Deposit formation in diesel fuel injectors

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Diesel engines widely used in transportation, power generation and construction applications rely on high precision fuel injection for their efficient operation. The build up of deposits within diesel fuel injectors inhibits engine performance, fuel efficiency and control of emissions. A greater understanding of the deposits - morphology, chemistry and interactions with the underlying steel surface - is an enabler for fuels to be designed to prevent and reverse harmful deposit formation. Until now investigations have focussed on the exterior of the nozzle and in some cases low magnification scanning electron microscopy (SEM) and energy dispersive x-ray spectroscopy (EDS) studies of the surface of the nozzle channel. This is for the simple reason that the size and geometry of the nozzle makes it difficult to accurately section and gain quantitative chemical analysis, quite apart from investigating the deposit-steel interactions.

Here we show for the first time in this field, how careful mechanical sectioning, combined with focussed ion beam SEM (FIB-SEM) lift-out, leads to samples that can be analysed from the micron to the nanoscale; encompassing both surface analysis and characterisation through the depth of the sample right down to the interface with the underlying steel. We look at deposit formation and growth in diesel injectors that have undergone different test cycles - 'keep clean' (CD KC), 'dirty up' (CD DU) and an industry standard test (DW10B). Both the CD DU and DW10B test fuels contained 1mg/kg Zn, a known foulant used to mimic real world deposit build up.

SEM-EDS studies were conducted to look at the surface chemistry and morphology of the deposit as well as propose a deposition mechanism for some samples. Whilst this provides information about the surface composition and morphology, to understand the deposition process, the deposit has to be looked at in cross section. Samples were prepared using FIB-SEM and studied in the transmission electron microscope (TEM) using scanning TEM (STEM) and EDS. Only using these techniques was it possible to see the underlying porous structure of the deposit and relate this to its chemistry. Similarly, the chemistry at the interface between the deposit and the nozzle-steel was probed revealing the chemistry of the initial layers of deposit which may provide insight into deposit initiation.