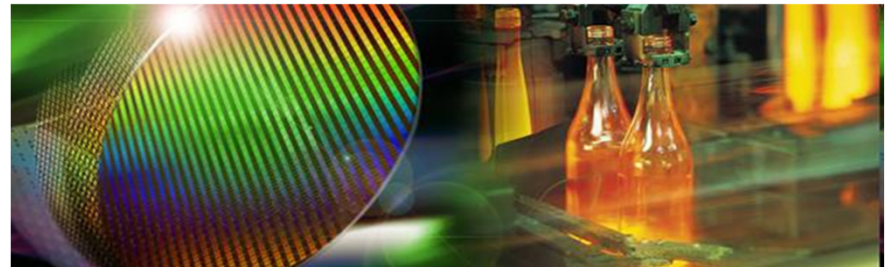


BASF Temperature Sensing

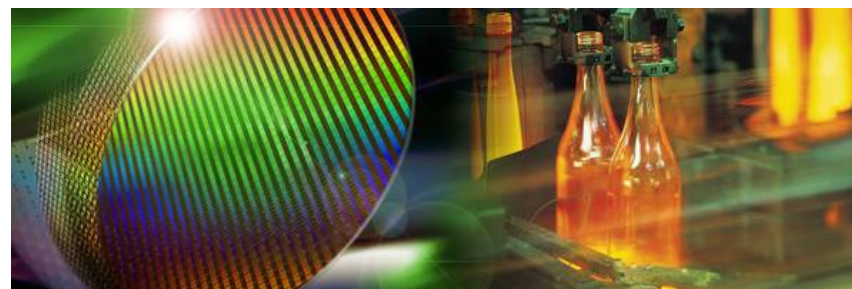
catalysts.basf.com/tempsensing
www.exactus.basf.com



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



Temperature sensing

Our strengths

- 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



Temperature sensing

Our strengths

- **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

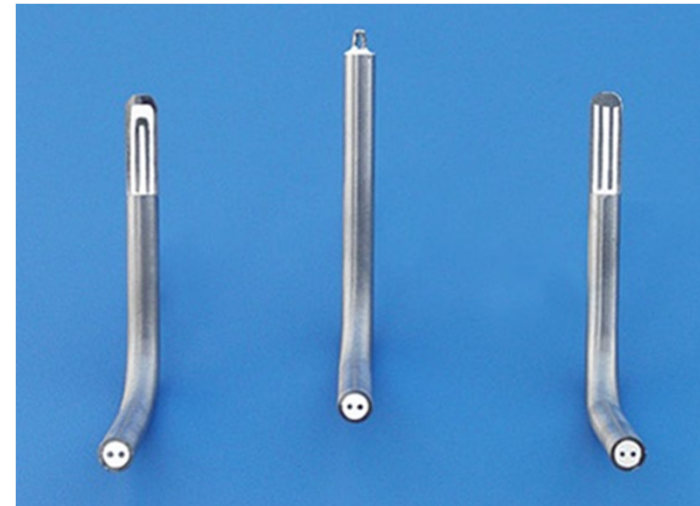
Portfolio technologies & operations

	PM Thermocouple	Optical Pyrometry
Description	<ul style="list-style-type: none">■ Contact■ Types R, S, B, P■ Consumable	<ul style="list-style-type: none">■ Non-contact■ Infrared■ Longer service life
BASF's Advantage	<ul style="list-style-type: none">■ Proprietary Fibro® technology■ Longer life or reduced PM■ ISO 9001:2017 Certified■ ISO 17025:2017 Certified	<ul style="list-style-type: none">■ Accuracy, precision, speed■ Exactus® patented edge
Production	<ul style="list-style-type: none">■ Fremont, CA	<ul style="list-style-type: none">■ Portland, OR■ Fremont, CA
	<ul style="list-style-type: none">■ Hand assembly following Lean Manufacturing principles■ Made-to-order with lead times ranging 3 days to 8 weeks■ Precious metal recovery services	
EH&S	<ul style="list-style-type: none">■ Products are Articles, with no hazardous materials involved■ Ergonomics and complacency are largest risks■ Awards recognize success building interdependent culture■ Received Safety Award of Excellence for a total of 12 years■ Working towards "zero waste"	

