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Revisiting the mechanism of solid oxide fuel cells (SOFC's); its difficulties and probable new mechanism

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Abstract: *In the present paper the mechanism of solid oxide fuel cells (SOFC's), its difficulties and problems have been revisited through reasoning and analysis. The solid oxide fuel cells are operated at very high temperatures (500°C-1000°C) and have efficiencies 60%-85%. Considering the high input thermal energy the efficiency of solid oxide fuel cells is much lower. Permeability of H^+ and O^{2-} ions is hindered by the formation of water in electrolyte. Because of these difficulties, the probable new mechanism for the SOFC's using ozone gas and H_2 gas is presented in this paper. This type of solid oxide fuel cell utilizing ozone and H_2 gas can be operated at room temperature requires no higher operating temperature.*

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I. Introduction:

In the present paper revisiting of solid oxide fuel cells (SOFC's) have been carried out through reasoning and analysis. The problems and difficulties of SOFC's have been presented. The probable new mechanism for the SOFC's using ozone gas and H_2 gas is presented.

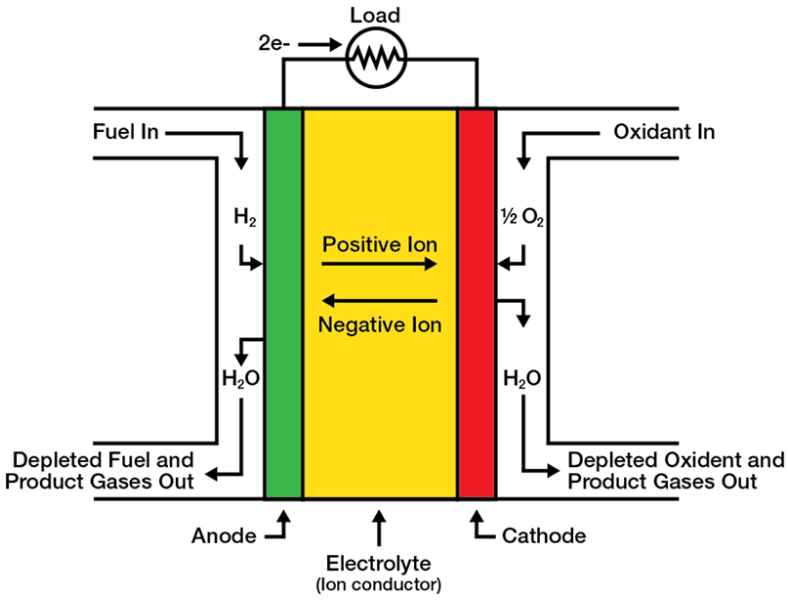

Figure 1. Basic structure of Solid oxide fuel cell (SOFC)

Solid oxide fuel cells (SOFC's) are devices which convert fuels like H_2 and O_2 to H_2O producing electricity. The basic structure of solid oxide fuel cells are shown in Figure 1 [1]. It consists of anode made up of Ni doped Yittria stabilized zirconia (YSZ) and cathode made up of Lanthanum strontium manganite oxide (LSMO) and electrolyte made up of Yittria stabilized zirconia. The anode, cathode and electrolyte used are porous. The reaction or mechanism of SOFC's as shown by NETL is as given below.

$H_2 \rightarrow 2H^+ + 2e^-$ (at anode) (1)
$\frac{1}{2} O_2 + 2H^+ + 2e^- \rightarrow H_2O$ (at cathode) (2)
The overall reaction is $H_2 + \frac{1}{2} O_2 \rightarrow H_2O$ (3)

The reaction mechanism of SOFC's as shown by astra.eu are given below [2].
$O_2+4e^-\longrightarrow 2O^{2-}$ (at cathode) (4)
$2H_2\rightarrow 4H^++4e^-$ (at anode) (5)
Over all reaction is $2H_2+O_2\rightarrow 2H_2O$ (6)

The reaction mechanism of SOFC's as shown by nptel.ac.in are given below [3]
Anode/Electrolyte Interface Reaction:

$$O^{2-}+H_2\rightarrow H_2O+2e^- \quad (7)$$

Reaction at the Cathode/Electrolyte Interface

$O_2+4e^-\rightarrow 2O^{2-}$ (8)

Overall reactions that occur are:
H2+ ½ O2→H2O (9)

