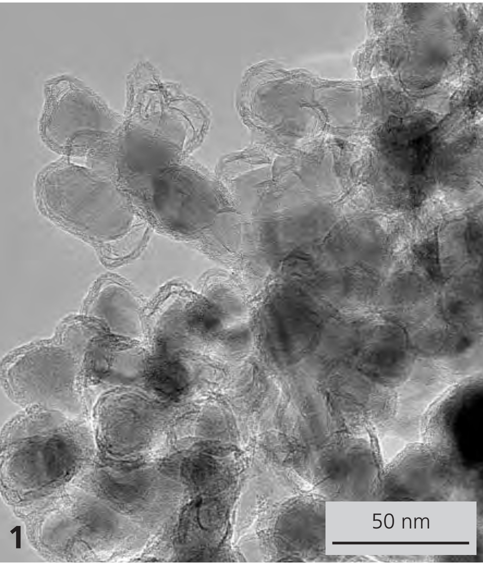
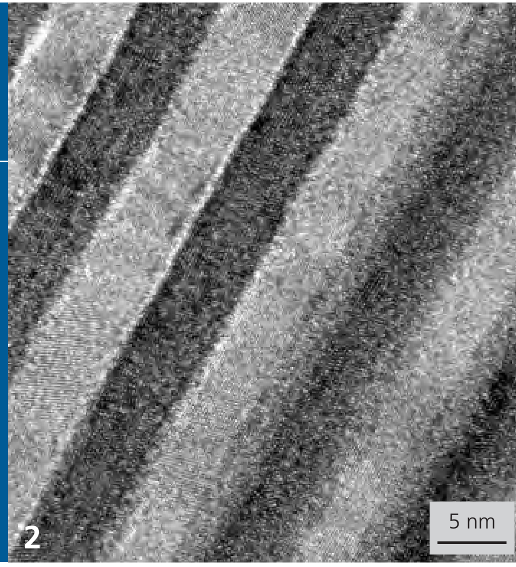
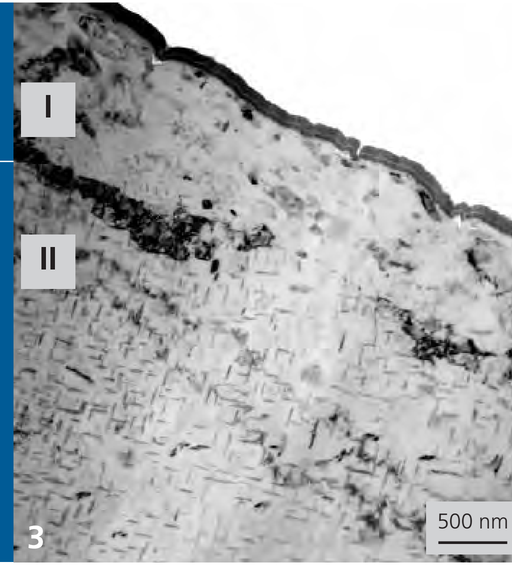






ANALYTICAL TRANSMISSION ELECTRON MICROSCOPY FOR PRODUCT RELATED MATERIALS DEVELOPMENT

THE TASK

Materials and material aspects form the foundation for many technological innovations. The desired material properties depend, to a large degree, on their microscopic structure. Microanalytical tools are therefore a necessity. Analytical transmission electron microscopy (TEM) plays a central role, since it is the only method that provides complete structural characterization down to the atomic level. Transmission electron microscopy combines the three fundamental analytical methods of imaging, diffraction and spectroscopy in one and the same analytical tool, which aid its comprehensive analytical capabilities.

The analytical transmission electron microscopy has decisively contributed to tailor the structure of materials with respect to their application relevant properties. The method is not only advantageous to address basic research questions but also

- to use for improving product related material properties (e.g. surface near region related technologies),
- to further develop material depending manufacturing processes (e.g. joining),
- for failure analysis and
- to evaluate the quality of manufacturing processes.

Thus it is the goal of Fraunhofer IWS engineers to utilize the technique for the product related materials development and also to offer this capability as a service to our customers.

