Johnson Matthey

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Advantages of Palladium Membrane Technology over Ambient Catalytic Technology for Hydrogen Purification in MOCVD Processes

Palladium (Pd) membrane technology is the preferred hydrogen purifier for MOCVD tools used in compound semiconductor applications. Palladium purifiers have been in use on these tools for over 20 years because they offer advantages in performance, purity, value and safety. The following information helps provide support for the use of Johnson Matthey palladium purifiers over ambient catalytic purifiers.

Product Performance and Gas Purity

- Solid Barrier with No Breakthrough - Unlike ambient catalytic purifiers, which allow hydrogen and impurities to flow through the purifier, the palladium (Pd) membrane is a solid barrier to all contaminants while allowing only hydrogen to pass through. Ambient catalytic purifiers' performance can be negatively affected by factors such as channeling, vessel orientation (vertical vs. horizontal), flow rate and temperature. Under some conditions, the catalytic material can desorb impurities, thus resulting in breakthrough.

- Handles High Inlet Impurity Challenges – Pd membrane purifiers remove all impurities from liquid or compressed sources. Compressed hydrogen typically has high levels of CO and CO_2. These levels are difficult to remove with catalytic purifiers, and the lifetime will be significantly reduced. In fact, high CO impurity levels can lead to the addition of CH_4 on the outlet of catalytic purifiers. Pd membrane purifiers continue to be the technology-of-choice for compressed hydrogen systems because of this ability to remove all impurities, at any inlet challenge.

- Handles Flow and Impurity Spikes – Because Pd membrane purifiers offer an absolute barrier to impurities, increases in flow or impurities will not lead to impurities in the pure gas. Catalytic purifiers can get "flooded" by temporary increases in flow or impurity levels, causing breakthrough of impurities. Once the flow rate and impurity levels go back to normal, the purifier will eventually begin purifying again; however, the damage is already done.

- Assured Performance – Unlike catalytic purifiers, the performance of a Pd membrane purifier can be assured using a routine helium leak check. The performance of catalytic purifiers will gradually decline over time, and breakthrough is difficult to monitor. The only method to assure outlet purity for catalytic purifiers is to use expensive analytical instruments, often as costly as the purifiers themselves. Additionally, feedback provided by these instruments is typically too late, as the contaminants have already entered the process.

- Methane Removal – Pd membrane purifiers remove methane, whereas, catalytic purifiers do not.

- The Compound Semiconductor Industry Standard – Pd membrane purifiers were established over 20 years ago as the industry standard for gas purity. It was the first hydrogen purification technology to be used by the Compound Semiconductor industry and continues today to be the product of choice for the overwhelming majority of Compound Semiconductor device manufacturers and MOCVD reactor manufacturers. They trust Pd membrane purifiers in their demanding applications more than any other type of hydrogen purifier, including catalytic purifiers.

- Proof of Performance – With new improved designs, incorporating venturi purging and enhanced thermal management, Pd membrane purifiers remain durable through emergency shutdowns due to power failures and process upsets. As a result, extended warranties are now available.

Product Value

- Less Expensive to Buy and Operate – Pd membrane purifiers are less costly than dual-bed catalytic regenerative purifiers. In fact, Pd membrane purifiers do not require regeneration. Point-of-use regenerable purifiers require power, vent, pneumatic and purge connections just as is required for Pd cells, but regenerable purifiers still do not provide the equivalent purity performance and ease of purity verification.

- Repairs – Pd membrane purifiers can be repaired and provided with a new warranty. Often, older model Pd membrane purifiers are actually improved because the latest improvements in design are incorporated in the repair process.

- Residual Value – Catalytic purifiers have no value when they are spent or replaced. Palladium, a precious metal, does have an intrinsic value and this value can be applied to a new Pd membrane purifier or converted to cash.

Product Safety

- Shipping Concerns – Many catalytic purifiers are pyrophoric, especially those that contain nickel. As a result, the Department of Transportation (DOT) does not allow these products to be shipped by air. Only properly certified shipping personnel can ship hazardous materials such as nickel catalytic purifiers, subjecting users to unanticipated costs and liabilities when returning these purifiers for regeneration. Pd membrane purifiers are non-hazardous and are thus not subject to these stringent DOT shipping restrictions. Shipping costs are lower, and procedures are simpler.

- Disposal – Catalytic purifiers are classified as hazardous, requiring special disposal procedures. Pd membrane purifiers are not hazardous.

Manufacturers of ambient catalytic purifiers have also made claims about "advantages" of their technology as compared to Pd membrane purifiers. The following claims are not accurate, and responses to each are provided:

Claim: Catalytic purifiers operate at low H_2 pressures while Pd membrane cannot support these lower pressures

Response: Pd membrane purifiers operate on liquid or compressed hydrogen supply systems. Compressed systems with inlet pressures of 250 psi allow the use of smaller purifiers for required flow rates. For liquid hydrogen systems with supply pressures of approximately 140 psi, slightly larger Pd membrane purifiers are necessary to supply the required flow rates. Most manufacturing facilities in the US and Europe use Pd membrane purifiers for their liquid hydrogen purification.

Claim: Catalytic purifiers have better uptime because they do not have membranes that can crack.

Response: Pd membrane purifiers can crack when the cell is repeatedly allowed to cool (i.e., from power failure) in presence of hydrogen. The proprietary V-purge system from Johnson Matthey protects the membrane by removing all H_2 automatically within minutes while replacing the hydrogen with nonreactive

nitrogen. This feature, combined with improved thermal management, significantly eliminates the risk of “cracks” caused by improper operation.

Claim: Catalytic purifiers dry down more quickly than Pd membrane purifiers during initial installation and startup.

Response: Pd membrane purifiers do not allow moisture to pass through, so there is no required “dry down” for the membrane startup. Any dry down time is related to purging of the piping system. This purging is required for any purifier technology to remove impurities introduced during installation.

Claim: Catalytic purifiers do not release hydrocarbons; the implication is that Pd membrane purifiers release hydrocarbons.

Response: Pd membrane purifiers remove all hydrocarbons, including methane, and other carbon species such as CO and CO_2. Catalytic purifiers do not remove methane and have a limited capability to remove some carbon species including CO_2. Therefore, purity is compromised with the use of catalytic purifiers because some impurities are allowed to pass through.