Electrochemical oxidation of methane and reduction of oxygen on the electrodes in the single-chamber solid oxide fuel cell (SC SOFC)

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Introduction

Natural gas, containing mainly methane, is likely to become one of the most important energetic sources in near future, justifying intensive research on its application as fuel. Single-chamber solid oxide fuel cells (SC SOFC) are one of the possible devices enabling direct conversion of methane to electricity. The aim of the present research is to characterize catalytic processes occurring on electrodes in the SC SOFC, in the presence of gas mixture composed of oxygen and methane. The observed differences in electrode potentials of the studied anode and cathode materials are reported as a function of varying methane concentration in the gas feed. The obtained results are additionally compared with data from theoretical calculations.

Materials and Methods

The following systems of electrodes were prepared: Au and Pt deposited on the solid electrolyte YSZ (ZrO_2+8%Y_2O_3) as well as of cermet Ni-$Ce_{0,8}Sm_{0,2}O_{1,9}$ and Au deposited on electrolyte YSZ. The built fuel cells were supplied with the common gas mixture CH_4+O_2+Ar at 873 K. In the performed experiments, methane and oxygen concetration range was varried between 0 and 100% in the supplying mixture. The cathode and anode potentials were measured versus reference electrode, supplied with its own gas mixture. The measured open-circuit potentials of these electrodes as a function of gas mixture composition, are compared with the calculated values, which were obtained based on the equilibrium taking place in the gas phase or in the adsorbed gas layer on the electrodes.

Results and Discussion

The selective properties of electrodes resulting in their distinct potentials were employed in SC SOFC. The observed catalytic processes occur both on the anode and cathode, in the presence of gas mixture containing oxygen and methane, proceed differently due to selective properties of these two electrodes. The equilibrium methane oxidation, taking place on the anode, is due to its selectivity. Conversely, the reactions occuring on the cathode are determined by the oxygen concentration in the gas mixture.

In the case of the electrode pair Pt/YSZ/Au, the stable value of potential difference (ca. 600 mV) is established in wide range of methane concentration in the mixture with oxygen. On the contrary, this potential difference is not observed while gas mixture containing hydrogen and oxygen is feed.

The maximum difference of potentials between anode and cathode is obtained for one-chamber cell system of cermet Ni-$Ce_{0,8}Sm_{0,2}O_{1,9}$ /YSZ/Au, resulting in ca. 1000 mV. The comparison between experimental data and theoretical values shows that under applied experimental conditions, cathode potentials depend mainly on oxygen partial pressure in the supplying feed mixture. On the other hand, on the anode, electrochemical oxidation reaction of methane takes place and equilibrium is reached between reagents. The anode potential values are equal to calculated values for the partial and total oxidation reaction of methane.

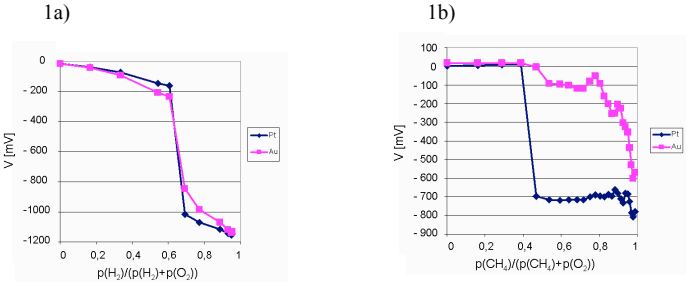

Fig. 1. Potentials of Pt anode and Au cathode supported on YSZ. The cell is supplied: 1a) with hydrogen and 1b) with methane.

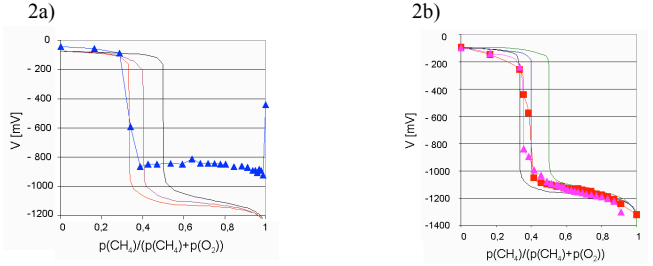

Fig. 2. Comparison of the anode potentials with theoretical values (solid lines) for different methane oxidation reactions: 2a) Pt anode potentials; 2b) Ni-$Ce_{0,8}Sm_{0,2}O_{1,9}$ anode potentials.

Significance

The typical process of methane conversion to electricity is based on its transformation into thermal energy, which next is used for generation of mechanical energy and finally to electricity, and is characterized by high lost energy, since the efficiency of this conventional process does not exceed 40 %. Fuel cells are energy generators in which direct fuel conversion to electricity proceeds, with efficiency even two fold higher than during conventional process. The performed experiments helped to choose the optimal materials for electrodes, defined as the maximum potential difference between them.

Acknowledgements

Authors acknowledge the National Science Centre of Poland for financial support in the frame of project 2012/05/B/ST4/00071.

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