Compact Hydrogen Generation through JP-8 Fuel Processing Using Microplasmas

CNF Project # 1184-04
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Abstract
Fuel cells have been researched extensively as means of converting high energy density fuels to provide long-lasting, compact power supplies for military and domestic applications. Reforming of hydrocarbon fuels leads to the highest system energy densities since these liquids are excellent sources of hydrogen at high density. While typical reforming operations rely on catalyst-driven processes, unfortunately fouling and lifetime issues have limited the effectiveness of most of these processes to date, especially for compact systems with greater restrictions on size, weight, operating temperature and materials of construction.

This project aims to study reforming of a heavy hydrocarbon military fuel (diesel-like JP-8 fuel) using a microplasma. Plasmas confined to microscale geometry exhibit extremely high ion, electron, and reactive radical densities and hence can activate chemical processes in place of catalysts and at lower reactor temperatures. We intend to implement microfabricated plasma reactors in order to benefit from scaling laws permitting processing at pressures greater than atmosphere.

Fabrication
We have fabricated the first set of microplasma reactors at CNF and will characterize them for their plasma operation with inert and well-characterized plasmas like xenon (Xe). We will ultimately introduce characteristic hydrocarbon species representative of those found in JP-8, and analyze the effects of the plasma. Optical emission spectroscopy will be used to analyze intermediates. Gas chromatography will be used to analyze the product distribution and to assess conversion. FTIR will be used for in situ chemical analysis within the reactor.

Plasma reactors were designed in AutoCAD (Figure 1) and microfabricated using various silicon processing techniques. Silicon wafers, 500 µm thick, served as the starting substrate. Silicon dioxide of substantial thickness (2 µm and 4 µm, on different wafers) was thermally grown on the silicon substrate using an MOS oxide furnace operating around 1200°C. Nickel anodes were created using lift-off photolithography and metal evaporation. Next, microchannels between the anode contacts were dry-etched into the dielectric layers using fluorine chemistry, and the etching continued in the silicon substrate by switching over to the Bosch process for deep reactive ion etching (DRIE). Finally, gold was evaporated onto the backside of the silicon substrate, and the silicon wafers were sawed into the final device size (1 cm by 0.8 cm).
Summary

The devices recently microfabricated at CNF are currently in the process of being evaluated for plasma performance by attaching them with their backside cathode against a platform onto which a negative voltage is imposed while grounding the nickel topside anode. The entire platform sits inside a small pressure-controlled chamber (see Figure 2) which can be filled with various ambient gases. Initial testing has begun using Xe gas. A microplasma was generated at atmospheric pressure and contained within the microtrench of the device (see Figure 3). Initial test results are very encouraging.

References
