X-ray Fluorescence Microscopy analyses of Three-Way Catalyst aging and deactivation in Gasoline Particulate Filter Application

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By 2015, the Gasoline direct injection (GDI) technology has captured almost 40% market share of the light-duty vehicles in the US [1]. However, comparing to conventional gasoline engines, GDI engines perform with higher particulate number emission [2]. To mitigate this issue, automakers proposed the application of Gasoline Particulate Filter (GPF) with the integration of three-way catalyst (TWC). This approach is considered to effectively reduce the manufacture cost, and to revolve the packaging issue in the exhaust system of light-duty vehicles [3-8].

A GPF is a flow-through monolith usually made of Cordierite, which is called the substrate. The substrate remains in highly porous structure that enables the gasoline exhaust to flow through the filter walls. TWC is coated on the porous substrate. Figure 1 shows schematically how the exhaust gas flow through a single cell of GPF. The lube-oil-derived ash components are known as one of the primary deactivation source. However, the ash accumulation and the TWC deactivation show different patterns in GPF, and the mechanism remains unknown. In this research, we focus on solving the deactivation mechanism of TWC in GPF. This research requires microscopic techniques to reveal the structural and element distribution of the catalyst as well as the ash in GPF.

The filter substrate contains mostly Si, Al and O. The effective catalyst elements are Ce and Zr. The elements that introduced by the lube-oil-derived ash are P, S, Ca and Zn. To understand the mechanism of the catalyst deactivation, the element distribution will reveal the ash distribution and the penetration depth of each lube-oil element into the filter wall. The element distribution is measured by the X-ray Fluorescence Microscopy (XFM) and the Scanning Electron Microscopy combining the Energy Disperse Spectroscopy (SEM-EDS).

The XFM experiments are performed at the 2-ID-E beamline at APS. The 2-ID-E beamline is capable of 2D and 3D element mapping of the samples with submicron resolution, which is a perfect tool to study the ash distribution because the ash should be adsorbed on the surface of the pores in the filter wall. Figure 2 shows an example of element mapping over a 300umx300um cross-section of a filter wall. Si mapping represents the substrate location, Ce mapping shows the catalyst distribution and S gives the penetration of the poisonous element into the filter material. The overlapped image of the three elements gives presents the relative position of each component. In future, SEM-EDS will be used as a complementary approach to study the element distribution in the nanometer lengthscale.

References:
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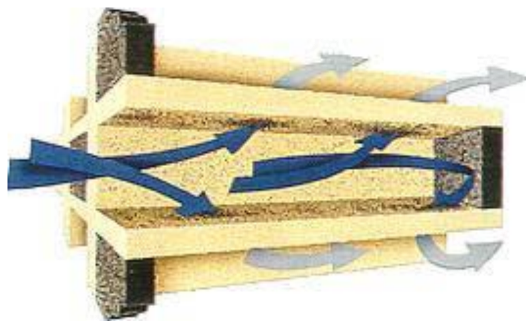

Figure 1. A cell of the wall-flow filter (source: Corning)

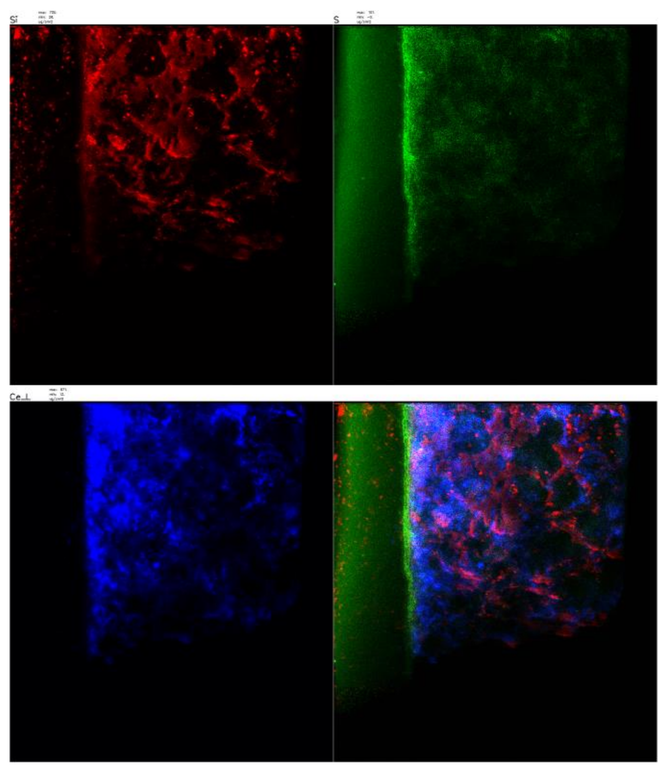

Figure 2. XFM results of a laboratory aged filter sample.