Topic number: 10.

FLOWING DISCHARGES IN $Ar - H_2$ MIXTURES

N. M. Sakan[(1)], M. Ivkovic[(1)], J. D. Drake[(2)], S. Popovic[(3,*)], L. Vuskovic[(3)]
Contacting author[(3,*)]

[(1)] Institute of Physics, Belgrade, Serbia
[(2)] University of Iowa, Iowa City, IA, USA
[(3)] Old Dominion University, Norfolk, VA, USA
[(*)] spopovic@odu.edu

A prospective unseeded hydrogen plasma-based high-Mach number fuel is a complex mixture of at minimum three initial species: noble gas (*Ar*), hydrogen, and air. Noble gas is added in the mixture to reduce the penalty of ionization. However, the presence of hydrogen, nitrogen, and oxygen molecules leads to complex branching inter-radical chemistry, which may result in the decrease of the degree of ionization. These processes are poorly understood and their study is the primary motivation for the present work. Effects on plasma properties upon addition of hydrogen have been noted in many cases [1-4].

In this work we are comparing experimental results on the decrease of ionization in an *Ar* plasma with variable ($1 - 10$ %) addition of hydrogen in two flowing pulsed discharges – microwave cavity discharge operating in the initial pressure range from 0.1 to 10 *kPa* (static pressure range from 0.5 to 50 *kPa*) and a pulsed dc discharge operating in the initial pressure range 1 to 10 *kPa*, but at static pressure 20 to 400 *kPa*. Apart from the pressure range, the two discharges differ in the degree of ionization, and departure from Saha equilibrium. Both discharges could serve as generic plasma sources for flowing combustion reactors, one at sub-atmospheric and other at super-atmospheric pressures serving as fuel reformation devices in renewable energy sources.

The initial question how addition of hydrogen in Argon plasma affects the discharge kinetics and parameters at sub-atmospheric and super-atmospheric pressures is addressed in this paper. Further addition of fuel components was planned and executed in the supersonic, low pressure version [1], but it is still in preparation for the high pressure version.

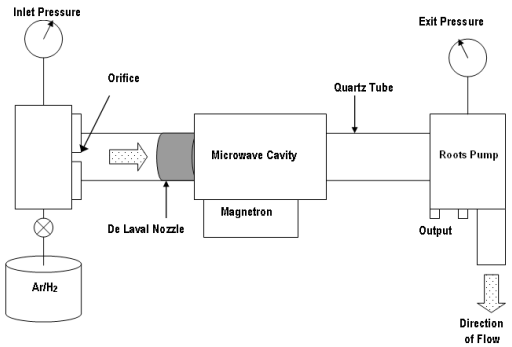

Fig. 1: Scheme of supersonic microwave discharge.

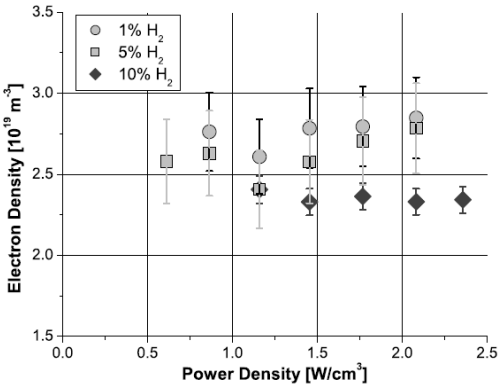

Fig. 2: Electron density drop in the cavity microwave discharge at 300 *Pa*, with different initial amounts of H_2 in the mixture. Statistical error is indicated.

The pulsed light source used for this study is laboratory made low pressure pulsed plasma source of specific design [5] with possibility to generate high electron number density helium plasma with N_e up to 10^{24} m^{-3}. The schematic drawing of discharge tube, together with experimental setup is given in Fig. 3. The separation between tungsten electrodes (placed inside a quartz

tube with an inner diameter of 8 mm) was 8 cm. Each electrode has a 0.6 mm diameter central opening to enable interferometric and spectroscopic measurements along the axis of plasma column.

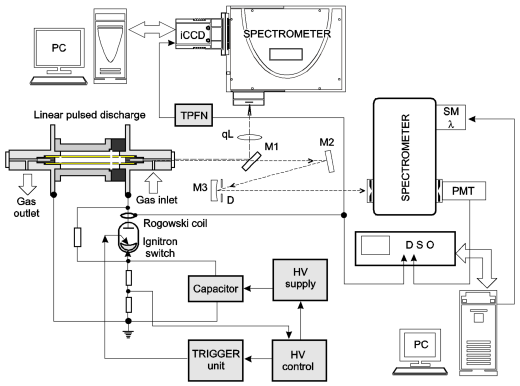

Fig. 3: Experimental setup

The discharge was driven by the low inductance 15 μF capacitor charged in this experiment up to 6 kV. In order to decrease the circuit inductance three electric cables are coaxially connected with cathode. For data acquisition two different line shape recording systems were used. In the first one, see right hand side of Fig. 3, a 1 : 1 image of the plasma source is projected, by means of: flat $M2$ and focusing $M3$ mirror (diameter $D = 50$ mm and focal length $f = 100$ cm), onto the entrance slit (15 μm wide and 1 mm vertical opening) of a 1 m monochromator (inverse linear dispersion 0.833 nm/mm). Behind the exit slit (15 μm) of the spectrometer thermoelectrically cooled photomultiplier (PMT) EMI 9813QB was mounted. The second data acquisition system is based on a 0.3 m Shamrock 303 spectrometer equipped with Andor ICCD camera DH724. A 1 : 1 image of the plasma source was projected on the 10 μm entrance slit by means of an optional folding mirror $M1$ and quartz focusing lens qL ($D = 36$ mm, $f = 33.6$ cm), see Figs. 1 and 2. The camera was synchronized with the trigger pulse forming network - TPFN activated by the pulse from the Rogowski coil.

Our primary aim is to determine the extent of ionization loss due to the addition of hydrogen and air in two discharges that are the closest by configuration to the anticipated plasma-assisted hydrogen combustion devices in high-Mach number gas flows. Additionally, we aim to use non-invasive, *in situ* diagnostic techniques to study the mechanisms of ionization loss and consequent decrease of active radicals needed for the enhancement of hydrogen oxidation.

Reference

[1] D. J. Drake, S. Popović, and L. Vušković, J. Appl. Phys., **063305** (2008).
[2] A. Bogaerts and R. Gijbels, Spectrochim. Acta B **57**, 1071 (2002).
[3] C. V. Budtz-Jørgensen, P. Kringhøj, and J. Bøttiger, Surf. Coat. Technol. **116–119**, 938 (1999).
[4] R. S. Mason, P. D. Miller, and I. P. Mortimer, Phys. Rev. E, **55**, 7462 (1997).
[5] K. Grützmacher and U. Johannsen, *Spectral Line Shapes*, **Nova Science Publishers**