DOE Hydrogen and Fuel Cells Program Record	
Record #: 11013	**Date:** June 2, 2011
Title: Platinum Group Metal Loading in PEMFC Stacks	
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Approved by: Sunita Satyapal	**Date:** July 25, 2011

Item:

Total loading of platinum group metals (PGMs) in state-of-the-art polymer electrolyte membrane fuel cell stacks has decreased by 2 orders of magnitude since the 1960s and 1 order of magnitude since the mid-1980s.

Supporting Information:

Prior to 1988, state-of-the-art polymer electrolyte membrane fuel cell (PEMFC) electrodes were constructed using Pt-based catalysts pressed directly into the surface of the polymer electrolyte membrane (PEM). Catalyst loadings were 35 mg/cm^2 in the PEMFC electrodes used in the 1960s in NASA's Gemini program [1], though advancements in fuel cell technology soon led to reduction of Pt content. By the mid-1980s, typical loadings were approximately 4 mg_{PGM}/cm^2 on each electrode [1].

DOE-supported research and development (R&D) in the 1980s resulted in a major reduction in PGM loading by the end of the decade. A patent filed in 1988 by Raistrick [2], of Los Alamos National Laboratory (LANL), disclosed a new method of electrode fabrication, in which a porous gas diffusion electrode is modified by impregnation with solubilized ionomer. By simultaneously achieving high electronic conductivity, high protonic conductivity, and facile gas transport, this type of electrode enabled simultaneous improvement in PEMFC performance and reduction in PGM loading to 0.35 mg_{PGM}/cm^2 in each electrode.

Further DOE-supported work at LANL in the late 1980s and early 1990s resulted in additional reductions in PGM loading, as disclosed in a patent filed in 1991 by Wilson [3]. Wilson demonstrated electrode preparation using catalyst "inks," consisting of carbon-supported Pt catalysts dispersed with an ionomer (Nafion ®) in a water-alcohol mixture. The inks were either painted directly onto the PEM, or painted onto a polytetrafluoroethylene decal and transferred to the PEM by hot-pressing. The resulting PEMFCs, with catalyst loading of 0.13 mg_{PGM}/cm^2 on each electrode, yielded performance as high as 3.4 W/mg_{PGM} at 0.67 V on humidified H_2 and air at 300 and 500 kPa, respectively [3]. Based on the claim that anode loadings could be reduced to 0.03 mg_{PGM}/cm^2 with little impact on performance [3], 5.4 W/mg_{PGM} may have been achievable during operation of these PEMFCs on pressurized H_2 and air. While high-performance operation at less than 0.2 mg_{PGM}/cm^2 total loading was demonstrated in this work, durability of these materials remained an issue. PEMFC developers continued to use higher PGM loadings throughout the 1990s and most of the 2000s to achieve good durability.

The advances in single cell PGM loading of the 1980s and early 1990s were translated to PEMFC stacks by the mid-1990s, with Ballard demonstrating operation of 80-cell stacks with electrodes similar to those developed at LANL [4]. Durability of over 3000 hours was demonstrated at Ballard using stacks operated on reformate, with a total PGM loading of less than 1 mg_{PGM}/cm^2 [4].

Further advances in low-PGM PEMFC technology were made in the 2000s, with DOE-supported R&D at 3M on nanostructured thin film (NSTF) catalysts. Progress during this decade resulted in NSTF catalysts capable of durable, high-performance operation at total PGM loadings as low as 0.15 mg_{PGM}/cm^2 [5]. While these loadings are similar to those demonstrated at LANL in the early 1990s, the performance and durability of PEMFCs incorporating NSTF catalysts is superior. The current 3M performance status in single cell testing is 5.6 W/mg_{PGM} at 0.67 V, achieved at significantly lower pressure (150 kPa on each side) than that used in the earlier work at LANL.

In 3M's short-stack testing with GM, NSTF materials with PGM loading of 0.25 mg_{PGM}/cm^2 demonstrated durable operation of over 2000 hours, while achieving 0.19 g_{PGM}/kW (surpassing the DOE 2010 target of 0.2 g_{PGM}/kW) [5]. The decrease in PGM loading in PEMFC stacks from approximately 8 mg_{PGM}/cm^2 in the mid-1980s to less than 0.25 mg_{PGM}/cm^2 in 2011 represents well over an order of magnitude reduction in PGM loading during this time.

References

[1] A. J. Appleby and E. B. Yeager, *Energy* 11 (1986) 137-152.

[2] I. D. Raistrick, U.S. Patent No. 4876115 (1989).

[3] M. S. Wilson, U.S. Patent No. 5211984 (1993).

[4] T. R. Ralph et al., *J. Electrochem. Soc.* 144 (1997) 3845-3857.

[5] M. K. Debe et al., Advanced Cathode Catalysts and Supports for PEM Fuel Cells, 2011 Hydrogen and Fuel Cells Program Annual Merit Review and Peer Evaluation, http://www.hydrogen.energy.gov/pdfs/review11/fc001_debe_2011_o.pdf