Temperature sensing

PM thermocouple technologies

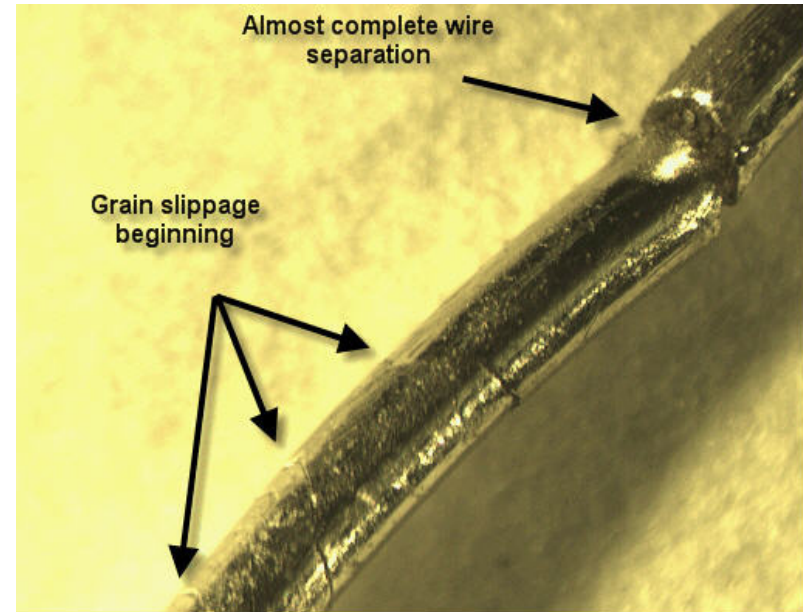
- Precious metal thermocouples are used in higher operating temperatures and provide higher accuracy and lower drift vs traditional base metal TCs
- BASF Proprietary designs and materials create competitive advantage
 - ▶ Fibro[®] wire: Reduces cost by extending service life or reducing precious metal 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

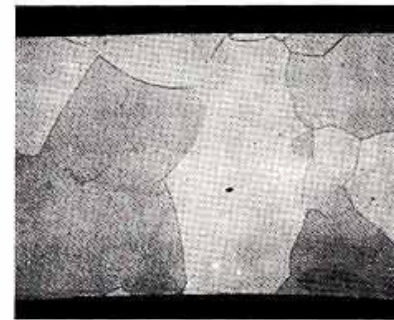
- Failure mechanism of pure Pt wire
 - ▶ Time at temp grain growth
 - ▶ Grain growth leads to grain slippage – And open junctions
- BASF's technical innovation
 - ▶ Fibro® developed
 - Fibrous grain structure
 - Oriented longitudinally
 - ▶ Testing confirms improved mechanical stability



How to take advantage of Fibro®

How Fibro® benefit's all industries

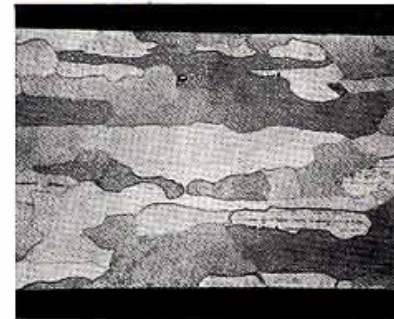
- Constant diameter wire
 - ▶ Increased lifespan
 - ▶ Significantly reduced grain growth delays grain slippage
- Smaller diameter
 - ▶ Equivalent lifespan at lower PM content
 - ▶ Mechanical stability increase allows smaller gauge to match lifespan of pure Pt



