FCC catalyst boosts bottoms upgrade

A combination of novel matrix technologies in a new FCC catalyst increased bottoms upgrading of residual feeds and improved profitability

OLAF PETER HARTMETZ and BERNHARD ZAHNBRECHER *Bayernoil*
SABEETH SRIKANTHARAJAH and MARIA LUISA SARGENTI *BASF*

Since the beginning of 2020, most of the recognised analyst companies have been making predictions about the refining products market, first related to the impact of IMO 2020 and later to Covid-19. We have seen how refineries are more and more under pressure. It is not unexpected that they will continue to struggle with challenges that include more physical constraints, increasing costs of environmental regulations, changing and declining demand of products, and additional supply issues.

In particular, the combination of a narrowing crude market and weak demand is set to keep refining margins at historic lows over the coming months and FCC units will face more challenges to maximise their profits.[1,2]

What will be the threats for FCC operation? Probably there is not a unique answer to this question. The observed trends require the FCC unit to be able to deliver a favourable contribution to profitability and – in most units – to maximise its capacity to process residual feeds.

Implementation of the IMO regulations already resulted in drastically changing markets and created short-term opportunities requiring refiners to show maximum adaptability to capture value. Thus it has become imperative that refiners take advantage of the most effective options available to them. Resid feeds are known to be an example of opportunity crudes that can drive higher profitability for a refinery, given their low purchase cost. However, the processing of this type of crude requires flexible operation and catalyst to convert such crudes to lighter molecules and higher value products.[3]

More residue processing and optimised slurry oil production requires the catalyst to further upgrade bottoms and provide additional unit flexibility by overcoming and releasing operational constraints.

BASF has been targeting catalytic solutions to fulfill the need for resid FCC units to anticipate IMO challenges among others. The primary focus was, in one direction, maximisation of processing capacity for residual streams or, alternatively, optimisation of slurry oil production. Both routes would support FCC operation to achieve the target product slate in preparation for IMO implementation.

The observed trends require the FCC unit to be able to deliver a favourable contribution to profitability and – in most units – to maximise its capacity to process residual feeds

As a result, BASF has introduced the next generation of catalyst for moderate resid operations, Altrium, with a focus on three key functionalities:

- Higher meso-macro porosity for a better pore connectivity network to increase diffusion and conversion of large molecules
- Enhanced nickel passivation capabilities to minimise dry gas and coke yields
- Maximum light cycle oil (LCO) to bottoms conversion to generate more valuable products.

In addition, the benefits delivered by Altrium helped to release the unexpected additional pressures and operational disruptions caused by Covid-19.

Linking the benefits

Altrium is based on the combination of two technologies: AIM (Advanced Innovative Matrix) and IZY (Improved Zeolite-Y). These technologies have been linked to deliver high performance and value for moderate resid processing applications.

AIM consolidates several novel matrix technologies that are selectively incorporated into the catalyst design for a broad selection of performance targets and applications. It offers the flexibility to fine-tune the zeolite to matrix ratio in order to maximise conversion to transportation fuels.

With the introduction of AIM, BASF initiates a new generation of matrix families capable of delivering high performance through improved porosity which further enables the diffusion of large molecules to more and better distributed active sites.

Furthermore, the matrix and zeolite in Altrium are produced in a single manufacturing process step to make sure they are intimately dispersed and adjacent to each other. This *in situ* process enables maximum flexibility and control of matrix morphology, resulting in a catalyst with higher attrition resistance, no chloride, and the lowest sodium content available.

