

Not all 5% Pd/C catalysts are the same

Support properties, precursor choice and synthesis all influence catalytic performance, says **Dr Artur Gantarev** of **Heraeus Precious Metals**

Carbon-supported precious metal catalysts play an indispensable role in the synthesis of fine chemicals, agrochemicals and APIs. Their performance in hydrogenation and hydrogenolysis reactions has established them as long-standing industrial standards.

Heterogeneously catalysed hydrogenations account for a significant share of fine chemical and pharmaceutical synthesis steps, with Pd/C and Pt/C catalysts widely used for this. Some key advantages of these catalysts are their robustness, atom economy and well-established processing behaviour, which leads to easy separation from the product and reusability.

Despite this critical role, these catalysts are still too often regarded as commodity materials and assumed to be interchangeable based solely on metal loading or a generic description such as '5 wt% Pd/C'. Additionally, the form and appearance of typical metal-containing activated carbon catalysts—often described simply

as black powders—offer little differentiation.

In practice, however, catalysts with identical nominal specifications can differ substantially in catalytic activity and overall process performance. Depending on the specific application, distinct conversion profiles, selectivities, and catalyst lifetimes or numbers of reaction cycles are observed. Figure 1 illustrates this, using the example of the hydrogenation of crotonic acid and nitrobenzene using various Heraeus catalysts, all of which have a Pd loading of 5 wt%.

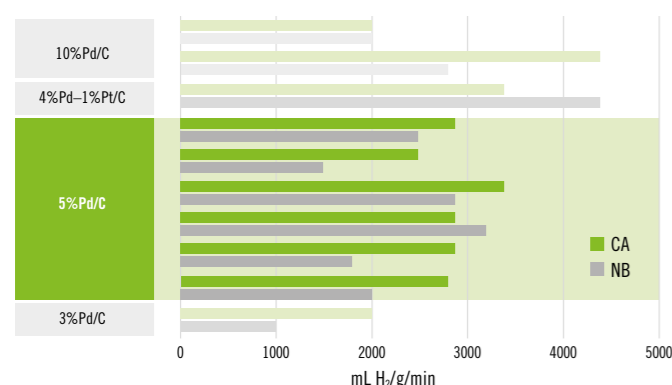
Based on this, choosing the most suitable individual catalyst for a certain process is crucial to boost the efficiency and the economics of the whole production process. Selecting from tailored catalyst options, such as Heraeus' HeraSelect* portfolio, can support this process-specific optimisation. To evaluate this choice, a certain understanding of the two key ingredients of heterogeneous carbon-supported catalysts—the carbon carrier and precious metal precursor—is needed.

Carbon supports

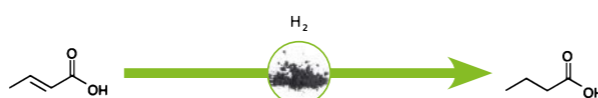
One of these differences lies in the complexity of activated carbon as a support material, which represents the first key ingredient of a heterogeneous precious metal carbon catalyst. Activated carbons vary widely depending on their raw feedstock, each providing distinct porosity, specific BET surface area, particle size distribution and adsorption properties. These structural parameters govern adsorption behaviour, metal anchoring, and the potential for achieving uniform or intentionally tailored metal distributions.

The porous architecture and chemical functionality of carbon supports determine the dispersion and accessibility of precious metal nanoparticles, thereby strongly influencing catalytic activity and stability in hydrogenation reactions. Additional variations in activation method (steam v. chemical), post-treatment (acid-washed v. non-acid-washed) and ash content further contribute to the diversity of available carbon supports.

Figure 1 - Hydrogenation activity of Pd/C catalysts



■ Crotonic acid (CA) hydrogenation



■ Nitrobenzene (NB) hydrogenation



Precursor chemistry & catalyst synthesis

Equally important is the choice of the precious metal component in form of a salt or precursor. Heterogeneous platinum, palladium and ruthenium catalysts can be synthesised from a range of precursor types, including chlorides, nitrates, and acetates, each exhibiting distinct reduction behaviour and nucleation kinetics. The precursor ultimately determines metal nanoparticle size distribution, crystallite sizes, oxidation state and the degree of metal-support interaction, all of which significantly affect catalyst performance and longevity.