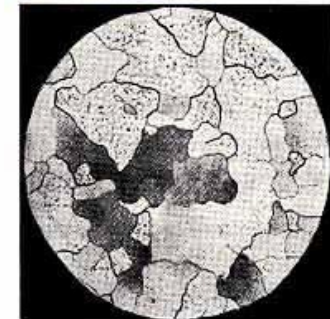
C.P. Pt-Longitudinal



C.P. Pt-Cross Section



Fibro Pt-Longitudinal



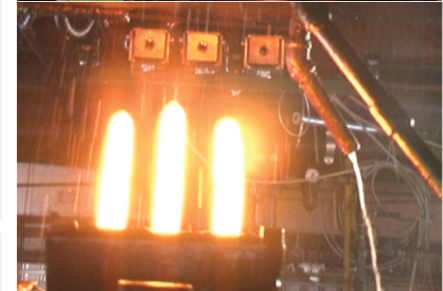
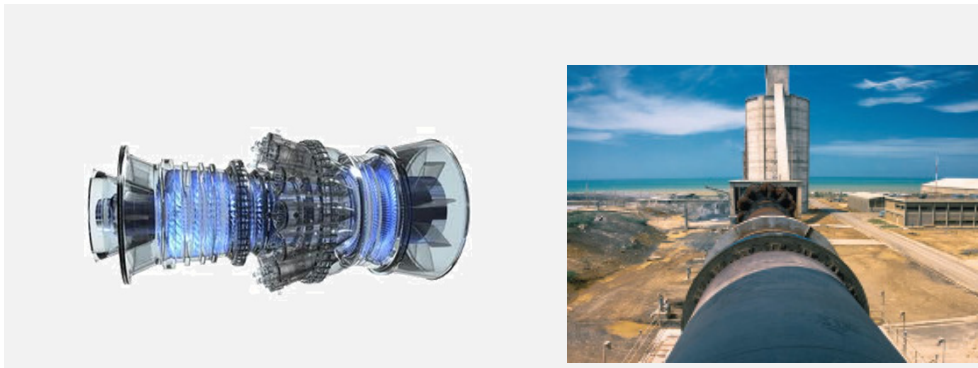
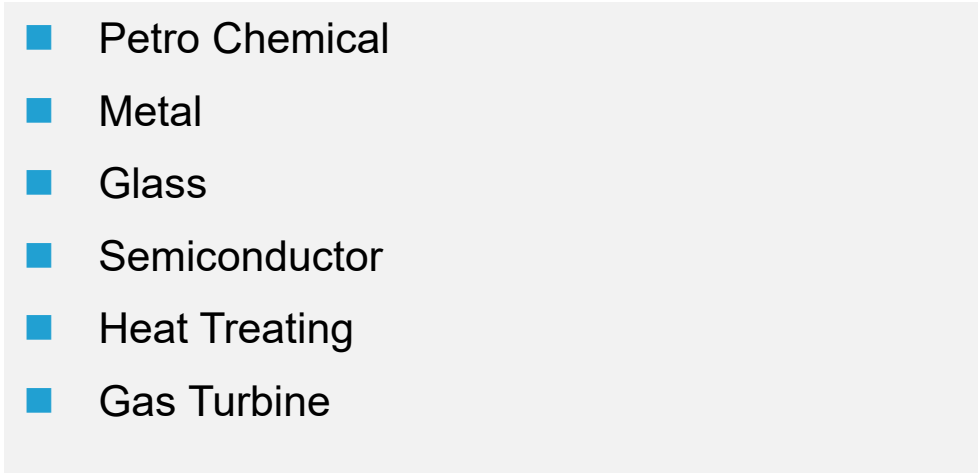
Fibro Pt-Cross Section

Photo micrograph of .032 dia. Fibro Pt wire and C.P. Pt wire after being heated to 1400°C for 10 hours. Longitudinal and cross section. Note the reduced grain growth of Fibro Pt (100x reduced 50%).

