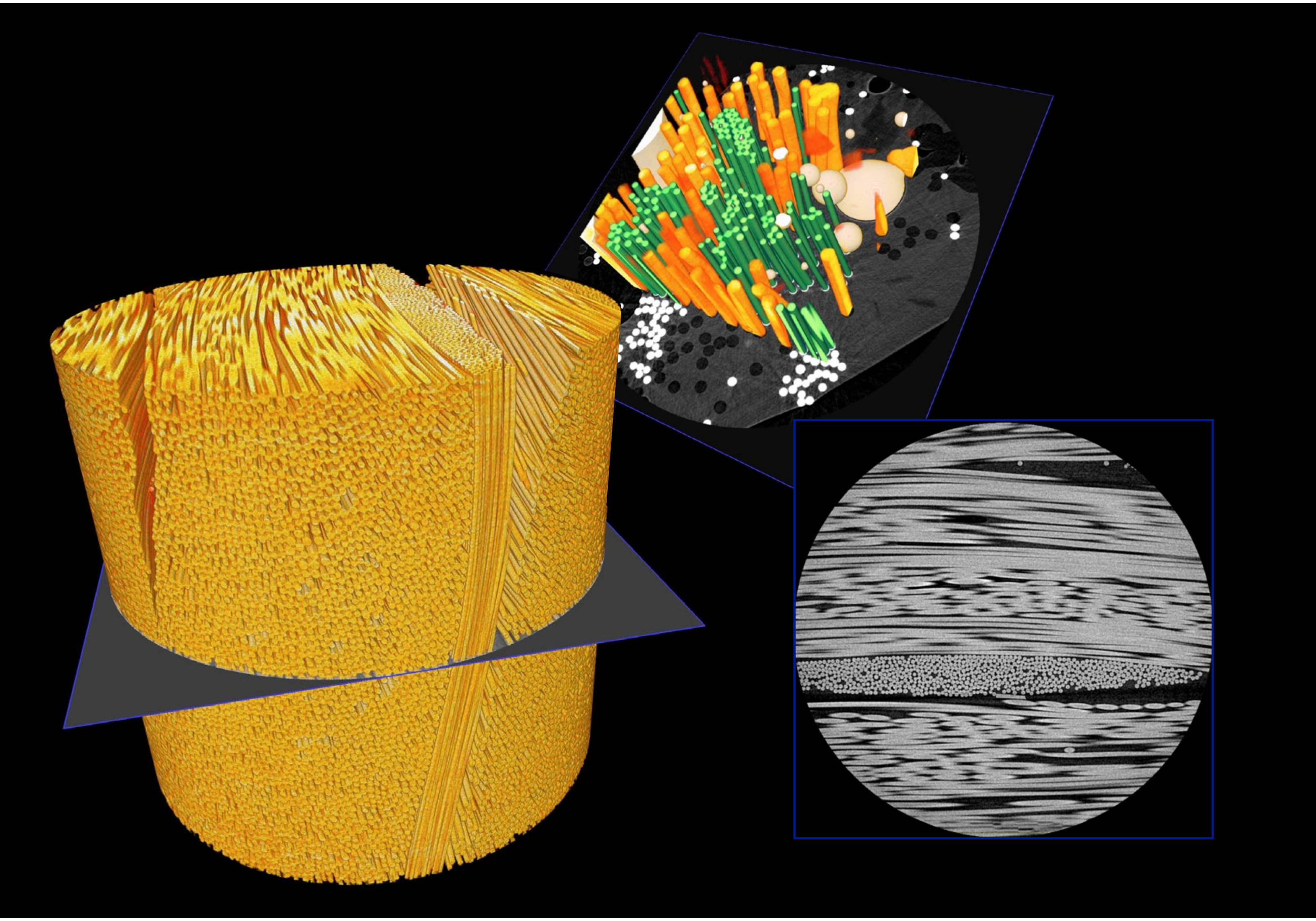
Application Note



Non-destructive 3D Quantification of Fiber Reinforced Polymer Composite Materials

ZEISS Xradia Versa X-ray Microscopes

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Non-destructive 3D Quantification of Fiber Reinforced Polymer Composite Materials

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Fiber-reinforced composite materials of a polymer matrix reinforced with fiberglass, carbon, or synthetic fibers are increasingly used in the construction of materials for the aerospace, automotive, marine, and construction industries due to their high performance, strength and light weight. The internal structure of fiber-reinforced composite material greatly affects the strength and function of constructed materials, and it is critical for engineers to be able to visualize and measure key features. ZEISS X-ray microscopes (XRM) can provide quantitative, high resolution, three-dimensional microstructural analysis of relatively large samples *in situ* to understand reliability and failure mechanisms. In addition, the non-destructive nature of X-rays provides the opportunity to image a sample before and after the application of tension or shear to observe resulting changes in the microstructure of these materials.

