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PROGRESS IN FLUORIDE ION BATTERIES (FIBs) - NEXT GENERATION ELECTROCHEMICAL STORAGE DEVICES

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ABSTRACT

Fluoride ion batteries (FIBs) have emerged as the most compelling energy storage systems that are being regarded as a potential substitute to the conventional lithium-ion batteries (LIBs). Fluoride is the most electronegative and smallest sized anion with a large mobility (beneficial for charge transport) and therefore, FIBs can in theory allow for a wide electrochemical potential window. These rechargeable batteries are based on fluoride ion shuttles between the cathode and anode electrodes in the electrochemical reaction. FIBs offer high specific energy, energy density, and thermal stability. Considering the number of combinations of possible materials' variations, they may also offer improved safety characteristics compared to Li-ion based batteries (LIBs). Not many publications exist in literature on the research regarding FIBs. To date, reported FIBs either operate with an ionic liquid, organic electrolyte or solid-state electrolyte at high temperatures. Recently in December 2018, Davis et al. from Honda, along with researchers at CalTech and NASA's Jet Propulsion Lab in California USA, published a report on new fluoride-ion batteries it is developing, in the journal Science [1]. This research led to a milestone in FIB technology-the ability to run energy cells at room temperature rather than heating them to at least 150 degrees Celsius. This article will review all these research progresses and breakthroughs made in the recent years in the areas of high temperature and room temperature FIBs along with their electrochemical stability. The performance, safety and utilization of new electrodes over the years will be discussed. Fluoride ion–mediated electrochemistry offers a pathway toward developing capacities beyond that of lithium ion technology.

The schematic of fluoride ion battery is shown in Fig.1, where metal fluoride MFx normally can be used as cathode and another metal can be used as anode. The battery reactions during the discharge process can be expressed as follows:

Cathode: $xe^- + MF_X \rightarrow M + xF^-$

Anode: $xF^- + M' \rightarrow M'F_X + xe^-$

Cell: $MF_X + M' \rightarrow M'F_X + M$

The charge process is reverse of the discharge process.

The electromotive force (E) of a battery can be directly calculated from the difference in the Gibbs free energy according to the equation: $\Delta G^0 = -z \cdot F \cdot E^0$ where G_r^0 is free Gibbs energy, z is number of electrons involved in the reaction and F is Faraday constant. The capacity (Q) of a battery can be calculated according to the equation: $Q = z \cdot n \cdot F$ where n is the amount of substance.

Keywords: Fluoride ion batteries, Lithium ion batteries, electrochemical, safety, fluoride ion shuttles, cathode, anode