NANOPARTICLE FORMATION BURNING BIOFUELS

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Biofuels are gaining increased attention as alternative to fossil fuels in order to address the climate change issue and energy security.

Biofuels may produce less net carbon dioxide emissions than oil-based conventional fuels. There is also a general idea about their ability to reduce exhaust emissions.

Experiments performed in laboratory-scale experiments and in engines have shown that the effect of biofuels on the formation of particulate matter is controversial.

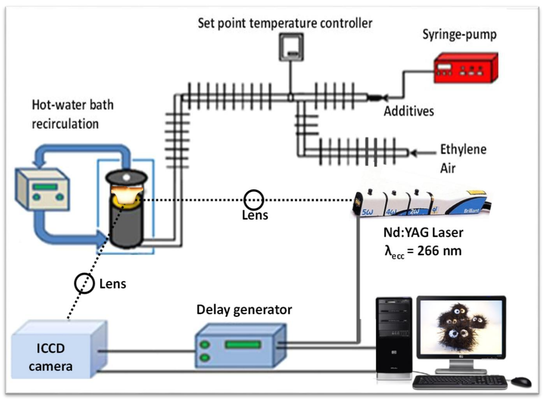
In this study: the role of ethanol, dimethyl-ether, furan, 2-methyl furan and 2,5-dimethyl furan on the formation of particulate matter is investigated in premixed and opposed-flow diffusion flames by using in situ optical techniques, differential mobility particle sizer and off-line chemical characterization.

BIOFUELS

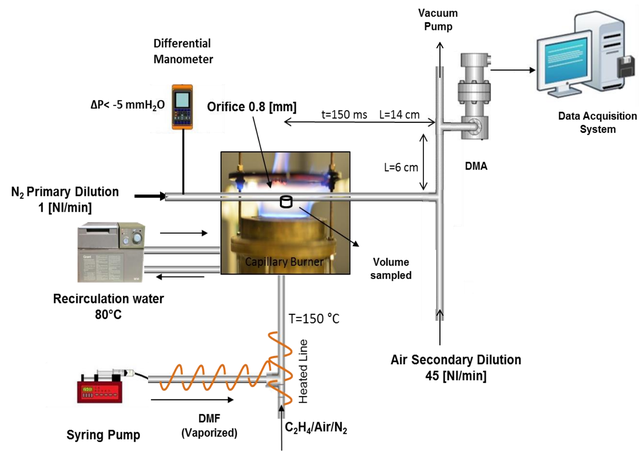
ETHANOL (EtOH)
DIMETHYL-ETHER (DME)
FURAN (F)
METHYL FURAN (MF)
2,5 DIMETHYL FURAN (DMF)

DIAGNOSTIC TOOLS

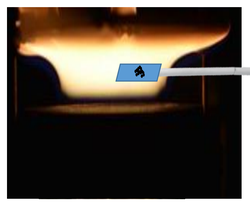
IN-SITU SPECTROSCOPY
LIF (Laser Induced Fluorescence)
LII (Laser Induced Incandescence)