The manufacturing process allows for additional flexibility. Firstly, a

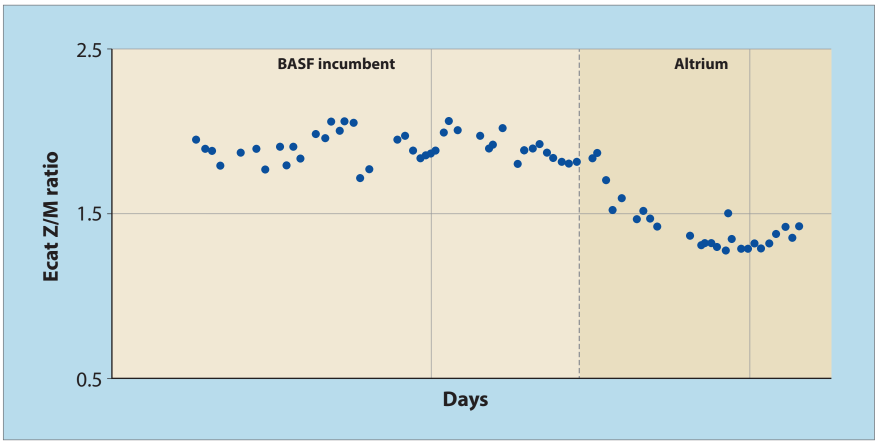

Figure 1 Trend of Ecat Z/M ratio during the change to Altrium FCC catalyst

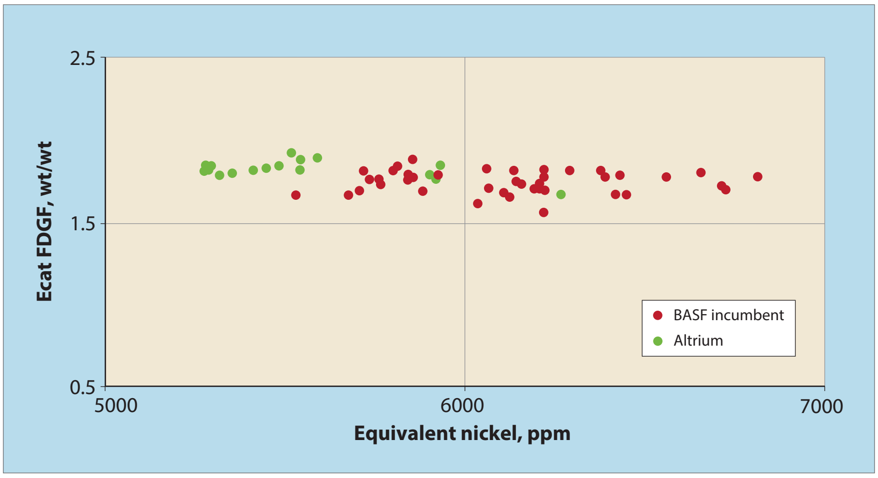

Figure 2 Trend of Ecat fluidised dry gas factor vs equivalent nickel (ACE data)

catalyst microsphere is manufactured from kaolin clay and functional matrix raw materials. Then zeolite is grown within the microsphere. Nutrients for zeolite growth are provided by the microsphere itself, giving rise to the term *in situ*. Because the zeolite is grown directly on the microsphere, an epitaxial layer is formed, eliminating the need for a separate binder. By using the *in situ* process, higher levels of zeolite can be included in the catalyst. Additionally, the process leads to a more open pore architecture, allowing for improved metals tolerance.

Commercial trial

Bayernoil Refinery GmbH is a refinery group of Varo Energy GmbH, Rosneft Deutschland GmbH, and Eni Deutschland GmbH. The company operates the largest refinery in the Bavarian region, ensuring security of supply in the region.

Production at Bayernoil has been running since 1964 on an area of about 300 ha southwest of the city of Neustadt. The refinery is supplied with crude oil from Trieste via the Transalpine Pipeline, producing propane and butane, refining gas, all types of gasoline, diesel, and light and heavy fuel oil.

Through continuous modernisation of the process plants and integration of the latest process technologies, it is one of the most productive refineries in the region with a Nelson Complexity Index of 8.1.

Operational background

The FCC unit at Bayernoil Neustadt is a UOP stacked design with 30 000 b/d processing capacity, operating in deep partial burn using a catalyst from BASF (the "incumbent"). Resid feedstock with high metals and Concarbon is converted to valuable products.

Due to changes in the market environment, increasing the LCO output as well as gasoline and LPG volumes has become more attractive for refineries. Altrium was introduced to increase yields of transportation fuels and to improve the overall profitability of the operation.