Temperature sensing

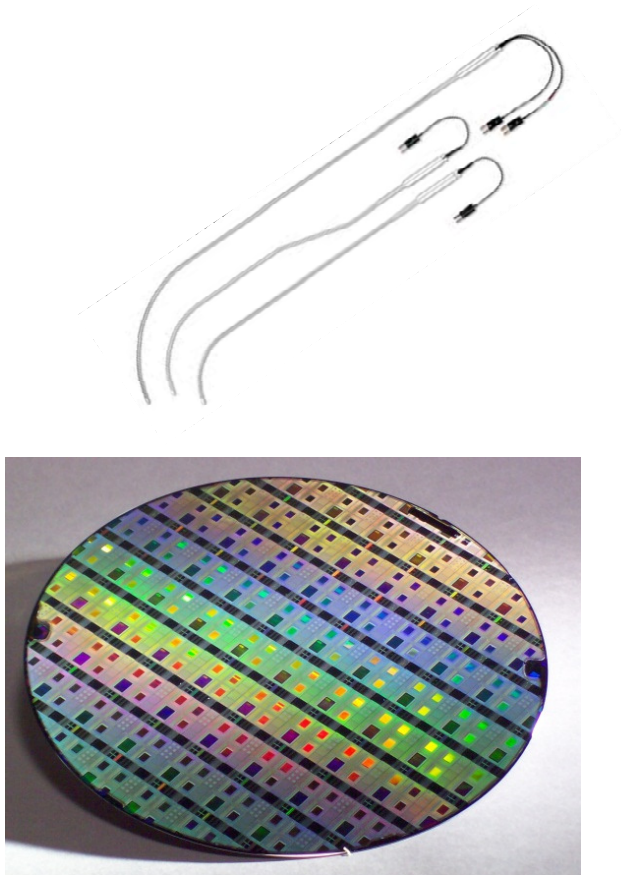
Major industries we serve

- Petro Chemical
- Metal
- Glass
- Semiconductor
- Heat Treating
- Gas Turbine



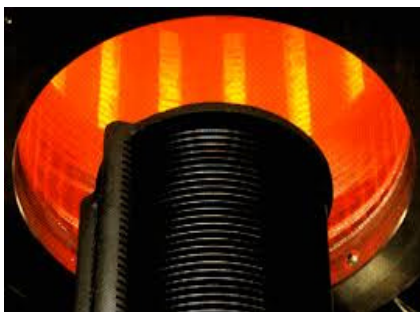
Temperature sensing

Semiconductor industry



Temperature sensing

Semiconductor industry



Semi/Wafer Fab

Diffusion Processes

- Profile – Spike TCs



Solar Wafer Fab

Diffusion Processes

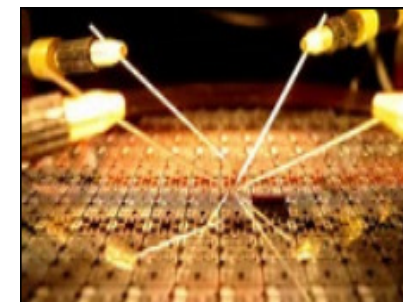
- Profile – Spike TCs



Exactus® Pyrometer & Thermocouples

Epitaxial Processes

- Epi TCs
- Exactus®



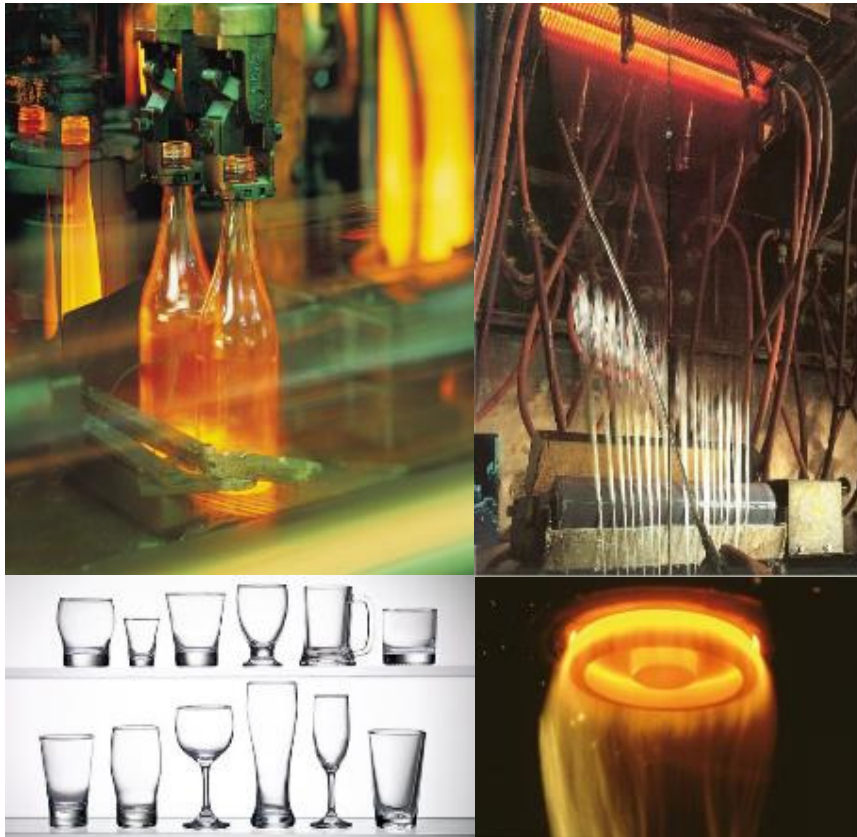
Exactus® Market expansion

Semiconductor

