

# Plasma-assisted CO<sub>2</sub> reduction in synthetic fuel processing

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Infrared laser absorption spectroscopy (IR-LAS) in conjunction with mass spectrometry was used to characterize the CO<sub>2</sub> reduction in expanding Ar/H<sub>2</sub> plasmas for synthetic fuel production. CO<sub>x</sub> was injected into the expansion part where the reaction mechanism could be radical and/or ion driven. The results suggest a separation of dissociation and hydrogenation step. Further work on materials tailored for plasma-catalysis is required to increase the conversion efficiency.

## 1. Introduction

Plasma processing of carbon dioxide into conventional fuels is considered as an alternative approach. While reducing the green house gas emissions, these fuels can be integrated in the existing transport infrastructure. The formation of CO from CO<sub>2</sub> is thereby considered the rate limiting step [1] in further hydrocarbon or oxygenate forming reactions. This paper discusses conversion efficiencies in plasma-assisted CO<sub>2</sub> reduction, i.e. dissociation and hydrogenation in a low temperature plasma expansion. The potential of plasma catalysis in this context is assessed.

## 2. Experimental

CO<sub>2</sub> was injected into the background of an expanding thermal plasma created from a cascaded arc in mixtures of H<sub>2</sub> and Ar. The flow of CO<sub>2</sub> was maintained at about 10% of the total flows of 3360 sccm. The total pressure in the magnetized expansion part, where the electron temperature is usually clearly below 1 eV, was kept at 1 mbar.

The plasma composition was characterized at the farther end of the plasma expansion using infrared laser absorption spectroscopy (IR-LAS). Quadrupole mass spectrometry (QMS) was used as a complimentary technique for measuring components that cannot be accessed by IR-LAS. Apart from the native stainless steel, aluminium and copper foils were used in close contact to the vacuum vessel to evaluate the influence on the steady-state gas composition.

## 3. Results and Discussion

Three distinct regimes of chemistry can be observed depending on the gas composition through the arc (from pure Ar to pure H<sub>2</sub>, fig. 1). In the first regime (I) charge exchange between CO<sub>2</sub> and Ar<sup>+</sup> ions followed by dissociative recombination of CO<sub>2</sub><sup>+</sup> - as observed for other molecular gases in this type of plasma - may be the dominant process. Ar<sup>+</sup> is quenched quickly with addition of few percentage of

H<sub>2</sub> to the flow [2] and so are the O<sub>2</sub> production and the CO yield which can be as high as 50 % in pure Ar.

In regime II the CO<sub>2</sub> dissociation levels off and production of methane starts (fig 1). Main stable products apart from CO<sub>2</sub> are CO and H<sub>2</sub>O (not shown in fig. 1). In regime III the chemistry is mainly driven by H radicals which leads to an increase in methane production. However, the CH<sub>4</sub> remains at a few %.

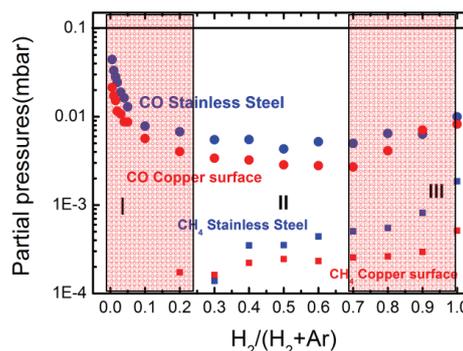


Fig. 1: CO and CH<sub>4</sub> produced during the CO<sub>2</sub> reduction in a plasma expansion of Ar/H<sub>2</sub> using different surface materials. Different regimes of chemistry are indicated (I - III).

Experiments performed with CO in place of CO<sub>2</sub> - where the conversion to methane starts at much lower additions of H<sub>2</sub> and may reach 25 % - confirmed that a syngas step (CO+H<sub>2</sub>) is also essential in plasma-catalytic approaches. A difference in the gas composition was observed, when certain surface materials were used (e.g. Cu, fig. 1). However, in contrast to conventional catalysis the CO concentration was reduced and so was the CH<sub>4</sub> formation.

## References

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- [2] R.F.G.Meulenbroeks et al *Physical Review E* 49, (1994) 4397-4406.