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PROCEEDINGS TITLE

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ABSTRACT

This guide has been prepared for authors of papers to be presented at the 3rd Thermal and Fluids Engineering Conference (TFEC), March 4–7, 2018, Fort Lauderdale, FL, USA. The abstract summarizes key findings in the paper and should be a paragraph no more than 250 words. The abstract summarizes key findings in the paper and should be a paragraph no more than 250 words. The abstract summarizes key findings in the paper and should be a paragraph no more than 250 words. The abstract summarizes key findings in the paper and should be a paragraph no more than 250 words. The abstract summarizes key findings in the paper and should be a paragraph no more than 250 words.

KEY WORDS: select up to 10 key terms for a search on your document

1. INTRODUCTION

Heat is difficult to measure, even at macroscales! At macroscales, key quantities of interest for heat transfer are temperature, heat flux, and thermophysical properties such as thermal conductivity, specific heat, etc. Conductive and convective heat transfer at macroscale are usually governed by diffusion processes because heat carriers (molecules, electrons, phonons, etc.) in these processes have short mean free paths and short wavelengths. In micro- and nanostructures, however, the mean free paths and even wavelengths of heat carriers become comparable or longer than the characteristic length involved in the transport process. Heat transfer can no longer be described by established theories applicable to macroscale. It is precisely these deviations from continuum that have drawn significant interests from scientific communities to understand micro-/nanoscale heat transfer. Such understandings have potential impacts over a wide range of applications, from microelectronics to energy conversion. Experimentally probing heat transfer in micro-/nanostructures is essential for scientific and technological endeavors, and significant progress has been made over the last two decades. This volume aims to provide a summary of the advances made in probing micro-/nanoscale heat transfer.

$$R(E) = \frac{\kappa}{2\eta} \int_{\Omega} (\nabla E \cdot \nabla E + \varepsilon)^{\eta} \, d\Omega \tag{1}$$

In many gasoline direct injection (GDI) engines hollow cone sprays generated by swirl or outwardly opening injectors are applied. In this study the spray of an outwardly opening injector is investigated. According to the geometrical shape of an outwardly opening pintle nozzle the fuel exits from an annular gap. Previous investigations have already shown that the hollow cone spray leaving this nozzle is composed of many single strings instead of a continuous conical sheet.

The dependency of the string spacing on boundary conditions has been described by different authors. [1]

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Table 1 Injected fuel mass

injection duration Δt [μs]	**injection pressure** [MPa]	**fuel mass** [mg]
300	1	1.7
300	2	3.0
300	3	4.0
300	4	4.7
300	5	5.4
300	6	6.0
300	7	6.5
300	8	6.9
300	9	7.2
300	10	7.6
300	11	7.7
300	12	8.0
100	10	0.6
200	10	4.3
400	10	10.3

stated that the string spacing is a function of the fuel rate, while [2] and [6] found out that the injection pressure has some influence on the string structure. Additionally, [4] mentioned that velocity affects the string formation, while the effect of ambient pressure can be neglected [5].

According to [3] and [6] the fluid flowing radially through the gap between pintle and seat exhibits an enlargement of the flow passage cross-sectional area, and thus flow separation inside the nozzle and buildup of air pockets at the nozzle exit can be observed [2]. This causes a two-phase flow inside the nozzle that is responsible for the stringy structure at the nozzle exit [1]. Investigations with a large-scale transparent nozzle [4] show that the surface structure cannot be the only reason for the strings, since the strings could be observed for the large scale nozzle as well as for the original nozzle although the corresponding relative surface roughness is quite different. Cavitation seems not to be responsible for the flow structure, even though it may enforce

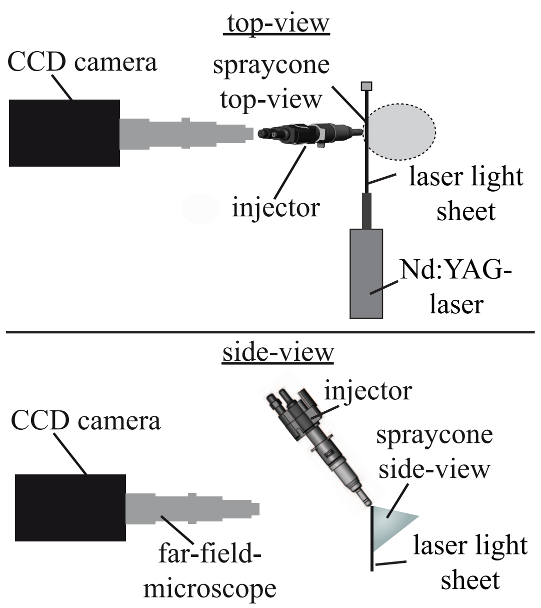

Fig. 1 Visualization setup.

or influence the string formation. [2] justified this statement with a volume-of-fluid-simulation that excludes the modeling of cavitation but shows the typical string structure. Additionally, [3] observed strings both for cavitating and noncavitating nozzles.