Most importantly, combining these two ingredients using the correct synthesis method results in a final catalyst with the desired physical properties. Even subtle changes in the synthesis sequence, such as the pH during impregnation, the drying rate, the reduction atmosphere or the temperature, can lead to significant differences in metal dispersion and catalytic outcomes.

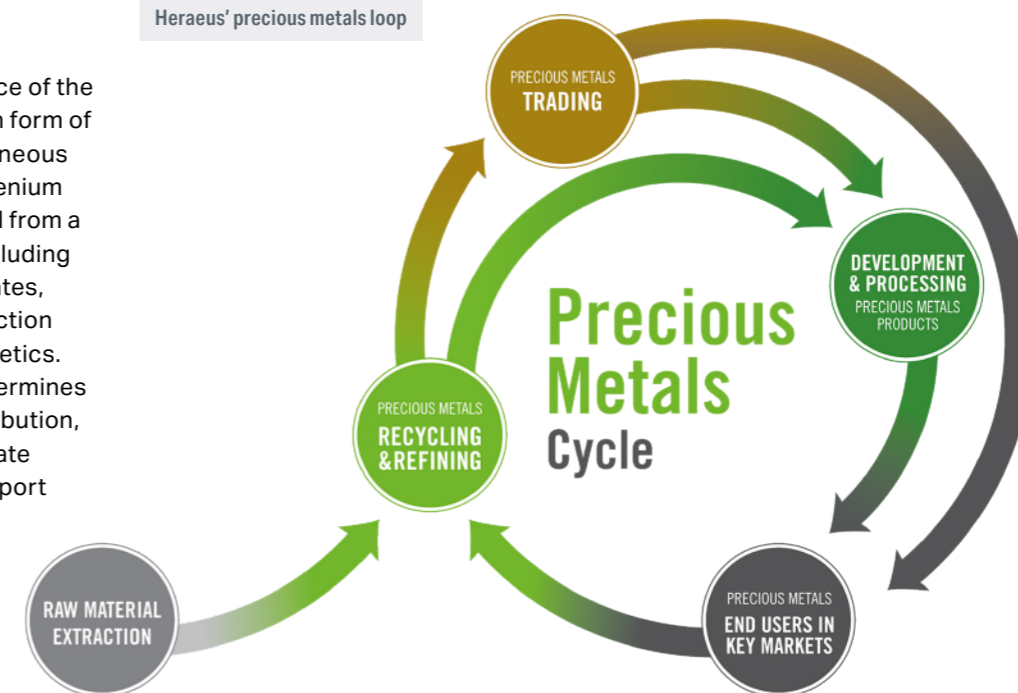
Consequently, catalysts designed with identical nominal loadings may exhibit markedly different properties, resulting in variations in reaction kinetics and sensitivity to deactivation, and thus process compatibility. The frequently cited example of '5 wt% Pd/C' therefore illustrates that nominal specifications neither capture the complexity of catalyst design nor reliably predict catalytic performance in a given application.

Process performance

In industrial hydrogenation processes, catalyst performance is defined not only by intrinsic catalytic activity but also by operational characteristics that influence process efficiency.

Filtration behaviour, for example, can vary considerably between different carbon supports. Particle size distribution, bulk density and

Heraeus' precious metals loop



cake permeability influence filtration rates and, therefore, batch cycle times. Supports with lower bulk density may enable faster filtration, while differences in wettability influence catalyst dispersion and washing efficiency.

Catalyst stability is another critical factor. Deactivation mechanisms, such as poisoning, coke formation, nanoparticle sintering or metal leaching, are well documented in heterogeneous catalysis. These processes can gradually reduce activity, alter selectivity, and affect reproducibility over the course of multiple reaction cycles. For process operators, this means that catalyst selection must consider the interaction between catalyst design and the specific reaction environment, including substrates, solvent systems, and operating conditions.

