Clean and efficient utilization of biomass in a direct carbon fuel cell

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Huge among of biomass is produced by nature from CO_2 and H_2O using sunlight as the energy source through photosynthesis process every year [1], and it provides basic necessities in people's daily life including food, clothes, houses and medications. Biomass is also an important energy sources and some researchers have been trying to find more efficient way to convert biomass to hydrocarbon fuels since the energy crisis of the 1970s [2]. Compared to the fossil energy, biofuels generate significantly less greenhouse gas emissions, which can reduce the pressure on the environment. Wood and other forms of biomass, as the main renewable energy resources, can be treated in lots of ways to produce biofuels [3]. Pyrolysis processes have a very long history and have been improved and widely used to produce coke and charcoal. Fast pyrolysis is a thermal decomposition process and can use biomass to obtain bio-oil and bio-char. The produced bio-oil is a kind of fuel for transportation and the bio-char combustion can produce electricity and heat. However the efficiency of coal-fired plants is not satisfied due to the Carnot cycle and a huge among of energy has been wasted, therefore, researchers invented a direct carbon fuel cell (DCFC) device which can convert the chemical energy stored in solid carbon into electricity directly without a reforming process. The overall cell reaction of DCFC is $C + O_2 = CO_2$, and due to a nearly zero entropy change ($\Delta S = 0.6$ J K^{-1} mol at 600 ^oC), its theoretical thermal efficiency approaches 100% and it has an achievable efficiency of 80%. In our previous work, a DCFC device has been established based on a $Ce_{0.8}Sm_{0.2}O_{1.9}$ (SDC) and carbonate composite electrolyte, which have a high conductivity at a relatively low working temperature. In this work, we combine the agricultural production process, pyrolysis process and DCFC technology together to achieve the goal of clean and efficient utilization of biomass to generate electricity and bio-oil, and the whole system can be described in Figure 1.

In China, corn as a main crop, has been widely cultivated in the northeast, north and southwest. Maize groats are used as human food or for the production of animal feed. While the remaining corn stover and corn cobs are used as the power source for cooking and heating. In the developed countries, taking the U.S. for example, bioethanol derived primarily from corn contributes 2% to the total transportation fuels mix. In order to use the biomass waste in a high efficiency and environmentally friendly way, we designed an energy conversion route with a DCFC system. The corn cobs shown in the Figure 1 are used. Firstly, the corn cobs were broke into small pieces and pressed into pellets with a diameter of 20 mm. Secondly, the corn cob pellets were put into a quarz tube with a diameter of 22 mm and heated at 700 ^oC in N_2 with a flow rate of 50 ml min^{-1} for 2 h. During the pyrolysis process, the biomass decomposes to generate bio-oil and bio-char. Bio-oil can be used as a fuel in many static applications such as furnaces, turbines and engines. After the pyrolysis process, the solid biomass char from corn cobs is obtained in yields of up to 25% wt on dry feed. Our work focuses on studying the electrochemical performance of bio-char in the DCFC system.

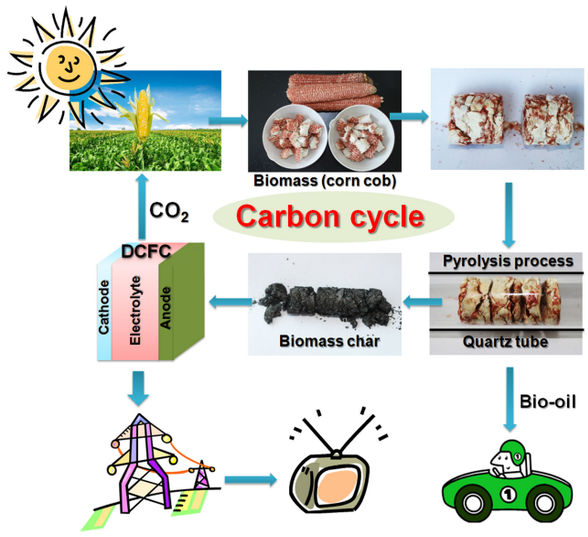

Figure 1. A clean and efficient energy conversion system using biomass as fuel.combine the agricultural production process, pyrolysis process and DCFC technology together to achieve the goal of clean and efficient utilization of biomass to generate electricity and bio-oil.

Biomass fuels have been playing a very important role in the human development process since the start of using fires by early hominids dating back to millions years ago. Nowadays, fossil fuels are still the dominant energy source in the human world and the main utilization of biomass is only for cooking and domestic heating. Due to the energy and environment crisis, people realize that the transition from nonrenewable carbon resources to renewable bioresources is in urgent need. Here we show a clean and efficient utilization of biomass in a novel energy conversion system. Using pyrolysis technology to produce biomass char and bio-oil from corn cobs, a high efficiency energy conversion system has been realized with a direct carbon fuel cell (DCFC) device using $Ce_{0.8}Sm_{0.2}O_{1.9}$ (SDC) and carbonate composite electrolyte. High electrochemical performance of biomass char with a peak power density of 185 mW cm^{-2} at an operation temperature of 750 ^oC has been obtained in the fuel cell discharge test. The whole system consists of agricultural production process, pyrolysis process and a DCFC device. Carbon elements are reused in the energy conversion cycle and the original energy source is from the sun. We anticipate our work to be a starting point for the clean and efficient utilization of biomass fuels to produce electricity by using DCFC and bio-oil for transportation, which requires the cooperation and efforts of researchers in various scientific fields**.**

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