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MEMORANDUM

FROM:	Robert B. Dopp	**DATE:**	10/29/10 7:39 PM
To:	To Whom it May Concern	**# of Pages:**	2

SUBJECT: Alkaline Fuel Cell (AFC) and H_2 Flow Cell using GridShift Coated Electrodes

ABSTRACT: GridShift Incorporated (GSI) has developed a way to coat nano catalysts onto a metallic surface in a way that allows excellent electrical contact to the particles while still exposing them to the electrochemical boundary layer for high efficiency and high rate water electrolysis. It also would make a high efficiency and high rate Alkaline Fuel Cell. Combining these two would result in a Hydrogen Flow Cell, which could be used to level periodic loads such as wind and solar installations or to level the grid by producing H_2, and O_2 and storing the gasses, then producing electricity to return to the grid.

PRINCIPLES OF ELECTROLYSIS: Water electrolysis to produce hydrogen and oxygen is an old technology originating just weeks after Volta introduced his Pile in 1800 by William Nicholson and Anthony Carlisle. The principle chemical equations are shown below**,** where the electrochemical flow is shown for alkaline environments, which is the condition used in this research. The anode produces one water molecule, but the cathode consumes two, resulting in a net loss of one water and the production of one mole of hydrogen and half a mole of oxygen.

Alkaline Water Electrolysis forming Hydrogen and Oxygen Gasses

Total Reaction: $H_2O \rightarrow H_2 + 1/2O_2$

Anode ("+" Terminal): $2OH^- \rightarrow 1/2O_2 + H_2O + 2e^-$

Cathode ("-" Terminal): $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$

PRINCIPLES OF ALKALINE FUEL CELL: The alkaline fuel cell (**AFC**) was invented by Francis T. Bacon I the 1930's, was the Fuel cell the Apollo missions took to the moon and is are used today in the Space Shuttle. This is because they run at higher voltage than PEM fuel cells, but generally at lower rates. They are among the most efficient fuel cells, having the potential to reach 70% Energy Efficiency but at rates below 500 mA/cm^2. The principle chemical equations are shown below**.** The anode consumes the hydrogen fuel and a hydroxyl, producing 2 water molecules. The cathode consumes one oxygen atom and one water molecule to produce the charge carrying hydroxyl ion. The result is the production of water, heat, and electricity.

Alkaline Water Electrolysis forming Hydrogen and Oxygen Gasses

Total Reaction: $H_2 + 1/2O_2 \rightarrow H_2O$

Anode ("+" Terminal): $H_2 + 2OH^- \rightarrow 2H_2O + 2e^-$

Cathode ("-" Terminal): $1/2O_2 + H_2O + 2e^- \rightarrow 2OH^-$

The same 3D design for an electrolyzer runs backwards as a high rate and high efficiency alkaline fuel cell. The feasibility has been demonstrated, but more development is needed.

COATING A METALLIC SURFACE WITH NANO-CATALYST

GSI has developed a unique method to attach nano catalysts to a metallic surface in a way that has very low impedance to the reaction sites, covers all surfaces of a porous structure and leaves the particles well exposed to the electrochemical boundary layer. Many nano catalysts have been used in our experiments, with none being noble metals. At the time of this writing, we are using two catalysts in the

anode (Oxygen generating) electrodes and three different catalysts in the cathode (Hydrogen generating) electrodes. The coating is uniform on all surfaces within a three-dimensional metallic surface such as metallic foam or metallic "paper" made from fibers. As seen in **Figure 1**, the coating extends into all internal intricacies of the porous metal substrate greatly extending the reactive surface area.

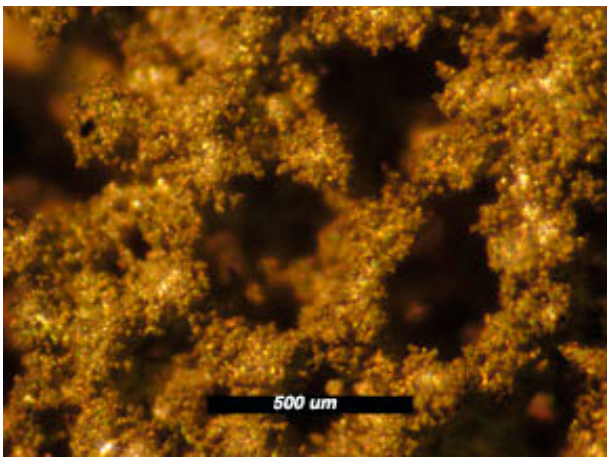

Fig 1: nano coating on a porous surface

NEEDED FOR AFC DEVELOPMENT

One important divergence from past AFC work will be using the full 3D capability of the electrodes by introducing both the fuel (H_2) and oxidizer (O_2) into the system as sparged gas producing an anolyte and catholyte flowing through the cells. This will allow the full 3D volume of the electrode to function giving much higher rate capability. **Figure 2** shows the existing power density of the two primary Fuel Cell systems in production today (SOFC and others not addressed here as they are lower power density still). With an AFC that is up to 1000 mA/cm^2 at about 700 mW/cm^2, then fuel cells for H_2 Flow Cells and for automotive applications are plausible and possible. The GridShift design could be the avenue to this goal.

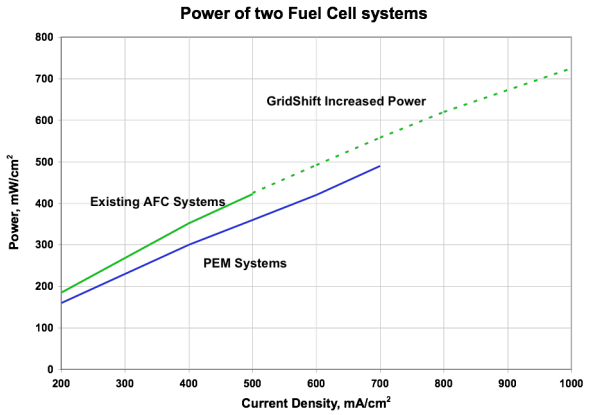

Figure 2: Existing and anticipated power of GSI AFC

A HYDROGEN FLOW-CELL

Combining the high-rate and efficiency electrolyzer with the high-rate and efficiency AFC, makes a hydrogen flow cell. During low electrical demand (and cost) hydrogen and oxygen would be made and stored. During high electrical needs, the gasses would be run through the AFC to make electricity. This load leveling would work very well for solar and wind installations, which are necessarily periodic in nature. It also would work well for load leveling the grid, which is the source of our corporate name: "GridShift Incorporated".

SUMMARY of TIME PROJECTIONS

Project	Years	End Product
Electrolyzer Refinement	2 Years to 2012	"Demo" unit capable of producing 1 kg H2 per day on household power.
Alkaline Fuel Cell (AFC)	3 Years to 2013	This unit will be essentially the Demo unit run backwards with fuels sparged into the electrolyte.
Flow Cell	3.5 Years to 2013	Combine the electrolyzer & AFC to store energy as H_2 and O_2 to Cycle 50 kWh