To maximise the profitability of the refinery, the FCC catalyst is designed to meet the specific requirements of the unit by means of its metals tolerance, surface area, rare earth on zeolite, matrix type, and pore architecture. Firstly, the pore architecture requires optimisation to facilitate the diffusion of heavy feed molecules and to help improve heavy molecule (bottoms) cracking. Secondly, the relative zeolite and matrix content requires optimisation to prioritise conversion or distillate yield.[4]

Altrium FCC catalyst has been fine-tuned and customised to achieve new operating targets for Bayernoil. To that end, the catalyst's design features include:

- A lower zeolite to matrix ratio (Z/M)

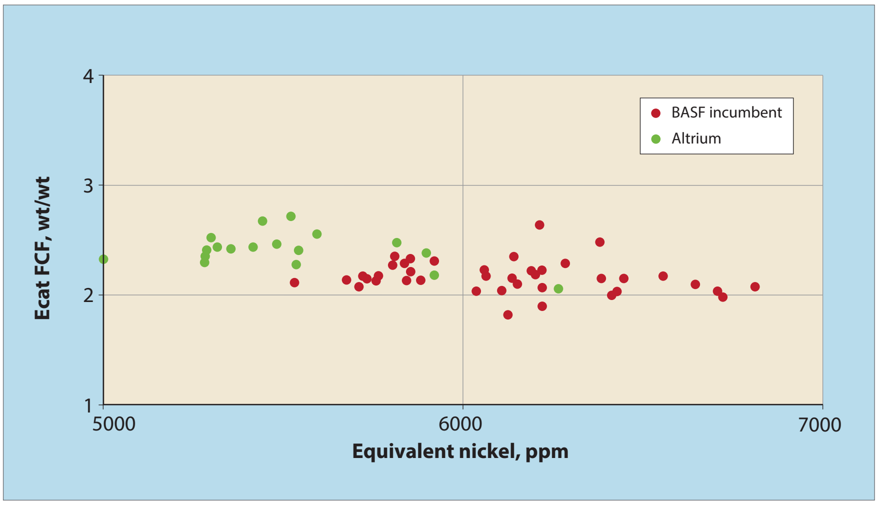

Figure 3 Trend of Ecat fluidised coke factor vs equivalent nickel (ACE data)

• Good metals tolerance, to maximise bottoms upgrading whilst maintaining low dry gas
• Ensuring that carbon on regenerated catalyst (CRC) is maintained at a low level to avoid disruption of the partial burn regime.

Figure 1 shows the trend of Ecat Z/M values while the unit was changing from the incumbent BASF catalyst to Altrium. A catalyst with lower Z/M will improve conversion of bottoms since the matrix surface area has been optimised to promote the cracking of heavy molecules and for pre-cracking oil to 'feed' the zeolite.

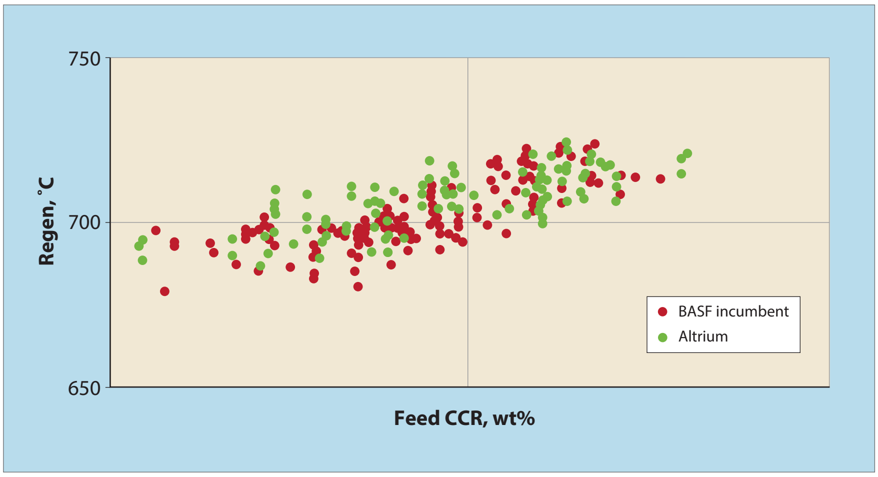

Figure 4 Trend of regenerator temperature vs feed Conradson carbon residue

The regenerator temperature is influenced by many factors including operating conditions, catalyst activity, feed qualities, and more

