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STRUCTURE, MORPHOLOGY, AND REACTIVITY OF SOOT PARTICLES

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The physical and chemical structure of soot, its elemental composition, the size of the primary particles, and the ratio of crystalline graphite-like to amorphous organic carbon depend on the starting materials and conditions of the combustion or pyrolysis process, i.e. fuel type, fuel/oxygen ratio, flame temperature, residence time, etc. [1]. High resolution transmission electron microscopy revealed that the internal structure of the primary particles of combustion soot depends strongly on the chemical and thermal environment under which they are formed and on the time available for annealing [2]. Very rapidly formed soot particles are nearly amorphous, with only some signatures of short-range order [3] with fullerene structures developing at slightly longer residence times in the combustion region. At longer annealing times or higher temperatures, more highly ordered carbon structures are developed.

Although the average elemental composition of combustion particles is usually dominated by carbon, a soot particle may be regarded as a complex three-dimensional organic polymer, rather than merely an amorphous form of elemental carbon [4]. The relatively low mass fraction of oxygen in soot may be deceiving, since most of it is actually found at the edges of the graphene layers in various functional groups. The character of these functional groups depends on combustion conditions [5, 6], with more efficient combustion regimes resulting in higher abundance of oxygen and more defective structures, i.e. smaller graphene layers, which exhibit more edges in total [7, 8]. This in turn increases the chemical reactivity of the particles and thus the ability to diminish the particles by oxidation processes, e.g. in after-treatment systems of diesel-engined vehicles using NO_x and oxygen.

Beside the direct harm due to the inhalation of the soot particles by humans, there also exists an indirect risk potential. Soot particles in the atmosphere have strong impact on the radiation balance, and thus on the global climate [9]. In general, particles can scatter and absorb light to different degree. However, soot particles can absorb light and increase warming but at the same time they act as nuclei for cloud particles, which scatter and reflect light and cause a cooling effect. Here, structure, morphology and reactivity of soot are again important parameter to know in order to understand its true risk potential.

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