EX-SITU DIFFERENTIAL MOBILITY PARTICLE SIZER

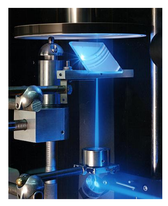


SOOT DEPOSITION ON QUARTZ DISKS



OFF-LINE ANALYSES

RAMAN



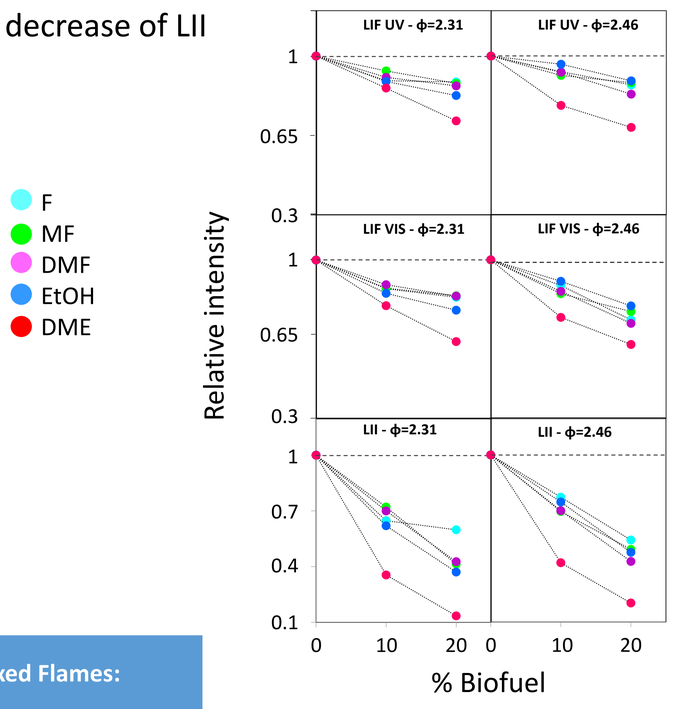
UV-VIS

FTIR

PREMIXED FLAMES

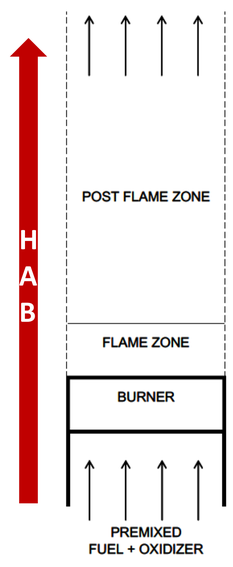
with respect to Ethylene flame:

- decrease of LIF UV and LIF Vis
- strong decrease of LII



in Premixed Flames:

- ✓ global particle concentration reduction
- ✓ stronger reduction of the >10 nm particle concentration
- ✓ different chemical structure of >10nm particles

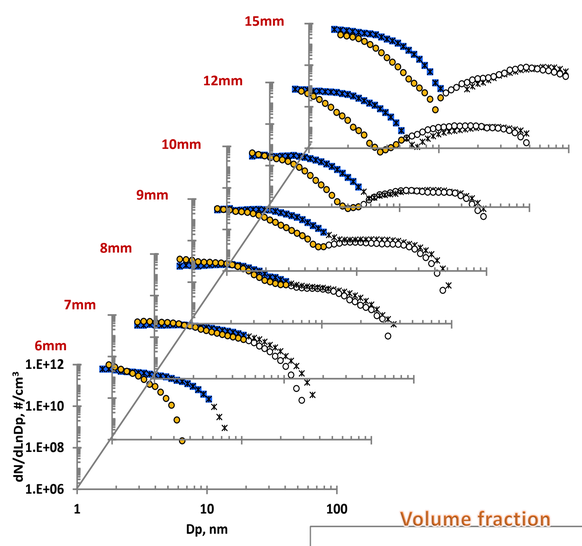


Ethylene flame (Dp<10 nm)
Ethylene/20%DMF flame (Dp<10 nm)

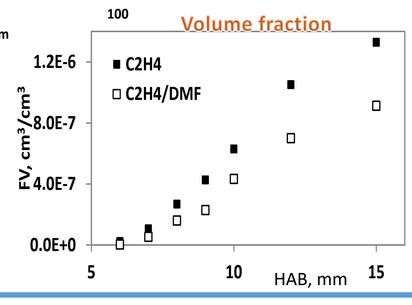
Ethylene flame (Dp>10 nm)
Ethylene/20%DMF flame (Dp>10 nm)

THE CASE OF ETHYLENE/DIMETHYLFURAN (80/20%)

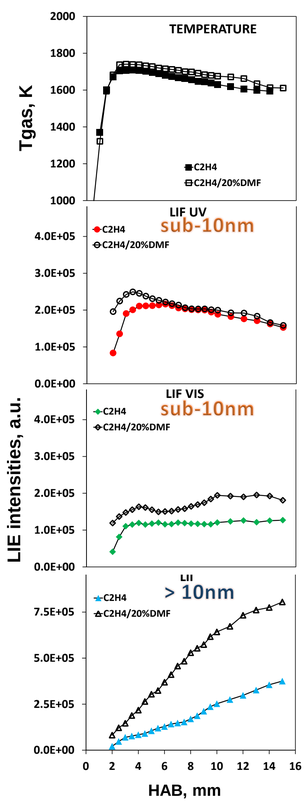
Particle size distributions at different Heights above Burner



