Meet the Paradigm Buster

An interview with John Lockemeyer,
Principal Researcher at Shell Catalysts & Technologies

Right now, in engineering offices, subcontractor workshops and project sites around the world, scores of ethylene oxide (EO) projects are under way. Their owners are keen to bring them online to benefit from ever-growing need for EO and monoethylene glycol as highly valued chemical intermediates.

In part, EO producers are reaping high returns from such projects because of the dramatic improvements in EO catalyst performance that have been made over the years by Shell. One of the most prominent individuals in this domain is John Lockemeyer, Principal Researcher, Shell Catalysts & Technologies (formerly CRI Catalyst Company)1, whose original contributions to EO catalyst development were recognised with the Southwest Catalysis Society's 2018 Award for Excellence in Applied Catalysis.

In this interview, John discusses the approaches he has taken to make major improvements in catalyst technology through deep understanding of fundamental aspects of catalysis and practical application in operating companies.

[1] In 2019, Shell combined its catalyst and licensing businesses which had been operating under the brands CRI Catalyst Company, Criterion Catalysts & Technologies and Shell Global Solutions into a single integrated business – Shell Catalysts & Technologies.

SHELL CATALYSTS & TECHNOLOGIES
TRANSFORMING ENERGY TOGETHER

QUESTION

John, you and your colleagues call yourselves the Paradigm Busters! Would you elaborate on that?

When we were developing Shell Catalysts & Technologies' high-performance (HP) EO catalyst family [see Figure 1 for the innovation timeline of four of Shell Catalysts & Technologies' five catalyst families], there were six generally held beliefs about commercial EO catalysts that turned out to be either outdated or incorrect when we examined them closely. Working through each of these myths led to a catalyst with far greater selectivity and activity stability than any previous EO catalyst.

We made phenomenal progress by challenging common beliefs. You often find that paradigms exist as folklore well beyond the technology to which they were originally applied. Many of our successes have come from challenging paradigms and asking hard questions about why those beliefs are in place.

I tend to ask the scientists and engineers questions such as, "Why can we not do such and such?". If the answer is, "That is just the way it is; it is the way it has always been," then I see that as an area ripe for exploration. If you challenge a paradigm, you typically find that it has outlasted its reason for existing, and that means that there is an opportunity to invent.

.

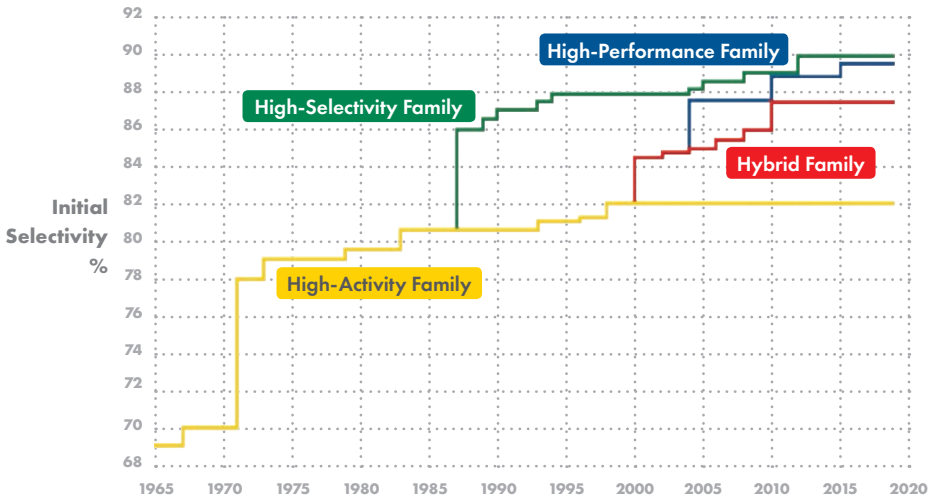


FIGURE 1
The innovation timeline of Shell Catalysts & Technologies' EO/EG catalyst families.

QUESTION

So, it is about being sceptical of the status quo?

Absolutely. The HP and Hybrid (HY) catalysts are good examples. Until the mid-1980s, Shell only had its high-activity (HA) catalyst, which made EO with about 80% selectivity. Then, with the discovery of the rhenium promotion effect by Ann Lauritzen (a former researcher in Shell's EO catalyst group), the high-selectivity (HS) catalyst family was born. These catalysts would operate at about 87% selectivity, but with shorter lifetimes, although these improved with subsequent generations.

