Three-Dimensional Characterization of the Inner Structure of Carbon Soot

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Carbonaceous materials have attracted continuous interest since more than twenty years. Due to the big variety of carbon soot and due to the possibility to use low-voltage aberration corrected microscopes, new insights are continuously gained. Carbon soot of various internal structures were studied, e.g. with nanopores or different terminating surface planes. The latter determine the adsorption process as well as the size and shape of catalytically active nanoparticles on the carbon support [1]. In order to study these effects, a three-dimensional characterization is necessary.

With the capability of electron tomography to reveal the three-dimensional morphology of materials in the nanometer range, we studied commercial Vulcan XC72 with 20wt. % Pt (ETeK Inc.). The tilt-series was acquired in bright-field TEM on a Titan 80-300 at 80kV with zero-loss filtering (cf. Figure 1). Special precautions were taken to minimize deposited electron dose (~3*10^7e-/nm^2 for entire series). Though phase-contrast images were used, the 3D reconstruction was possible. However, strong artifacts were observable at the reconstruction mostly related to insufficient alignment accuracy. Specially developed iterative algorithm was implemented in order to improve the consistency of the alignment. Thus, the reconstruction of clearly distinct (besides the artifacts) carbon atomic planes has been enabled (cf. Figure 2).

To the best of our knowledge, this is a first time that the inner atomic structure of carbonaceous material was revealed directly. In particular, the size and the shape of inner pores and interaction between adjacent layers are clearly visible.

1. D. Tománek, W. Zhong, and E. Krastev, Phys. Rev. B 48 (1993), p. 15461.
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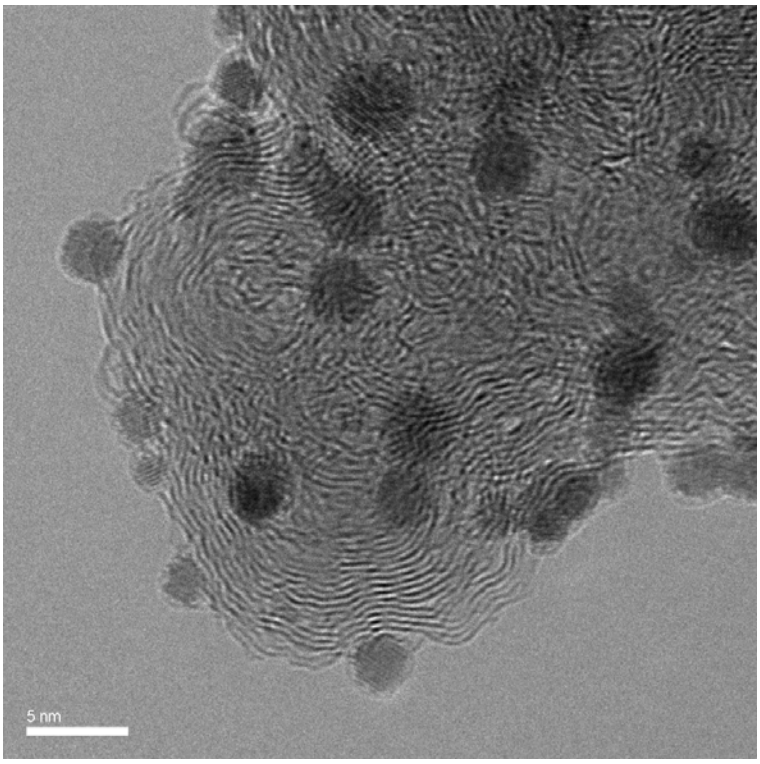

Figure 1. One of 46 tilt-images in total ranging from -66° to +69° (3° tilt increment) showing variously formed graphitic planes composing the interior structure of the soot particle acting as a support for the catalytically active Pt particles.

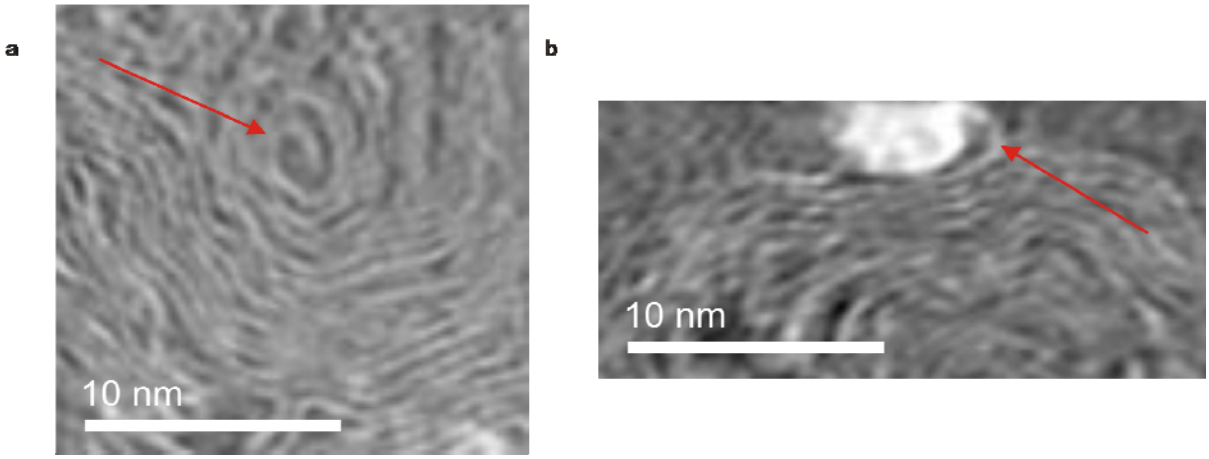

Figure 2. Cross-sections of the reconstructed tomogram revealing interesting features of the carbon soot particle: (a) shows a spiral-shaped graphitic plane in the interior of the soot particle; (b) shows a carbon monolayer covering a Pt-particle positioned on the outer surface of the soot particle.

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