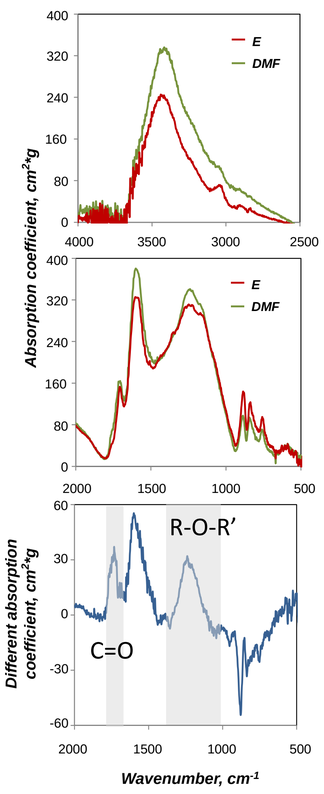
Volume fraction



LIE

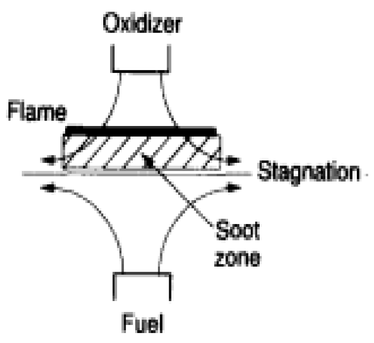


FTIR of >10nm particles at 15mm



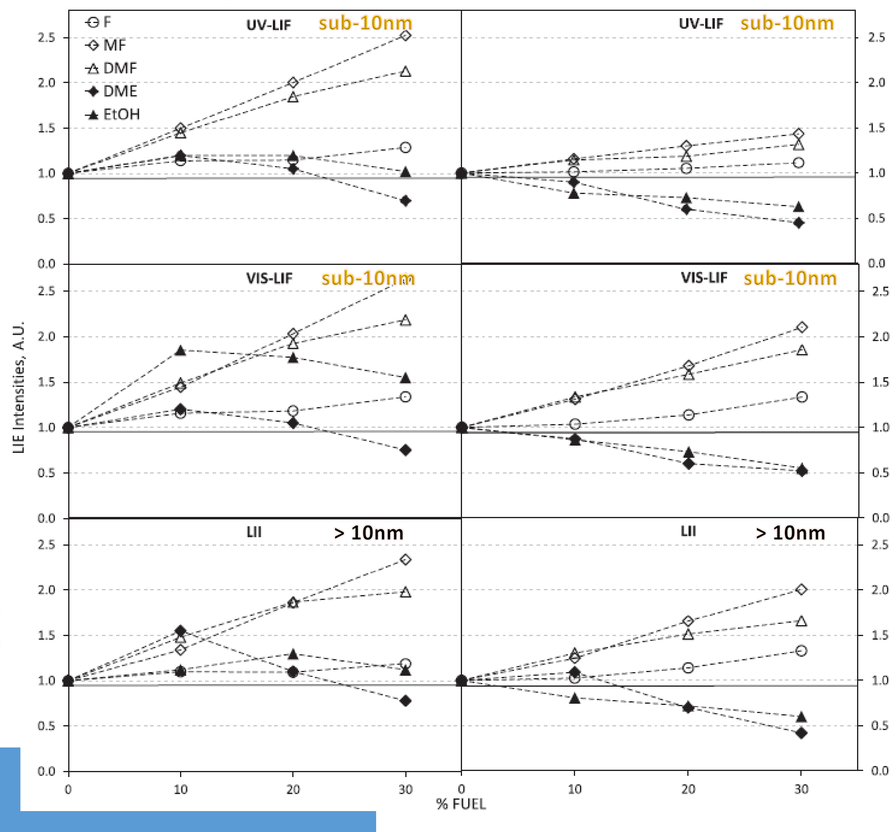
OPPOSED-FLOW DIFFUSION FLAMES

IN-SITU SPECTROSCOPY LIF & LII



Relative intensity of emissions with respect to pure ethylene flame as a function of the percentage of the total carbon fed as additive. Top to bottom: UV-LIF at 350 nm, VIS-LIF at 430 nm and LII at 550 nm.