- Backend

Temperature sensing

Glass industry

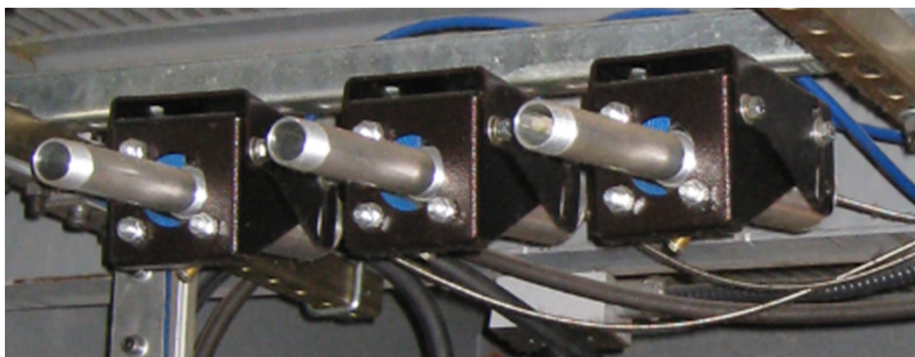


- Served glass markets
 - ▶ Container
 - ▶ Float
 - ▶ Fiberglass
 - ▶ TV Glass, Lighting
 - ▶ Tableware
- Extensive experience
- Technology leader
- Global Presence

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



Optical Pyrometers



Thermocouples

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

ENCLAD[®] cable

- Mineral insulated precious metal thermocouple cable

Standard

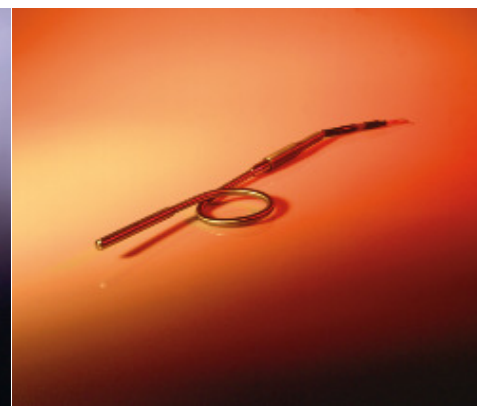
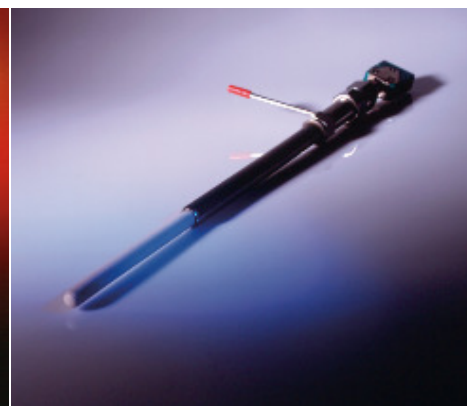
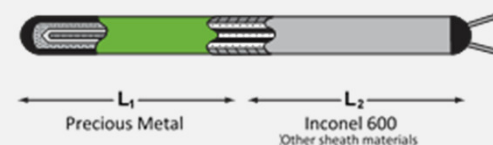
ENCLAD[®] thermocouples

