Assessing the benefits of novel nanoporous silicon nitride membranes to capture and analyse particulate emitted from spark ignited hydrogen internal combustion engine.

Salvatore Lagana, Antonino La Rocca, Kevin Webb, Michael Fay, Alasdair Cairns.

Department of Mechanical, Materials and Manufacturing Engineering, C39 Coates Building, University Park
The University of Nottingham, NG7 2RD
Email: salvatore.lagana@nottingham.ac.uk

The objective of this study was to determine whether, in comparison to the most advanced graphene oxide (GO) grids, there would be any further advantages to analysing the exhaust particle captured on a novel nanoporous silicon nitride (SiN) grid. A spark ignited internal combustion engine powered by hydrogen was used in this investigation and it was operated using a baseline lubricant oil. One speed-load condition was chosen to generate a nanometric particulate output. As part of the capturing setup, an in-house probe was designed and manufactured to hold the TEM grid in the centre of the exhaust stream. The exhaust stream was sampled using a modified AVL smokemeter, which was set to sample "n" times 20,000 mL based on the length of time the grid was left exposed to the gas. While the engine was run at steady-state conditions, a DMS500 with the catalytic stripper was used to measure the particles concentration in the exhaust. As solid particles were detected, two TEM grids, one in graphene oxide (GO) and one in silicon nitride (SiN) were used in turn to capture the particles in the exhaust. Following capture, the particles were examined by HR-TEM at the University of Nottingham's Nanoscale and Microscale Research Centre (nmRC) using a JEOL 2100F TEM. A 250kV incident electron beam was used, and it could be magnified up to 250,000 times. The microscope was equipped with a Gatan Orius CCS camera. Additionally, EDX could be carried out using the X-MaxN 80 T that is available.
The results shows that the custom-made particle sampling setup successfully capture particles including sub-10 and sub 23nm particles on both grids. TEM analysis shows a wide range of particle types i.e. clusters, agglomerates, small particles and crystalline features. As expected, the main elemental composition of these particle can be correlated to oil composition. Particulates can be observed using EDX on the GO grid, but the amount of background carbon from the substrate overwhelms the amount from the particles. The small number of particulates from the H_2 engine required our proposed new method to fully understand composition. However, because silicon and nitrogen make up the majority of the C-free substrate, the SiN grid quantifies the carbon from the particle with greater accuracy. Additionally, elemental analysis can be studied anywhere on the SiN grid, but the GO grids need to be used away from the lacey carbon film and the copper mesh.

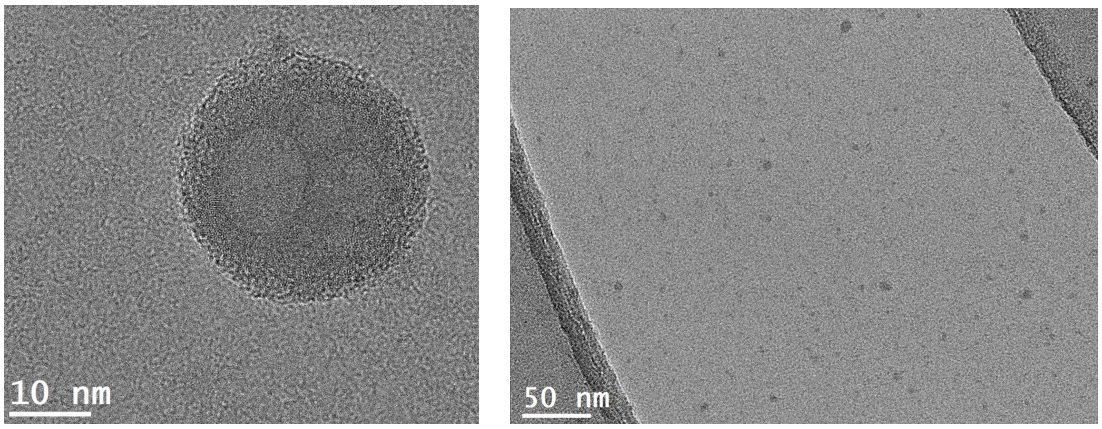

Figure 1. TEM images of particles captured on the grids: sigle particle (left), multiple 10nm particles on the right.