Fuel side (pyrolysis) | Oxidant side (oxidation)



in Opposed-flow diffusion flames:

- ✓ particle concentration increases

COMPRESSION IGNITION ENGINE EXHAUST

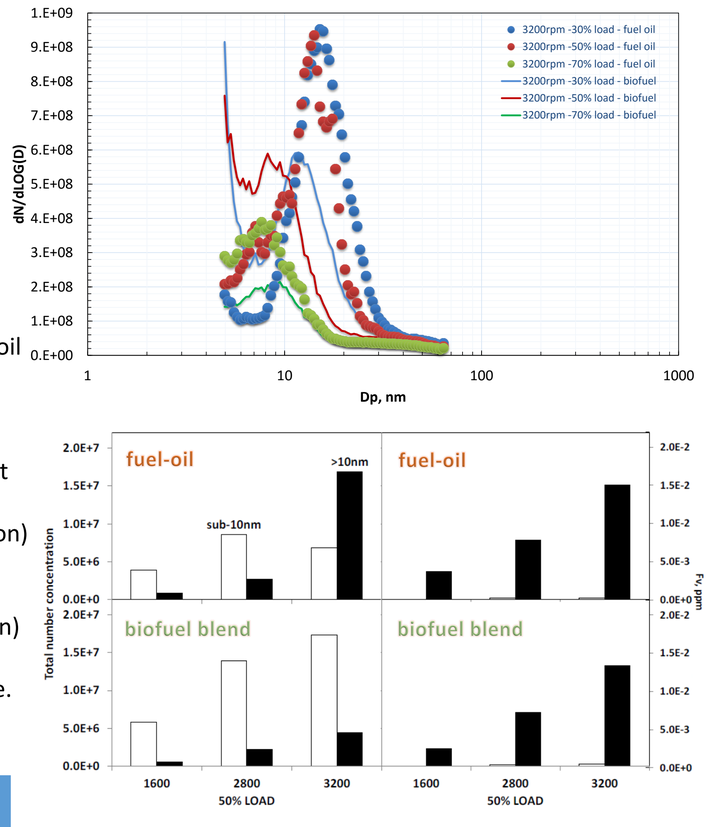
Biofuel (Rapeseed Methyl Ester with fuel oil -20/80%) and Fuel Oil
Three-cylinder, six valves, 1028 cm³, common rail diesel engine.
Aerosol sampled at 1.5m from the exhaust valves, thermal conditioned at 300°C and diluted by a DEED (up to the critical dilution)

Particle total number concentration (left column) and volume fraction (right column) for sub-10nm (white) and larger particles (black) retrieved from PSDs showed above.

In Diesel Engine:

- ✓ strongly reduces the >10nm particles

DIFFERENTIAL MOBILITY PARTICLE SIZER



courtesy of B.M. Vaglieco, E. Mancaruso, A. Magno & S. Di Iorio

CONCLUSIONS

- In premixed flame conditions biofuels are more effective on large particles reduction; also for high addition of biofuel sub-10nm particles are still produced.
- In opposed-flow diffusion flames, the operating conditions typical of practical combustion systems, biofuels act as enhancers of sub-10nm particles production.
- Particles larger than 10 nm produced in biofuel flames present enhanced absorption characteristics of oxygenated functionalities.
- In practical conditions (Diesel engine) the addition of biofuel (RME) strongly reduces the >10nm particles.

References

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- *C. Russo, F. Stanzione, A. Tregrossi, Ciajolo A., Infrared spectroscopy of some carbon-based materials relevant in combustion: qualitative and quantitative analysis of hydrogen, Carbon, 74 (2014) 127–138*
- *M. Sirignano, M. Conturso, A. D' Anna, Effect of furans on particle formation in diffusion flames: an experimental and modeling study, Proc. Combust. Inst., 35 (1) (2015) 525–532.*
- *M. Conturso, M. Sirignano, A. D'Anna, Effect of furanic biofuels on particles formation in premixed flames: an experimental study, Fuel 175 (2016) 137-145.*
- *C. Russo, A. D'Anna, A. Ciajolo, M. Sirignano, Analysis of the chemical features of particles generated from ethylene and ethylene/2,5 dimethyl furan flames, Combust. Flame, 167 (2016) 268-273.*