Integrating design in production

To navigate these complexities, Heraeus Precious Metals combines broad access to diverse carbon carriers and precursor options via a global network of activated carbon suppliers with the ability to integrate and combine these variables

in a systematic and application-oriented manner.

The materials include high-BET carbons (e.g. based on coconut shell), low-impurity acid-washed variants and structurally tailored support grades. This diversity is essential for matching specific hydrogenation processes with carriers that offer a balance of porosity, surface chemistry, filtration behaviour and mechanical stability.

In addition, the company produces precious metal precursors in-house and can make platinum-group metal salts at scale. This integration enables tight control over precursor quality, availability and consistency. Because precursor chemistry directly influences the catalysts microstructure, the ability to adjust precursor properties on demand is crucial.

Heraeus Precious Metals operates a global manufacturing network that supports both catalyst development and industrial supply. This includes production facilities at its headquarters in Europe and at the Ravindra Heraeus joint venture in India. Their integration into Heraeus' global network enables expanded manufacturing capabilities and cost-optimised supply options, particularly



Powder & shaped PGM/C catalysts



relevant for sectors where large catalytic volumes or cost-sensitive formulations dominate, such as agrochemicals or high-throughput intermediates.

This capability operates in parallel with the company's broader precious metal value chain, which – next to catalyst production – encompasses metal trading and recycling. The resulting closed-loop system supports traceable and resource-efficient management of precious metals throughout the entire catalyst lifecycle.

Lifecycle management & precious metal recovery

Lifecycle assessment and management has become an increasingly important dimension of catalyst selection. Precious metals represent both economic and environmental value, and recovering them from spent catalysts is essential for reducing long-term operational costs and minimising environmental impact. Modern refining processes can recover well over 90% of precious metals out of spent material, integrating them back into the production cycle.

Heraeus's TÜV Süd-certified Circlear* programme extends this approach by enabling the use of catalysts produced entirely from recycled precious metals

from the outset. These materials can offer up to ~99% lower CO₂ footprint than primary metals. Such options allow manufacturers to align catalytic processes with sustainability goals without compromising purity, performance or process consistency.

Catalyst design for continuous processing

As the Fine Chem and Pharma industry continues shifting toward continuous processing, processes and catalyst design must also evolve. Classical powder catalysts, while well suited for batch hydrogenations, can present challenges in continuous reactor set-ups. Pressure drop fluctuations, dust formation, and channelling may occur and reduce overall process efficiency.

Against this background, the demand for shaped forms of carbon-based catalysts for hydrogenation and related applications is increasing. However, the transition to shaped catalysts introduces additional complexity in identifying a catalyst tailored to a specific production process.

In flow environments, mechanical robustness and controlled particle size are particularly critical. A wide range of shaped carrier types exist based on alumina (predominantly α - and γ -phases), titania, zirconia and

others. Heraeus also offers custom development of shaped carbon-supported precious metal catalysts. These include extrudates, granules and other geometries based on carbon, engineered to deliver low dust formation, uniform flow distribution and enhanced structural stability in continuously operated reactors.

Conclusion

Taken together, the performance of a carbon-supported precious metal catalyst is not defined by its nominal loading nor general formulation but by the combined influence of carrier selection, precursor chemistry, synthesis route, process integration and lifecycle strategy.

As the field moves toward more selective transformations, continuous operation, and lower carbon footprints, integrated capabilities that address the increasingly complex technical and sustainability requirements of modern hydrogenation chemistry will become increasingly decisive in enabling reliable, future-ready catalysts. ●

* - Circlear and HeraSelect are trademarks of Heraeus



Dr Artur Gantarev
GLOBAL TECHNICAL SALES MANAGER

HERAEUS PRECIOUS METALS

✉ artur.gantarev@heraeus.com
🌐 www.heraeus-precious-metals.com

Exclusive webinars
and videos.
Intuitive navigation.
Responsive design.
Improved ad
visibility.

Check out the all-new
Speciality Chemicals
Magazine website at:
specchemonline.com