A detailed study of the influences of different injection conditions on the string-like structure has not been accomplished so far. Therefore, the goal of this investigation is to give a detailed comparison of the impact of injection conditions on spray structure at the nozzle exit. Visualization measurements with a far-field microscope are applied to identify the interspacing of the string structure at varying injection pressures and injection durations. Additionally, laser correlation velocimetry (LCV) is used to investigate the velocity of the strings, and to examine possible correlations between the string structure and the spray velocity at the exit.

These results are needed to understand the phenomena in order to validate numerical simulations.

1.1 Measurement Sensitivity, Uncertainty, Reproducibility, and Calibration

Heat flux cross small structures such as nanowires is very tiny, and high-sensitivity heat flux meters are needed for thermal measurements. Similar to macroscale heat flux measurements, nanoscale heat flux measurements usually require knowing temperature differences between two points and thermal resistance between the same points, from which the heat flux can be calculated. The key for small heat flux measurements is to create structures with large thermal resistance values between the two temperature measurements points.

Suspended structures. Suspended structures used for nanowire thermal conductivity measurements serve as a good example. From the entire volume, it is clear that significant progress has been made in experimental techniques to probe nanoscale heat transfer phenomena, and the experimental results have led to new understandings of heat transfer physics, generated new challenges, and opened new opportunities. From my own perspective, the following are some significant challenges.

2. CONCLUSIONS

Significant progress has been made in terms of tailoring the radiative properties with micro-/nanostructured materials. Rapid developments have been made in fabricating periodic gratings and nanostructured periodic arrays of metal materials over thin films and multilayers. Magnetic responses have been demonstrated in the infrared and even visible spectral regions. Further research is needed to understand the coupling mechanisms between various modes and localized surface plasmons. While FDTD and RCWA can be used to calculate the radiative properties for engineered surfaces with micro-/nanostructures, faster computational algorithms are needed with complicated structures to assist the design for specific applications. The optical constants are often different in the nanostructured materials as compared with the bulk solid. Furthermore, for high-temperature applications, the chemical and thermal stability must be considered, as well as the size- and temperature-dependent optical constants of the materials.

Aligned metallic nanowires may exhibit unique optical and thermal radiative properties due to the surface-enhanced absorption and scattering, anisotropic dielectric function, and magnetic resonance (between parallel wires), and may be applied to diffraction optics as well as IR polarizers and in the control of optical and radiative properties. Detailed models considering both surface scattering and volume scattering will allow better understanding of the radiative transfer in these inhomogeneous structures. Methods for fabricating more uniform structures in large areas with a high yield are still needed. Measurements at longer wavelengths, i.e., mid- to far-IR, will help in understanding the effective medium behavior as well as the magnetic response.

VACNT arrays show great promise for radiometric applications as nearly perfect absorbers and emitters in a broad spectral region. EMT appears to be able to describe the visible and infrared properties of CNT arrays reasonably well. Specular and diffuse black materials made of SWCNTs or MWCNTs should be valuable for space-borne radiometric systems, high-power laser radiometers, absolute cryogenic radiometers, and infrared calibration facilities. The chemical stability and mechanical rigidity of these structures also need to be further investigated. A challenge that exists in the materials growth process is how to control the growth conditions so that arrays with a controllable degree of alignment and surface morphology can be reproduced. In terms of optical properties of CNTs, quantitative understanding of the anisotropic optical behaviors should be pursued. There is a need to investigate the polarization-dependent reflectance and transmittance at oblique incidence.

Submission Deadline: Full paper PDF should be submitted before **June 16, 2017**.

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NOMENCLATURE

Be	dimensionless variable	(-)	Q_A	third variable	(kJ)
C	second variable	(s^2)	w_x	fourth variable	(m^2/s)

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