Liquid aluminum air battery operated at high temperature

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A unique metal air battery system has been tested. This metal air battery system has an intentional use of oxygen ion as the conductive species to avoid any accumulation of metal oxide on the cathode. Secondly, liquid anode is used to make the metal oxide easily diffuse internally to gain high electric power. Thirdly, aluminum metal is used for the anode because of its high energy density and worldwide availability. These unique principles may provide high power, higher energy, and low cost battery.

The theoretical energy density for this battery system, for example at 800^{o}C, is 7kWh/kg or 17kWh/L which is very competitive against the lithium air battery system of 13kWh/kg or 6kWh/L at 25^{o}C. The cost of aluminum metal is just $0.4/kWh in 2012.

As it is well known, one of the biggest problems for the lithium air batteries is its low power density. Lithium air battery can be operated at as very low current density as 0.5mA/cm^2 [1]. This is probably because of the lithium ion transporting to and accumulating on the cathode as solid. Therefore many researchers need to put their efforts to remove it. If the product is liquid like in sodium sulfur battery system, more power might be available. Recently, Dr. Sadway's group has reported a full liquid battery which can provide high power density up to 20mW/cm^2 [2]. This is a proof that liquid metal can be applied for high power use. Other examples are sodium sulfur and sodium nickel systems. For metal air battery, Dr. Huang's group published a series of patents for metal air batteries with yttria-stabilized zirconia (YSZ) electrolyte [3]. They obtained the maximum 5mW/cm^2 though the anode was still solid metals. The author recently has obtained more than 100mW/cm^2 with this presented aluminum air battery as shown in Figure 1 [4]. About the same overpotential has been observed at the same charging and discharging current. The open circuit potential was about 1.8V which is slightly lower than the number obtained from thermodynamic properties. Small hysteresis has existed in this cyclic voltammetry. The detail will be presented in this meeting.

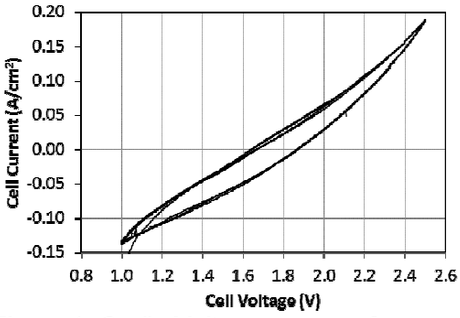

Figure 1. Cyclic Voltammogram of proposed aluminum air battery

References:

[1] B. Kumar, J. Kumar, R. Leese, J. P. Fellner, S. J. Rodrigues and K. M. Abraham, *Journal of Electrochemical Society*, **157** (2010) A50-A54

[2] D. J. Bradwell, H. Kim, A. H. C. Sirk, and D. R. Sadoway, *Journal of the American Chemical Society*, **134** (2012) 1895−1897

[3] K. Hwang, C. Lu, J. L. Shull, S. W. Liu, and S. D. Vora, *US Patent Application Publication* 2001/0256448 A1 "Molten salt containing metal electrode for rechargeable oxide ion battery cells operating below 800^{o}C"

[4] M. Ohashi and J. W. Van Zee, *Invention Disclosure to University of South Carolina*, SCRF #00919