Shortly after I joined the EO catalyst research and development group in 1994, my colleague Randy Yeates and I asked a fundamental question: Why can we not invent a catalyst that has both high activity and high selectivity? Like the rest of the industry, we seemed to have accepted that these were mutually exclusive factors.

What we found was that there was no reason, according to the fundamental science, why it could not be done; we just did not have the technology. So, we embarked on a programme aimed at creating a catalyst that would be both highly selective and very active. And, in 2004, we did just that: we commercialised the HP family, which combines the attributes of HA and HS catalysts. In 2000, on the way to the HP invention we developed the HY family, whose selectivity was in between that of the HA and the HS catalysts (about 84% under the same conditions) and that was also very active. It starts out like a HA catalyst, but then it becomes more selective.

QUESTION

Pushing against people's beliefs and established ways of doing things must be difficult. Presumably, you must encounter a lot of resistance.

Well, that can happen, but it helps if you have a champion to back you up. I have been fortunate enough to have leadership that gave me the space to explore in my work.

Without that, one might be inclined to give up because it can be a tough, long road, so you really must believe and you must have the resources too. The EO research and development group serves a major business with a strong track record of innovation and growth, so we have always been prepared to invest in research.

But it requires patience and commitment from the business, especially in EO, because it can take many years to commercialise a new idea. Fortunately, Shell has remained committed to our research and development efforts over many decades.

QUESTION

Of course, catalysts are only part of the story; the process is also vital. How closely do you work with your process technologist counterparts?

That is a timely question because we implemented some really valuable performance improvements through the integration of catalyst and process technology quite recently.

When we were commercialising the HP catalyst it became clear that, quite frankly, it was so good, so stable, the existing process was not going to challenge it. So, our process technologists worked with the catalyst research and development team and redesigned the process around the much more stable and selective HP catalyst, thereby increasing the design work rate (the volumetric production rate) significantly. That is extremely valuable for customers, for example, it means that a reactor can be eliminated from the line-up, which would substantially reduce the capital cost

QUESTION

I would like to dive into the science a little bit. Perhaps, you could give us a flavour of some of the research you have done.

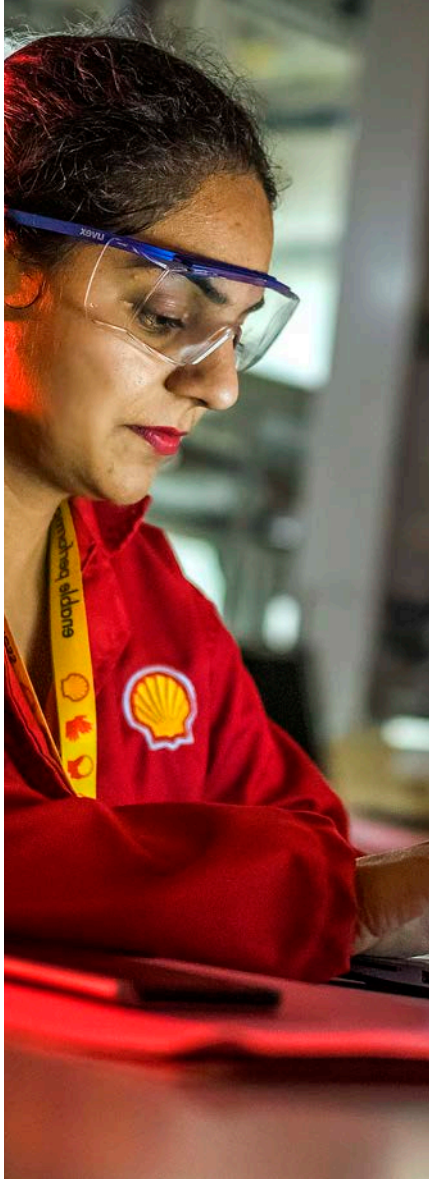
One of the most notable workstreams focused on understanding the sintering of silver particles on the surface of the catalyst. This issue affects all silver oxidation catalysts.

The reaction occurs at relatively high temperatures and causes the catalyst to lose activity. The higher the temperature, the faster the sintering process proceeds, so it feeds on itself. When we started the HP catalyst development, we investigated how to control the sintering because, if we could solve that problem, we could extend the catalyst life.

