9th ETH-Conference on Combustion Generated Nanoparticles
15th -17th August 2005, Zurich, Switzerland

Structure - Reactivity Investigations on Diesel Engine Soot

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Abstract:

Bulk and surface properties of soot and carbon black are important factors that play a key role in understanding of the overall oxidation behaviour of these materials. These are the main issues to be investigated in order to improve the efficiency of continuously regenerating particulate traps of diesel engines. However, the majority of soot and carbon black studies do not attempt a detailed investigation of the microstructure or general morphology. Many studies have ignored the fact that several structural types of carbon have been used as model substances in oxidation, reactivity or atmospheric studies including flame soot, carbon black, and amorphous carbon, reflecting the common opinion (or assumption) that the structure of soot particles differs little even if they stem from various sources or are prepared under different synthesis conditions.

We want to present the application of high-resolution transmission electron microscopy to study the microstructure of diesel engine soot and carbon black samples. The heavy duty diesel engine soot nanoparticles that are generated in a low-emission diesel engine indicate a change in the formation mechanism of soot under low-emission conditions. The soot nanoparticles are defective, functionalized and highly reactive. The reduction of the emission rate of soot particles may not be automatically beneficial for environment protection and for reducing the epidemiological effect for human health. The technological improvement in engine management carries new risks, as the soot becomes biologically accessible with a large amount of functional groups on defective sites of the rough soot particle surface.

To correlate reactivity towards oxygen, functional groups and nanostructure the carbon samples are investigated with thermogravimetry, diffuse reflectance infrared fourier transform spectroscopy, X-ray photoelectron spectroscopy. We focus on soot from a heavy duty diesel engine, soot from a diesel engine in black smoking conditions, a spark discharge soot, and a furnace carbon black from Degussa. It is found, that the amount of defects plays, as well as the functionalization, an important role in the onset of combustion in the TG/TPO experiments. Clear differences in reactivity towards oxidation are observed. The defective carbons oxidize faster than well graphitised soot samples. This can be correlated with the micromorphology and the functionalization of the soot materials. The fact that soot from modern Euro IV diesel engines is more easily oxidised, might give new impulses for exhaust treatment technologies. One has also to be aware that model soot substances have to be carefully chosen and investigated for any future development. These findings may have consequences for health risk assessment and for future exhaust treatment systems.