Fuel Processor Catalysts for Fuel Cells

BASF
The Chemical Company

BASF FUEL PROCESSOR CATALYSTS

BASF – The Chemical Company

Just as catalysts make the right reactions happen, so do we. Our process catalysts and technologies combine the strength of BASF – The Chemical Company, with the experience of our chemists and engineers and expertise in process technology.

Our dedication to catalyst chemistry results in products and services that meet and exceed customer expectations and requirements. We are committed to work diligently with you to understand your needs and translate them into the right product for your process.

WE CATALYZE YOUR PROCESS

You Benefit from a Broad Range of Competencies

We offer a broad variety of technologies and products to the fuel cell industry. With our long term experience in the fuel processor area, we deliver a wide variety of adsorbents and catalysts needed to generate hydrogen for fuel cell applications.

The catalysts are used for but not limited to the following applications:

- Desulfurization
- Reforming
- High and low temperature CO-Shift
- CO fine polishing
- Anode tail gas oxidation

Product Line

D Series Catalysts + Adsorbents	R Series Catalysts	S Series Catalysts		CO Series Catalysts
Sulfur Removal	Steam Reforming (SRM) Autothermal Reforming (ATR)	High Temperature CO-Shift	Low Temperature CO-Shift	CO Removal
FUEL → H_2				
25–50°C	500–900°C	250–400°C	180–300°C	80–240°C

D SERIES CATALYSTS + ADSORBENTS SYSTEMS FOR SULFUR REMOVAL

Sulfur – A Challenge for Fuel Cell Systems

Natural gas and liquefied petrol gas contain a range of sulfur compounds which petroleum can severely deactivate fuel processor or fuel cell catalysts.

BASF D Series adsorbents and catalysts are used to remove sulfur before the fuel is fed into the reformer. D Series products have been qualified for numerous fuel cell units. Our D Series adsorbents are key to providing uninterruptable power for data centers and hospitals – in a highly efficient and reliable way.

D Series Catalysts Benefits:

- High desulfurization capacity
- Suitable for a wide range of sulfur components
- Simple and robust desulfurization solution

D Series – Improved Solutions for Sulfur Removal

Sulfur Removal	Steam Reforming (SRM) Autothermal Reforming (ATR)	High Temperature CO-Shift	Low Temperature CO-Shift	CO Removal
FUEL → H_2				
25–50°C	500–900°C	250–400°C	180–300°C	80–240°C

D Series Product Portfolio

BASF offers a wide range of desulfurization materials for a variety of operation and system conditions. Together with our customers, we can then identify the most appropriate product to efficiently and effectively remove sulfur from the natural gas and LPG feeds.

Usually, a two-stage adsorption process is most efficient. For special cases, a hydrodesulfurization or oxidation sulfur removal can be offered.

Product	Removal Type	Selectivity	Metal Type	Typical Operating Temperature	Shape
Two-Stage Sulfur Removal Adsorbents					
DP-45	Stage I, Removal of inorganic components	H_2S, COS, Mercaptanes and THT	Base Metal	<250°C	Pellets
DP-100/ DP-200 DP-300/ DP-330	Stage II, Removal of organic components	THT, DMS, Disulfides	Zeolite	<50°C	Extrudates
Selective Catalytic Sulfur Oxidation (SCSO)					
DM-80	Conversion of organic and inorganic compounds to SO_2/SO_3	Conversion of sulfur compounds to SO_2/SO_3 (Oxidation)	Precious Metal	250–275°C	Monoliths
DP-20	SO_2 removal	Trap for SO_2	Base Metal	250–400°C	Extrudates
DP-25	SO_2/SO_3 removal	Trap for SO_2/SO_3	Base Metal	250–400°C	Extrudates

Keep the sulfur in a cool place with our desulfurization materials.