- With plugs, connectors & special vacuum seals

Composite-sheath

ENCLAD[®] thermocouples

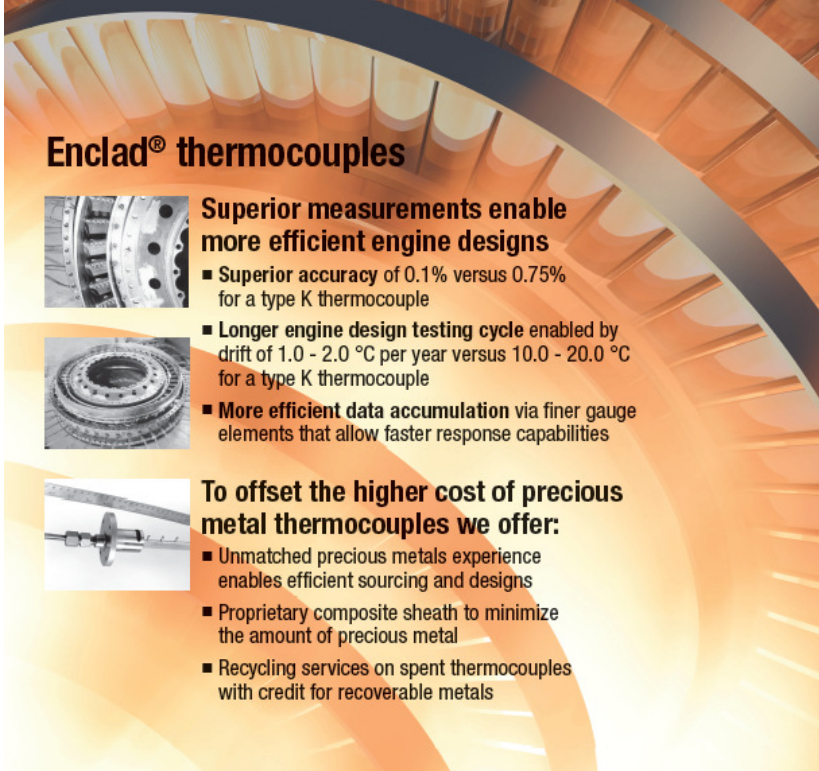
- With plugs, connectors & special vacuum seals
- Combine precious metals with base metal