The reaction mechanism of SOFC's as shown by chimica are given below [4]
$H_2 + O_2^- \rightarrow H_2O + 2e^-$ at the anode side (10)
$O_2 + 4e^- \rightarrow 2O_2^-$ at the cathode side (11)
$O_2 + 2H_2 \rightarrow 2H_2O$ is the overall reaction (12)

The problems and difficulties of the above SOFC's mechanism [1-4] are presented in results and discussion and the probable mechanism of SOFC's using ozone and H_2 gasses to produce electricity are also presented

II. Results and discussion:

According to NETL the general reaction for SOFC are shown below and the anode, cathode and electrolyte are porous.
$H_2\rightarrow 2H^++2e^-$ (anode side)
$1/2O_2+2H^++2e^-\rightarrow H_2O$ (cathode side)
Overall equations are ½ $O_2+H_2\rightarrow H_2O$
NETL reported that positive H+ ions permeable from left side (anode side) to right side (cathode side) through electrolyte. It is also reported that O^{2-} ions permeable from right side (cathode side) to left side (anode side) producing electricity. There is a chance that the H^+ and O^{2-} ions combine in the electrolyte to form water and this in turn hinder the further permeability of H^+ and O^{2-} ions thereby reducing the overall efficiency. If water is formed in electrolyte then permeability of H^+ from left side to right side and permeability of O^{-2} from right side to left side is difficult hindering the production of electricity. It is also reported that the efficiency of SOFC's are around 60%-85% [5]. It is also reported that the SOFC's are operated at temperatures (500 ^oC to 1000^oC). The operating temperature of SOFC's is (500 ^oC to 1000^oC), considering this high input thermal energy the overall efficiency is much lower percentage. At these higher temperatures, the steam engine can be operated to produce electricity. Steam engine can also be used to run the vehicles instead of SOFC's.

The reaction mechanism of SOFC's as shown by astra.eu are given below [2]. They have shown a video describing the working principle of SOFC's and is as follows from top to bottom.
$O_2+4e^-\longrightarrow 2O^{2-}$ (at cathode)
$2H_2\rightarrow 4H^++4e^-$ (at anode)
Over all reaction are $2H_2+O_2\rightarrow 2H_2O$
In the above equations the oxygen is converted in to oxygen ion with the intake of two four electrons, one need to check how these initial four electrons are produced. This doubt the working principle of SOFC's by astra.eu

In the above reaction mechanism (equations 7-12] by nptel.ac.in [3] and chimica [4] the reaction is written in one order from top to bottom, there is a doubt how the oxygen ions are formed initially. If one considers the mechanism from bottom to top then the question arises how four electrons are formed initially.

In view of the above the probable new mechanism for the SOFC's using ozone gas and H_2 gas is presented below. The ozone gas gets dissociated in to oxygen and oxygen ion under visible sunlight. Then the oxygen ion gets converted in to oxygen molecule and four electrons (at cathode). Then at anode the hydrogen reacts with oxygen molecule and four electrons to produce water. The electrons flow from cathode to anode. The reactions are given in equation (13-16). The important point regarding the SOFC's using ozone and H_2 gas is that it can be operated at room temperature. The mixed or combined gases (O_3 and H_2) can be passed at both the anode and

cathode sides to produce electricity and this can be operated at room temperature. This is one advantage of SOFC's using ozone and H_2 gases. SOFC's utilizing ozone and H2 needs a trial.

$O_3 \rightarrow O_2 + O^{-2}$ (under sunlight) (13)
$2O^{-2} \rightarrow O_2 + 4e^-$ (at cathode) (14)
$2H_2 + O_2 + 4e^- \rightarrow 2H_2O$ (at anode) (15)
Over all equation are $2H_2 + 2O^{-2} \rightarrow 2H_2O$ (16)

III. Conclusions:

Through reasoning and analysis the mechanism of solid oxide fuel cells (SOFC's), its difficulties and problems have been reviewed. One of the problems is hindering of the permeability of H^+ and O^{2-} due to the formation of water in electrolyte. The efficiency of solid oxide fuel cells operated at very high temperatures (500^{o}C-1000^{o}C) is around 60%-85%. Considering the high input thermal energy the efficiency of solid oxide fuel cells is much lower percentage. In the present paper, the probable new mechanism for the SOFC's using ozone gas and H_2 gas is presented. This type of solid oxide fuel cell utilizing ozone and H_2 gas requires no higher temperature and can be operated at room temperature, this is one advantage.

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