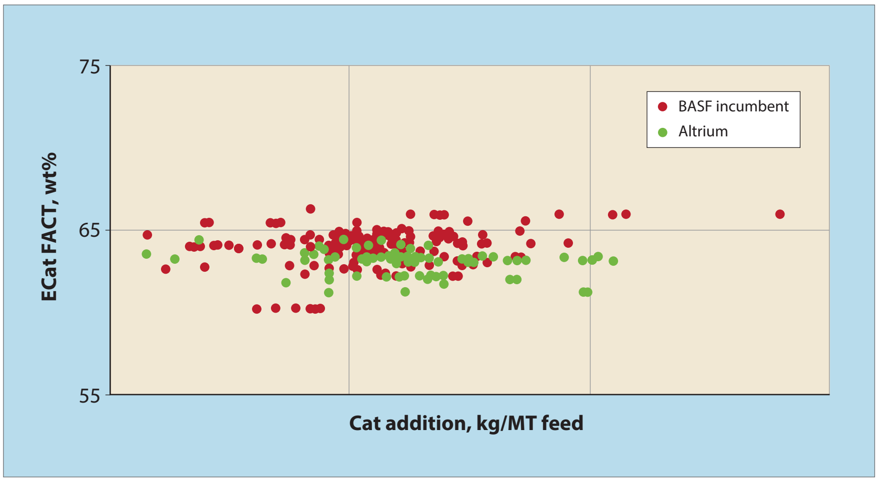

Figure 5 Trend of Ecat activity vs specific catalyst addition rate

Ecat comparison

The progress of the commercial trial has been monitored with regular evaluation of Ecat in the Advanced Cracking Evaluation (ACE) unit. The fluidised dry gas factor (FDGF) is the dry gas production (C_2 and lighter) adjusted for conversion. Hydrogen product, and therefore FDGF, is strongly influenced by metals contamination. With Altrium, the FDGF has been maintained through the full range of typical metals levels (see **Figure 2**). This means reliable operation of a wet gas compressor that has not been impacted by changes in dry gas yields.

In the same way, the fluidised coke factor (FCF) provides a measure of the coke of the equilibrium catalyst adjusted for conversion (see **Figure 3**). In this case, the performance has been maintained constant over a broad range of metals levels, normalised to nickel equivalent. This trend is particularly important to deliver a stable regenerator temperature and delta coke during the operation whilst improved conversion is achieved.

FCC operating conditions during the trial

The regenerator temperature is influenced by many factors including operating conditions, catalyst activity, feed qualities, and more. **Figure 4** shows that similar regenerator temperatures were maintained with the new catalyst while processing feeds in the typical Conradson carbon residue (CCR) range.

The reported Ecat activity, known as FACT (fluidised activity test), is the weight percent conver-

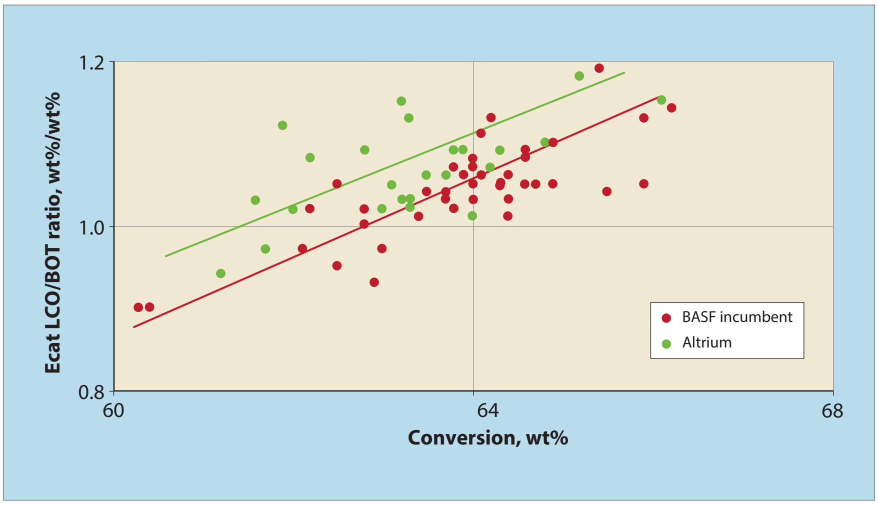

Figure 6 Comparison of Ecat LCO/BOT vs conversion (ACE data)