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

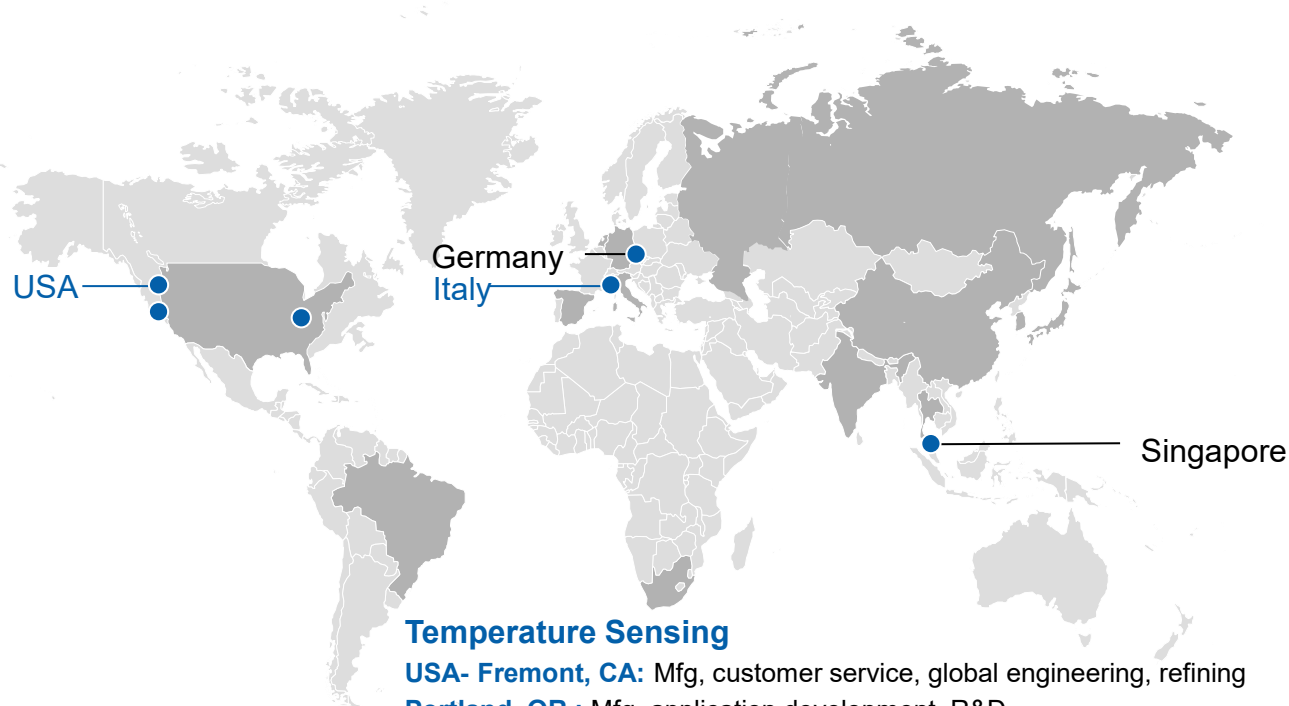


Enclad[®] thermocouples

- Superior measurements enable more efficient engine designs
 - Superior accuracy of 0.1% versus 0.75% for a type K thermocouple
 - Longer engine design testing cycle enabled by drift of 1.0 - 2.0 °C per year versus 10.0 - 20.0 °C for a type K thermocouple
 - More efficient data accumulation via finer gauge elements that allow faster response capabilities
- To offset the higher cost of precious metal thermocouples we offer:
 - Unmatched precious metals experience enables efficient sourcing and designs
 - Proprietary composite sheath to minimize the amount of precious metal
 - Recycling services on spent thermocouples with credit for recoverable metals

Temperature sensing

Global temperature sensing footprint



- **Temperature Sensing**

Temperature Sensing

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

BASF Corporation 46820
Fremont Blvd Fremont,
CA 94538, USA Tel: +1(510) 490-2150

BASF Italia Srl
Via di Salone 245, 00131 Roma, Italy
Tel:+3906 4199 2357

	Phone	Fax	Cell
James Peterson General Manager james.peterson@basf-catalystsmetals.com	+1 (510) 445-6119	+1 (510) 490-0651	+1 (248) 310-5711
Louisa DeGroen Global Sales Manager – Semi louisa.degroen@basf-catalystsmetals.com	+1 (925) 866-1710	+1 (510) 490-0651	+1 (510) 417-5152
John J Grossi Technical Sales Manager john.grossi@basf-catalystsmetals.com	+1 (928) 681-2847	+1 (510) 490-0651	+1 (510) 396-4132
Mark Foerch Sales Manager – Europe mark.foerch@basf-catalystsmetals.com	+49 173 3478850	+49 6103 9888250	+49 173 3478850
Tia Silva Customer Care Manager tia.silva@basf-catalystsmetals.com	+1 (510) 490-2150 Ext. 105	+1 (510) 490-0651	+1 (510) 944-3421

 **BASF**

We create chemistry