25–50° Celsius

R SERIES CATALYSTS
CATALYSTS FOR REFORMING

Materials for Steam and Autothermal Reforming of Different Fuels

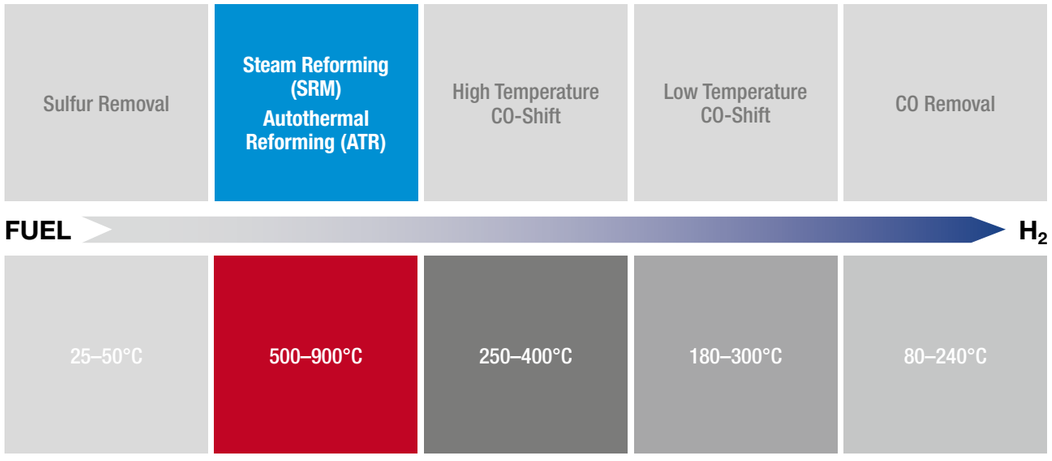
Hydrogen production is one of the key factors involved in the development of fuel cells. As hydrogen is not widely and economically available, hydrogen for fuel cells must be produced from hydrocarbon feedstocks such as natural gas, LPG, gasoline, diesel and alcohols.

Hydrogen production must therefore be accomplished on a much smaller scale than conventional industrial production of hydrogen. Hence, new technologies for reforming are required, and this necessitates new developments in catalysts. Consequently, our R Series Catalysts keep residential homes powered at any time.

R Series Catalysts Benefits:

- Resistant to frequent load changes and start/stop cycles
- Operation at high space velocity
- Enable compact reformer design
- Tolerant to liquid water
- Tolerant to air

R Series – Improved Solutions for Reforming



R Series Product Portfolio

BASF offers a wide range of reforming catalysts, both base metal and precious metal materials, for different fuels and reforming technologies.

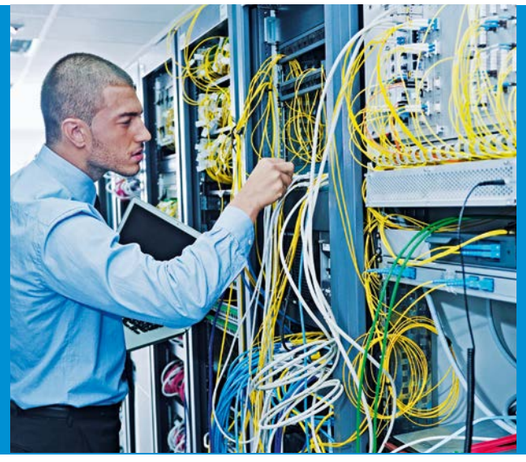
Monoliths: Powerful catalysts with astonishingly low pressure drop.
Pellets: Durable and efficient, non precious metal containing catalysts – ideal for any reactor design.

Product	Fuel Feed	Metal Type	Typical Operating Temperature	Typical Operating Space Velocity (hr^{-1})
Monoliths				
RM-47	LPG, NG*	Precious Metal	550–850°C	<30,000
RM-75	NG	Precious Metal	550–850°C	<30,000
RM-05	Methanol	Precious Metal	250–400°C	<30,000
Pellets				
RP-61	NG, pretreatment of C_2 + hydrocarbons	Base Metal	380–550°C	<8,000
RP-75	NG	Base Metal	400–750°C	<10,000
RP-60	Methanol	Base Metal	200–290°C	<10,000

* Has potential to work on gasoline, diesel fuels

Our catalysts will take the hot seat – to give you hydrogen.

500–900° Celsius



S SERIES CATALYSTS
CATALYSTS FOR CO-SHIFT REACTIONS

High Temperature CO-Shift

Fuel processors must be able to withstand frequent start-ups and shutdowns as well as condensing and vaporization cycles. In addition, oxygen breakthrough from the upstream reformer during the start-up is always possible. Conventional CO-Shift catalysts react rapidly with oxygen, resulting in temperature excursions and damaging the material. Therefore, a new generation of high temperature CO-Shift catalysts using precious metal instead of base metal was developed with outstanding performance and stability.

Low Temperature CO-Shift

BASF offers a new generation of Cu-catalysts for low temperature CO-Shift that tolerates changes in atmospheres without any loss in activity. These catalysts can be used in the temperature range from 180–280°C and can tolerate peak temperatures of 320°C. Used as small pellets, high specific activity of this material is ensured. Another benefit is the strong adsorption of trace sulfur compounds from the reformate stream, protecting the fuel cell against impurities.

S Series Catalysts Benefits:

- Precious and base metal catalysts
- Outstanding performance and stability
- High specific activity

Back-up and off-grid systems can count on maximum performance of our S Series Catalysts – whenever they need it.