The result was a detailed understanding of the sintering process and methods for controlling it that helped us to improve the catalyst's stability.

I cannot tell you how we solved it – that is a trade secret! But it involved very high-tech techniques such as electron beam lithography, which is used in the microchip industry (see Figure 2).

FIGURE 2
CRI Catalyst Company used electron beam lithography to help uncover insights into the sintering of silver particles and demonstrated the technology by producing a 1-mm square version of its company logo, entirely composed of silver nano-dots.



QUESTION

In addition to electron beam lithography, what other techniques have you used?

We have also used electron microscopy, X-ray photoelectron spectroscopy, computational chemistry and a wide variety of other techniques.

We have also done isotope labelling studies and other kinetic studies to help understand the fundamentals of the catalyst and the catalytic process better.

Some of these techniques are really pushing the boundaries; they are cutting edge. And they have to be because, these days, inventing better new EO catalysts, or any kind of catalysts for that matter, requires state-of-the-art science. In the past, you might have been able to develop a better system through an empirical approach involving trial and error, but you can only take that so far.

QUESTION

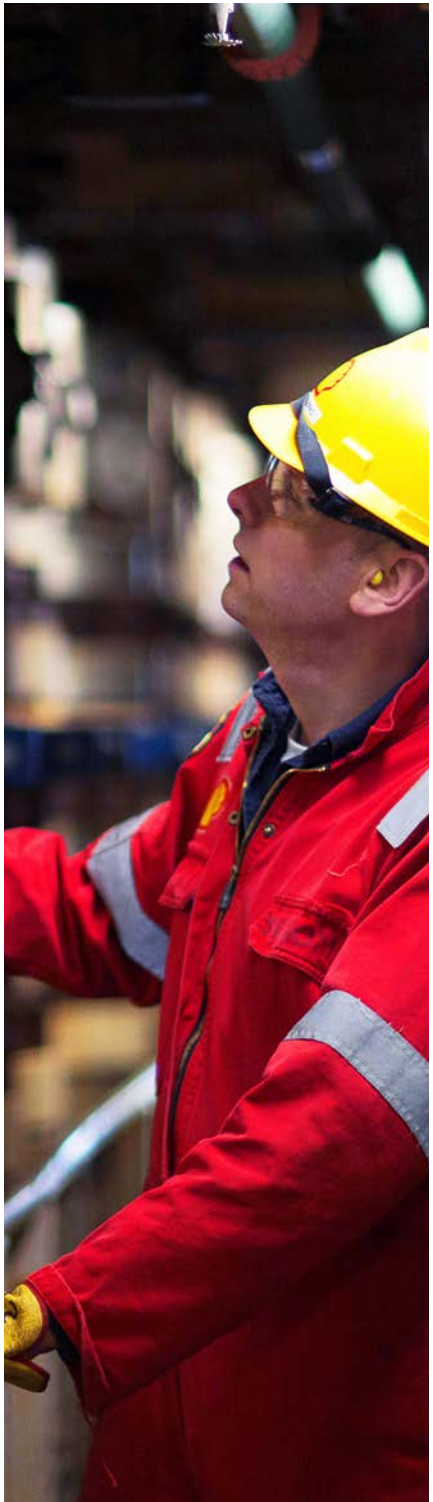
The Southwest Catalysis Society's award was an individual award, but I have noticed that you are keen to emphasize the roles of others.

Of course I am because the inventions that we have commercialised over the years build on the achievements of the scientists who preceded me and the dedication of the research and development , manufacturing, and business teams within Shell Catalysts & Technologies.

Moreover, they require teamwork in abundance. When I first came into the group, I immediately realised that the problems were too difficult to solve on my own. I just did not have the skill set, so I recruited people by trying to get them excited about my problem: surface scientists, physicists, engineers, other chemists. That really matters. It is imperative, if you are going to solve problems that have been there for many years, that your team provides different skills and perspectives.

What is also key is that we are part of a major catalysis organisation. Shell Catalysts & Technologies is a market leader in refining and petrochemical catalysts that operates research laboratories, development facilities, manufacturing plants and business units throughout the world. And we sit within the Shell Group, which operates large, complex industrial refining and petrochemical facilities worldwide. Consequently, we can draw on expertise from all kinds of technology areas. You really need to have that depth and breadth to make advances in mature technology areas.

