TECHNICAL NOTE

FUEL CELL CATALYST MATERIALS

NON-PRECIOUS METAL CATALYST

CURRENT STATUS

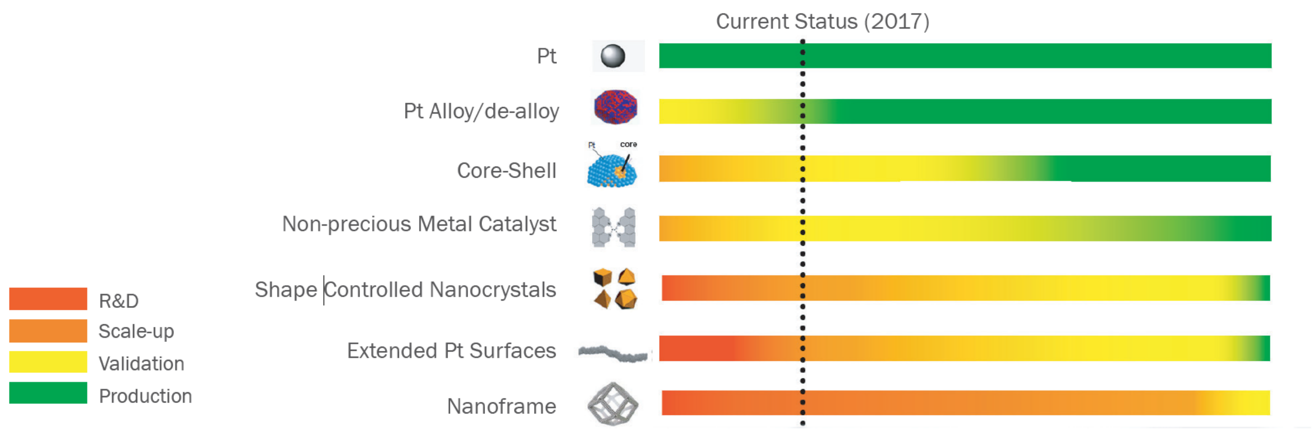
At both the cathode and anode of a proton exchange membrane fuel cell (PEMFC), platinum group metals (PGMs) are typically used to catalyze the desired redoxreactions. As these metals are commodities, and are quite scarce, increased demand for PEMFCs will only serve to increase the price of these catalysts if the loading is not reduced significantly from current levels.

This clearly highlights the need to reduce PGMs within a PEMFC. Fortunately, promising strategies are available to overcome this challenge. In fact, Ballard recently announced that we will begin supplying the world's first PEMFC to use a non-precious metal catalyst at the cathode.

STATE-OF-THE-ART ELECTROCATALYSTS

During the past decade, a wide variety of highly promising catalysts have been developed. Broadly, these catalysts can be categorized as: 1) Pt, 2) Pt alloy/de-alloy, 3) core-shell, 4) non-precious metal catalysts, 5) shape controlled nanocrystals, 6) extended Pt surfaces, and 7) nanoframes.

Many of the promising next generation catalysts demonstrate exceptional activity (up to 60x higher than conventional Pt catalysts) based on laboratory testing. Unfortunately, translating these promising results from the lab to real-world fuel cells has globally been a significant hurdle. Accomplishing this goal requires extensive knowledge of the complex materials-interactions that can occur within a fuel cell, advanced technology for scaling-up promising designs, as well as a deep understanding of real-world operating conditions and failure modes.



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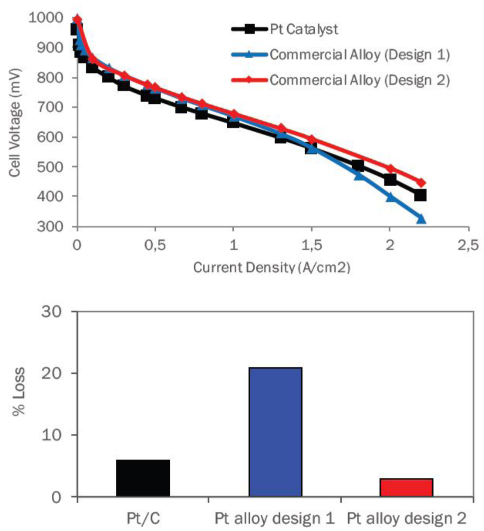
STRATEGIES FOR OVERCOMING REMAINING GAPS

With over 35 years of experience in fuel cell development, Ballard Power Systems, Inc. is uniquely positioned to help overcome remaining challenges in developing robust fuel cell designs that are able to maximize the expected benefits of next-generation anode and cathode catalysts.

Cathode Example

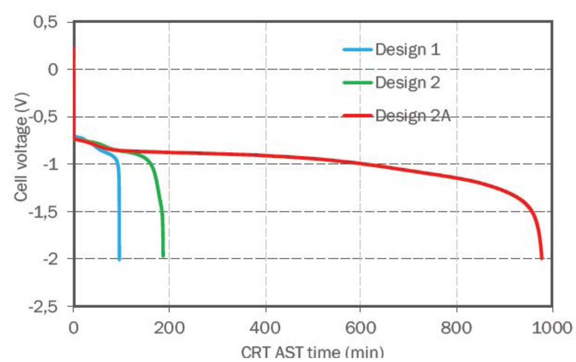
It has been widely observed that by alloying metals such as cobalt and nickel with platinum, the activity of the cathode catalyst can be greatly improved. However, these metals are not stable in a fuel cell catalyst layer environment, and can leach out of the alloy catalyst during operation, leading o performance losses, particularly at higher current densities. Drawing on Ballard's extensive mechanistic understanding of this failure mode, we have developed novel catalyst layer design to overcome this challenge, achieving both higher performance and durability than conventional catalyst layers.



Air polarization curves for a commercial Pt/C catalyst, and a Ptalloy catalyst with two different catalyst layer designs. In each design, the catalyst loading is 0.4 mg/cm2. Performance loss for each design following 5000 voltage cycles between 0.6 – 1.0 V under air.

Anode Example

A critical failure mode in PEMFCs results from insufficient fuel reaching the anode catalyst, due, for example, to a blockage in the anode flowfield, leading to extreme potential excursions at the anode and negative cell voltages known as 'cell-reversal'. The severity of these excursions means that available anode materials corrode rapidly. Fortunately, Ballard has developed a highly innovative and proprietary catalyst treatment/ anode catalyst layer design which greatly mitigates this degradation and allows system cost reduction. This design provides a strong competitive advantage, enabling Ballard to meet the most demanding requirements for both automotive and non-automotive applications.



Cell reversal lifetime for three designs. Design 1 and Design 2 are the same catalyst layer design, but with different anode catalysts. Design 2A uses the same catalyst as Design 2, but with Ballard's catalyst treatment and novel catalyst layer design.

Here for life™

Ballard Power Systems,Inc.
9000 Glenlyon Parkway
Burnaby, BC V5J 5J8
Canada

Contact us
(+1) 604.454.0900
marketing@ballard.com
ballard.com