S Series –
Improved Solutions for CO-Shift Reactions

Sulfur Removal	Steam Reforming (SRM) Autothermal Reforming (ATR)	**High Temperature CO-Shift**	**Low Temperature CO-Shift**	CO Removal
FUEL →				**H_2**
25–50°C	500–900°C	250–400°C	180–300°C	80–240°C

S Series Product Portfolio

CO-Shift catalysts for low and high temperature applications.
BASF offers both base metal and precious metal catalysts.

Product	Temperature Shift	Metal Type	Typical Operating Temperature	Typical Operating Space Velocity (hr^{-1})	Shape
SP-01	High Temperature	Precious Metal	250–450°C	<15,000	Pellets
SM-06	High Temperature	Precious Metal	250–400°C	<15,000	Monoliths
SP-60	Low Temperature	Base Metal	190–280°C	<8,000	Pellets

High or low – our catalysts will give you the best.

180–400° Celsius

CO SERIES CATALYSTS
CATALYSTS FOR CO REMOVAL

Highly Selective Catalysts for CO Removal

Low temperature fuel cell systems tolerate only small amounts of carbon monoxide (CO). Depending on the operating temperature of the CO-Shift catalyst, some thousand ppm of CO have to be converted to carbon dioxide (CO_2). BASF offers different catalytic approaches:

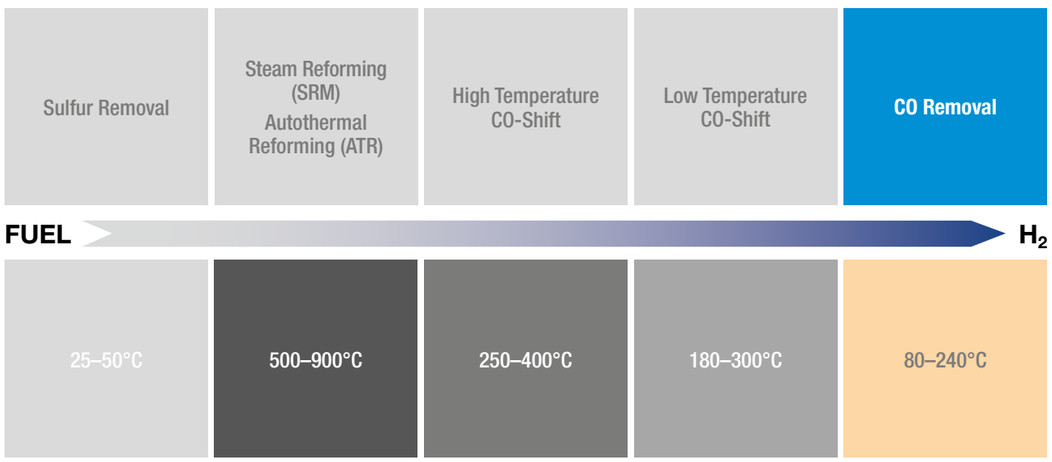
- Catalysts for CO-selective methanation
- Catalysts for CO-selective oxidation
- Catalysts for Tail Gas Oxidation. BASF offers catalysts to remove CO and VOC from tail gas streams to meet emission regulations and/or to generate heat.

CO Series Catalysts will keep your portable fuel cell systems healthy – no matter what.

CO Series Catalysts Benefits:

- Robust material
- Long lifetime
- Outstanding performance
- Tailored solutions

CO Series – Improved Solutions for CO Removal



CO Series Product Portfolio

BASF offers a wide range of CO removal materials for a variety of operating and system conditions.

Product	Combustion Type	Metal Type	Typical Operating Temperature	Typical Operating Space Velocity (hr^{-1})	Shape
Selective CO Removal					
COM-01	Preferential Oxidation	Precious Metal	90–200°C	<40,000	Monoliths
COP-01	Selective Oxidation	Precious Metal	80–160°C	<12,000	Pellets
COP-03	Selective CO Methanation	Precious Metal	180–260°C	5,000	Pellets
Tail Gas Oxidation					
COM-03	Methanol Combustion	Precious Metal	200–700°C	20,000–78,000	Monoliths
COM-10	H_2 & CO Combustion	Precious Metal	<1,000°C	<200,000	Monoliths
COM-100	H_2, CH_4 & CO Combustion	Precious Metal	400–750°C	<50,000	Monoliths

Our catalysts are picky, when they have to be.

80–240° Celsius

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About Us

BASF's Catalysts division is the world's leading supplier of environmental and process catalysts. The group offers exceptional expertise in the development of technologies that protect the air we breathe, produce the fuels that power our world and ensure efficient production of a wide variety of chemicals, plastics and other products, including advanced battery materials. By leveraging our industry-leading R&D platforms, passion for innovation and deep knowledge of precious and base metals, BASF's Catalysts division develops unique, proprietary solutions that drive customer success.

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BF-9208 A4 Rev. 05/13

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