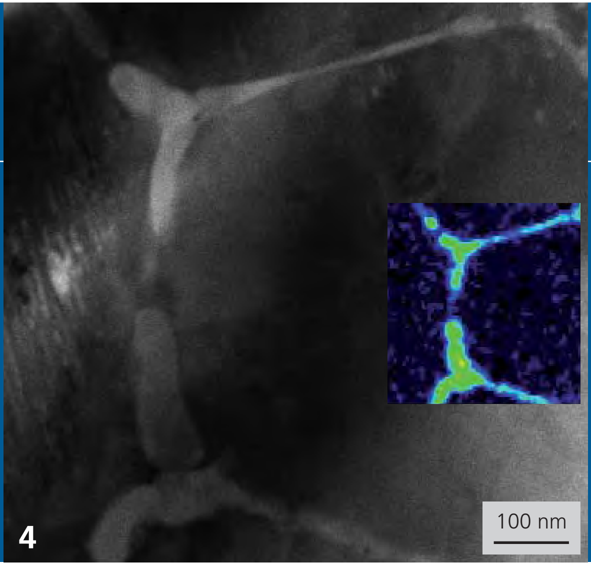
OUR SOLUTION

At Fraunhofer IWS laboratories the analytical transmission electron microscopy is combined with powerful metallography, scanning electron microscopy and materials testing capabilities. The successful application of the technique requires not only broad materials knowledge and methodical experience, but also modern and efficient laboratory equipment. The unit, installed at the IWS, is a TEM JEM-2100. This machine includes a high-resolution pole-piece, a scanning unit, an EDX system for element analysis, two mutually completing camera systems and a very precisely adjustable piezo controlled sample holder. Fabrication methods are available to prepare electron beam transparent samples from many materials and components.

The following results present an overview of Fraunhofer IWS research efforts to develop product related materials.

RESULTS

Current research is devoted to the synthesis of silicon carbon nanoparticles in a so-called “core & shell” arrangement. This material is planned as an electrode material in lithium ion batteries (Fig. 1). TEM investigations provide information such as the structure, size and distribution of the nanoparticles as a function of the synthesis conditions. This information in return provides the opportunity to optimize synthesis parameters.



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Another research topic at Fraunhofer IWS is the development of reactive multilayer coatings (RMC), which are applied in low heat impact joining processes for various material combinations (see pages 86 / 87). An important aspect of this development is to avoid diffusion within the coating stack during the fabrication. TEM analysis demonstrated that specific barrier coatings help to avoid this undesired diffusion effect (Fig. 2).

New materials and material combination require efficient methods for the fabrication of mixed material joints. Promising IWS technologies are the electromagnetic pulse welding and the laser induction roll plating. Transmission electron microscopy analysis is very helpful to study undesired phase seams, which may form at the interface between two materials during such joining processes. The TEM results provide hints as to how to reduce the formation of these phase seams, which are used to improve the quality and strength of the joints (see pages 40 / 41, 42 / 43).

High performance car engines face enormous wear challenges. Piston and cylinder materials need to be optimized, which requires a thorough understanding of the actual wear mechanisms, when the engine is in operation. For example, during the engine's operation the surface region of the cylinder liners undergoes structural change. Conventional metallography and scanning electron microscopy proved insufficient to capture these effects. The analytical challenge was resolved by applying additional TEM investigations. The study clearly demonstrated a correlation between the surface quality of the final manufacturing step and the resulting operational wear (Fig. 3).

Tool steels are in general hard to weld due to high carbon content. This is also true for modern processes such as laser beam welding. Comprehensive TEM studies provide information on the structure formation in the weld material, which contributes to improving the weldability of high speed steel (Fig. 4).

1 *SiC nanoparticles, encapsulated with amorphous and graphitic carbon (TEM)*

2 *Zr/Al RMC with (upper left) and without (upper right) diffusion barrier*

3 *Proof of a machining related deformation layer on a cylinder liner surface made from ALUSIL:*
I recrystallized,
II Al/Cu particle deformed

4 *Solidified structure in the weld material of high speed steel (TEM, EDX): increased molybdenum concentration at grain boundaries*

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