Microwave and Gliding Arc Plasma Pyrolysis of Methane: Comparison of the Plasma Sources

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Abstract

Hydrogen is already today highly relevant for the chemical industry. In the future hydrogen could also be used as a green fuel, as energy carrier or for energy storage. However, in the face of climate change new energy efficient and greenhouse gas-free production methods are necessary for the utilization of hydrogen on larger scales. The pyrolysis of methane in a plasma is a promising production method for turquoise hydrogen.

Here, we will present a microwave plasma torch and a gliding arc plasmatron operating at atmospheric pressure in an argon-methane mixture. We will compare the two plasma sources in terms of methane conversion, energy efficiency and product selectivities. The two plasma sources are integrated in one setup. Both plasma sources are operated with the same gas supply and diagnostics ensuring good comparability between the experimental results obtained with both sources. In the microwave plasma torch a total flow rate of 60 slm and 2.45 GHz microwaves with a forward power between 600 W and 3300 W are used to sustain a plasma with a diameter of about 1.2 cm and a length of up to 60 cm. In the center temperatures of up to 4300 K are achieved. The gliding arc plasmatron is substantially smaller. Therefore, only 10 slm of total flow rate are used. However, the input power (30-330 W) is also smaller leading to a similar specific energy input per methane molecule (SEI). In the gliding arc plasmatron temperatures of up to 5500 K are achieved.

A continuous gas analyser with nondispersive infrared sensors for methane (CH_4) and the two main gaseous side products ethyne (C_2H_2) and ethene (C_2H_4) and a thermal conductivity sensor for the main product hydrogen (H_2) is used to analyse the product gas stream. Additionally, solid carbon is produced as a side product. In both plasma sources the methane conversion increases with the SEI. At constant SEI the methane conversion increases with increasing methane admixture. Methane conversions of up to 65 % are achieved. At low methane admixtures, C_2H_2 is the most important side product with selectivities of up to 100 %. With increasing methane admixture, the selectivity towards C_2H_2 decreases to about 40 % and solid carbon becomes the most important side product. At the same SEI and methane admixture the conversion in the gliding arc plasmatron is higher than in the microwave plasma. However, higher SEIs can be used in the microwave plasma leading to higher conversion. The selectivity towards C_2H_2 is higher in the gliding arc plasmatron while in the microwave plasma the selectivity towards solid carbon is higher.

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