal thermocouple cable</td>
</tr>
<tr>
<td><strong>Standard ENCLAD® thermocouples</strong></td>
<td>With plugs, connectors &amp; special vacuum seals</td>
</tr>
<tr>
<td><strong>Composite-sheath ENCLAD® thermocouples</strong></td>
<td>With plugs, connectors &amp; special vacuum seals, Combine precious metals with base metal</td>
</tr>
</tbody>
</table>

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[Image of ENCLAD® Thermocouples]

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[Logo: BASF]

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[Text: We create chemistry]
Temperature sensing
BASF ENCLAD® thermocouples – gas turbine application

- Qualification Testing
  - Land Based
  - In-Flight
- Engine Development
  - High Temperature Testing
- In-Flight Experience
  - Platinel®
- Work with Leading Manufacturers
  - GE
  - Honeywell
  - Pratt & Whitney
  - Rolls Royce
Temperature sensing
Global temperature sensing footprint

- **USA - Fremont, CA**: Mfg, customer service, global engineering, refining
- **Portland, OR**: Mfg, application development, R&D
- **Iselin, NJ**: Sales, general management, Catalyst Global HQ (Temperature Sensing is part of Catalyst)
- **Italy – Rome**: Customer service, global engineering, EU sales
- **Germany – Frankfurt**: EMEA sales office
- **Singapore**: Customer service, sales, PM recovery
Fremont Operations
(Epi, Diffusion, Control, Glass, Enclad, W/Re)
3rd Silicon Valley location since 1980

- Stand-alone, dedicated location
- Clean room for Semi products
- Freeze Point and Comparison Calib.
- ISO 9000 certified
- Award-winning LEAN manufacturing
- Sr. leaders 20-30 years experience
- Fastest turnaround of orders
- Expandable, flexible workforce
# Temperature sensing
BASF contacts for Temperature Sensing Group

## BASF – Temperature Sensing Products

<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
<th>Email</th>
<th>Phone</th>
<th>Fax</th>
<th>Cell</th>
</tr>
</thead>
<tbody>
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<td>+1 (510) 417-5152</td>
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<td>+1 (510) 490-0651</td>
<td>+1 (510) 944-3421</td>
</tr>
</tbody>
</table>
We create chemistry