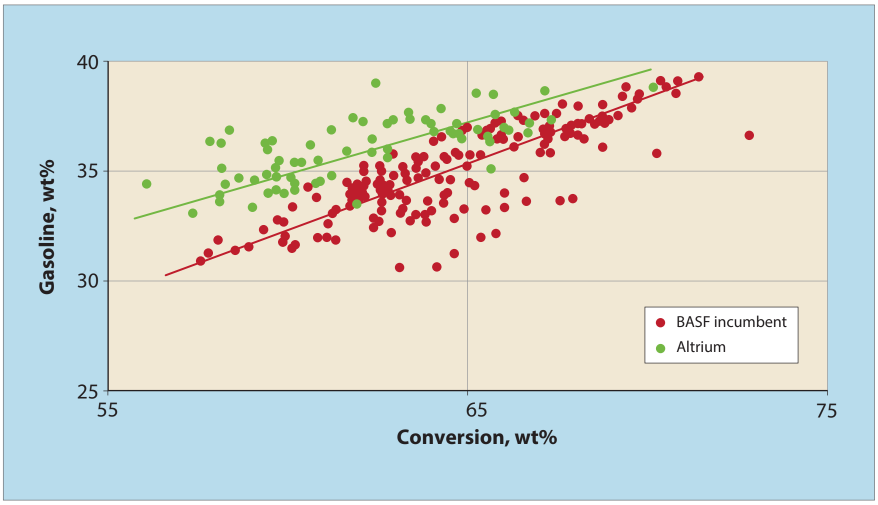

Figure 7 Comparison of gasoline yields vs conversion in the FCC unit

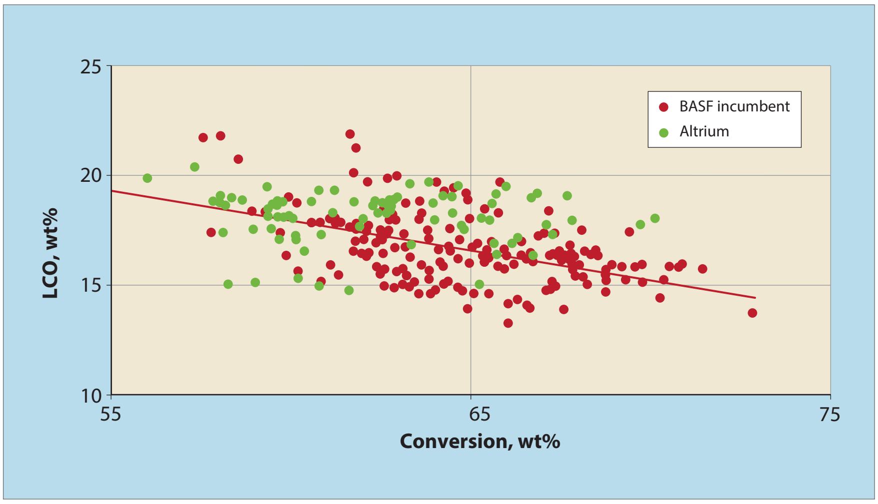

Figure 8 Comparison of LCO yields vs conversion in the FCC unit

sion obtained for a catalyst sample in an ACE unit run with a standard feedstock. It has been constant at the specific catalyst addition rates range used for the operation (see **Figure 5**). Since in-unit conversion is a function of FCC process conditions, feedstock properties, and catalyst properties, FACT activity provides a separate evaluation of the catalyst's contribution to unit conversion. With Altrium, the Ecat activity of the inventory was stable within the typical range of specific catalyst addition rates used at Bayernoil.

FCC unit performance

With Altrium, the light cycle oil to bottoms ratio (LCO/BOT) improved (see the Ecat comparison data (ACE) in **Figure 6**). This improved performance led to increased conversion to valuable products. This has been achieved thanks to the conversion of big molecules. With the new catalyst, the highly dispersed zeolite crystals on the surface of the stable, proprietary matrix provide access for feed cracking. The feed then cracks on active material, rather than on an amorphous matrix, thereby improving selectivity and reducing formation of coke. At the same time, over-cracking is minimised due to a reduction of secondary diffusion of cracked products to the zeolite residing internally. The net result is high bottoms conversion with low coke, and higher yields of valuable liquid products during the operation.

The contribution of the new catalyst to product yields can be seen in **Figures 7** and **8**. Overall, Altrium contributed to improved bottoms upgrading, resulting in less slurry (reduced by approximately 2.5-3.0 wt%, see **Figure 9**), and more valuable products, gasoline, and LCO.