In this use case, we present the application of Xradia Versa for detailed non-destructive imaging of fiber composite samples. Xradia Versa instruments provide submicron spatial resolution, high contrast and the unique ability to maintain high resolution at large working distances for detailed imaging of large intact samples. Figure 1 and 2 show the analysis of the resulting 3D datasets.

Methodology and Results

This study analyzed two fiber composite materials: one sample composed of carbon fibers in epoxy resin and the other, a commercial product known as Twintex®, a composite of polypropylene and E-glass fibers in a polymer matrix. The carbon fiber sample shown in Figures 3 and 4 was a 10 cm x 15 cm x 2 mm sample imaged at 1.46 µm voxel. The novel use of scintillators optimized by objective make the detectors of

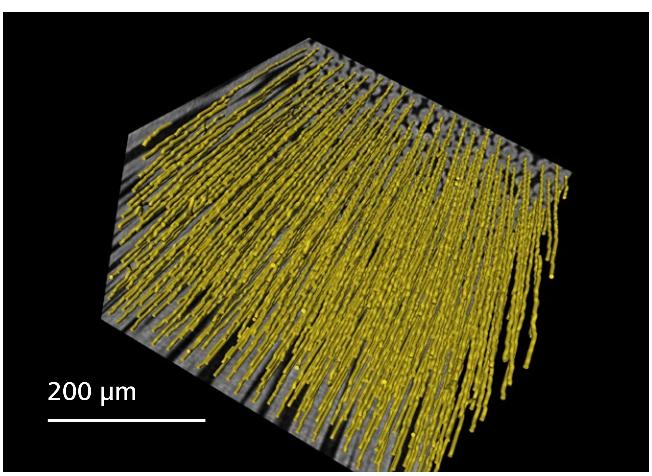

Figure 1: Carbon fiber composite, courtesy of ICMCB

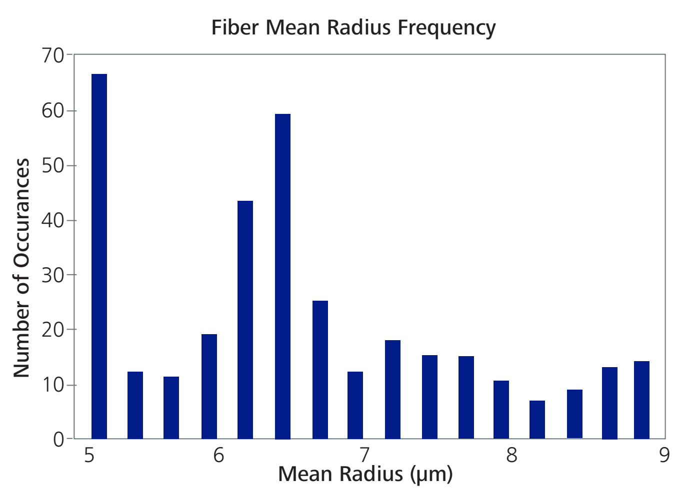

Figure 2: Quantification of fiber mean radius

Xradia Versa 3D X-ray microscopes uniquely suited to imaging these low Z materials with good contrast. For this scan, the system operated at 60 kV and used high absorption contrast imaging to visualize voids in the epoxy and clearly differentiate carbon fibers from the surrounding matrix for segmentation analysis.

The Twintex® sample, a four-layer thermoplastic composite measuring 85mm x 17mm x 2 mm, was imaged at 1 μm voxel at 40 kV. The material is a continuous fiber composite composed of a polymer matrix and E-glass with polypropylene fiber reinforcements (Figures 5 and 6). Imaging and subsequent analysis provided information including void content, fiber orientation, and the interface between composite layers.

Conclusion

This case study demonstrates that Xradia Versa can be effectively used for 3D structural analysis of fiber reinforced composite materials, which is often limited by traditional microscopic techniques. Due to their non-destructive nature and unique architectural design, Xradia Versa can acquire high contrast and high resolution images of polymer fiber composites, preserving the sample so that it may then be studied with additional methods such as dynamic mechanical analysis and mechanicalshear tests.