Collaboration is also important. We have long-term research partnerships with leading companies outside Shell. For instance, our work with catalyst carrier specialist Saint-Gobain NorPro has led to some substantial advances.



QUESTION

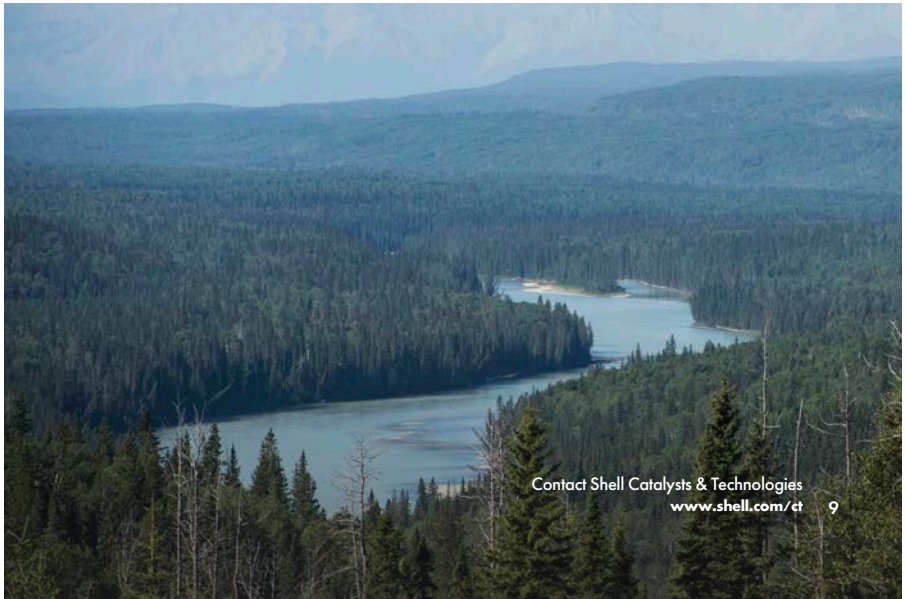
Shell itself is a major EO producer, how much does that inform your research and development focus?

We have a highly skilled and experienced process development team at Shell, which designs and licenses the EO/ethylene glycol process. Collaboration between the catalyst and process teams has enabled us to create the best possible offer for licensees. It is the interactions between teams and with customers that really matter.

Interaction with all customers, whether Shell or third-party businesses, is critical. I know many customers on a first-name basis. If you do not understand what the challenges are in the commercial environment, there is the risk that you will invent something that cannot be useful.

Ideally, when an invention goes from the laboratory to commercial fruition, customers will want to buy it because it will solve some problem they have encountered. That was the case with the HY catalyst, which enabled the high-activity market to run at higher selectivity, and it was so for the HP catalyst, which enables most plants to run with high selectivity at higher production rates for longer. It is proving to be the case with the new high-tolerance (HT) catalyst that we launched recently, too. The addition of HT to Shell Catalysts & Technologies' product portfolio enables us to operate in any of the conditions that we encounter in plants around the world.

So, having intimate knowledge of our customers' challenges, and having them in the backs of our minds when thinking about what to invent, is important because otherwise we would be researching in a vacuum and that is unlikely to be useful.



QUESTION

Many thanks John. I would like to close on a personal note: What is it about catalysis and chemistry that you find so inspiring – what drives you?

Like other chemists, I get to think of something that has never existed and then make it real. And with EO catalysts, these inventions are deployed on a world scale and affect the global economy and lives of people worldwide, and that is a huge kick.

About John Lockemeyer

- Invented three of Shell Catalysts & Technologies five catalyst families and has had a major impact on the other two
- Has been granted almost 40 US patents, most in EO catalysts
- Received the Southwest Catalysis Society Award for Excellence in Applied Catalysts

SHELL CATALYSTS & TECHNOLOGIES
TRANSFORMING ENERGY TOGETHER

About Us

- Shell Catalysts & Technologies is the world's leading supplier of EO catalysts and more than 50% of the world's EO is currently produced using its catalysts.
- Shell Catalysts & Technologies' EO processes have been selected more than 88 times by chemical companies around the world.
- The Shell Group is a major producer of EO and ethylene glycol through its production facilities in Canada, China, the Netherlands, Singapore and the USA.

Contact Shell Catalysts & Technologies

www.shell.com/ct