Improvement in profitability

The economic performance delivered by Altrium was estimated based on the normalised yields

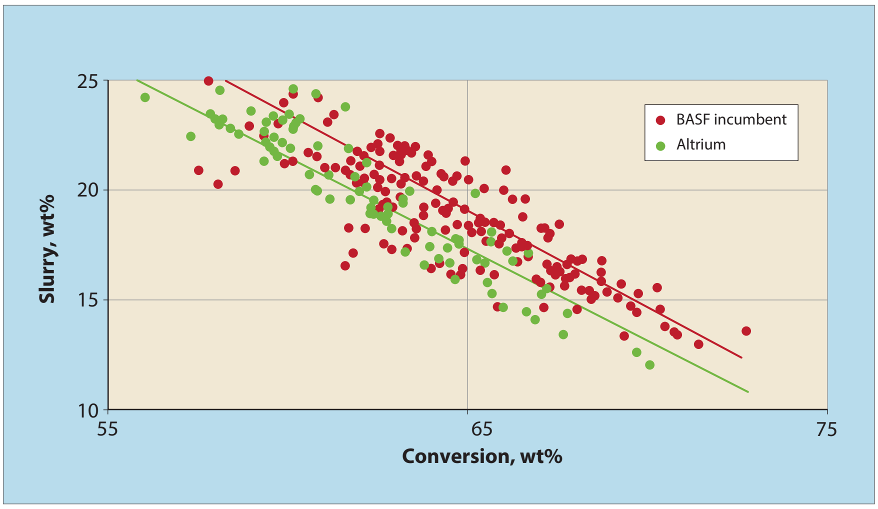

Figure 9 Comparison of slurry yields vs conversion in the FCC unit

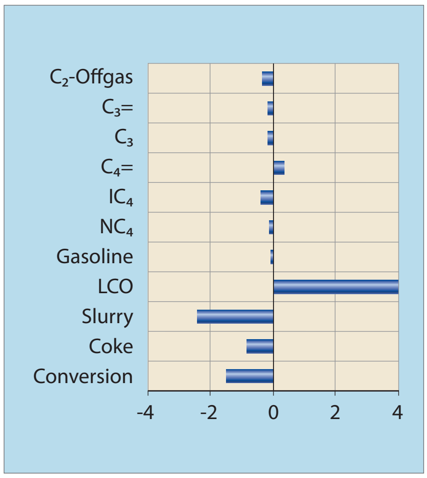

Figure 10 Comparison of performance based on normalised yields

shown in **Figure 10**. The normalised values show that gasoline yields were preserved while coke and slurry yields were reduced. The conversion was calculated as:

100 – light cycle oil (LCO wt%) – Bottoms (BOT wt%)

Thus the conversion obtained decreased in favour of more valuable LCO yields.

Under these conditions and using standard refinery product prices, an improvement in profitability of $0.50-0.60/bbl was achieved. Nevertheless, during actual operation the product slate was further optimised to take advantage of market conditions.

Conclusion

A combination of the latest BASF matrix technologies in the new Altrium FCC catalyst demonstrated superior performance and delivered additional benefits to Bayernoil Neustadt's FCC unit operation. While maintaining reliable and stable operation, the refiner increased bottoms upgrading of residual feeds into more valuable products.

Strong collaboration between Bayernoil Neustadt and BASF Refinery Catalysts enabled a better understanding of the refiner's needs, enabling BASF to deliver a customised solution and to secure successful performance in the unit.

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Olaf Peter Hartmetz is Senior Process Engineer FCC and SMR Commercial Optimisation and Troubleshooting at Bayernoil Neustadt refinery. He holds a diploma in chemical engineering from Karlsruhe Institute of Technology. *Email: OlafPeter.Hartmetz@bayernoil.de*

Bernhard Zahnbrecher is Senior Process Engineer and FCC Technology Expert for mid- and long-term projects at Bayernoil Neustadt refinery. He holds a diploma engineer degree (MS) in technical chemistry.
Email: Bernhard.Zahnbrecher@bayernoil.de

Sabeeth Srikantharajah is Additives & Technical Account Manager EMEA with BASF SE, Germany. With over 20 years' experience in the oil industry and refinery operations he specialises in the FCC process, technology, equipment and catalysis. He holds a diploma in chemical engineering from the University of Applied Science Münster.
Email: sabeeth.srikantharajah@basf.com

Maria Luisa Sargenti is Technology and Technical Marketing Manager with BASF SE, Germany. With 20 years' experience in different industrial applications and several technical and commercial roles, she holds an MSc in chemical engineering from the University Simon Bolivar, Venezuela and an EMBA from the Vertice Business School, Madrid, Spain. *Email: maria-luisa.sargenti@basf.com*