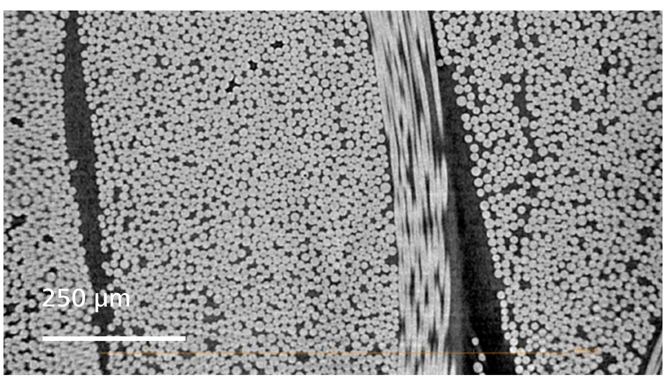

Figure 3: Virtual orthogonal slice of the composite, showing carbon fiber and epoxy.

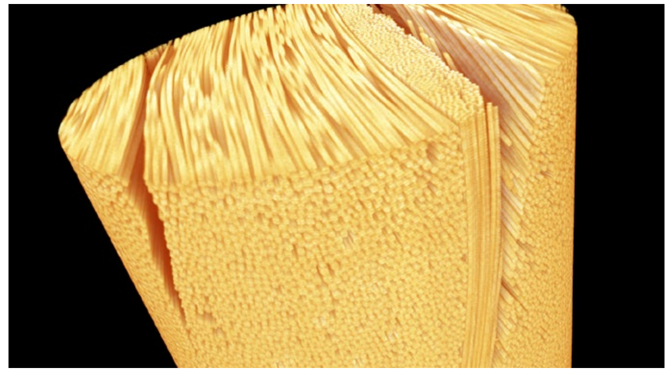

Figure 4: 3D rendering image of the composite, showing carbon fiber. Courtesy of ICMCB

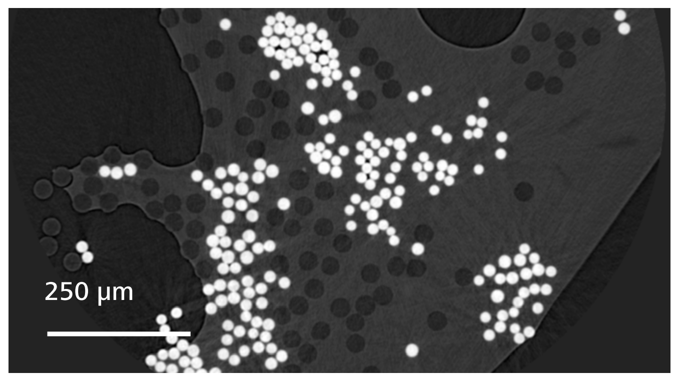

Figure 5: Virtual cross-section of Twintex composite, showing polypropylene (dark) fibers and E-glass (bright) fibers. Voids in the composite can clearly be seen as dark spherical shapes. Courtesy of Professor Milani, University of British Columbia

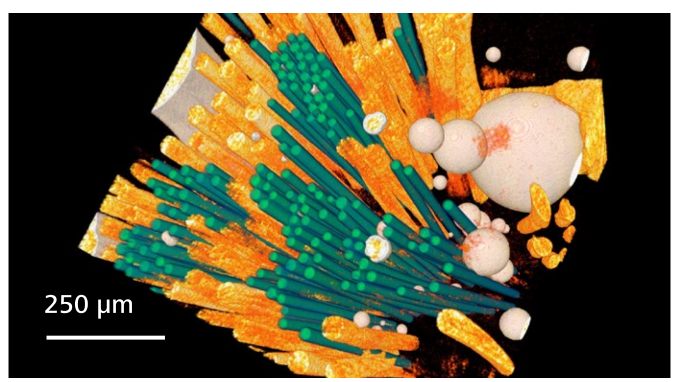

Figure 6: Segmented 3D image of the composite, showing green fibers (E-glass), orange fibers (polypropylene), and white spheres (voids). The analysis indicated that E-glass fibers are clustered together and randomly distributed, which may influence the strength of the material, and that there are many unconsolidated polypropylene fibers left in the sample. Courtesy of Professor Milani, University of British Columbia

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