APPLICATION NOTE

Ceramic materials characterization

Imaging and elemental analysis with scanning electron microscopy

Ceramics often have grain sizes and microstructure that impact material performance. Grain boundaries and microstructure can be optimized with ceramic processing parameters for specific product requirements. Scanning electron microscope (SEM) images with material contrast are used to quantify the grain sizes and distribution. Thermo Scientific Phenom desktop SEMs use a backscattered electron detector (BSD), which inherently provides compositional information, leading to fast, automated image analysis.

Elemental identification with EDS is used to correlate composition to microstructure. EDS data can be used in ceramic research and development to chart nanoparticle diffusion through a porous ceramic, to identify second phases on ceramic surfaces or to analyze agglomerates or contamination.

Advanced ceramic materials are used in many industries, including automotive, renewable or alternative energy, healthcare, electronics, and aerospace. Ceramic materials are optimized for products requiring high modulus and hardness, high melting point, high thermal expansion and corrosion resistance. Microstructure, grain size and volume, agglomeration, surface roughness, porosity and elemental distribution impact ceramic performance.

Advantages of BSD

The microstructure of ceramic materials can be characterized using a SEM. As shown in Figures 1 and 2, a BSD image indicates material differences with heavier elements being brighter in the SEM image compared to lighter elements. This contrast provides easy thresholding to determine grain sizes and coverage. Using a BSD also allows for lower vacuum levels, minimizing beam damage and sample charging.

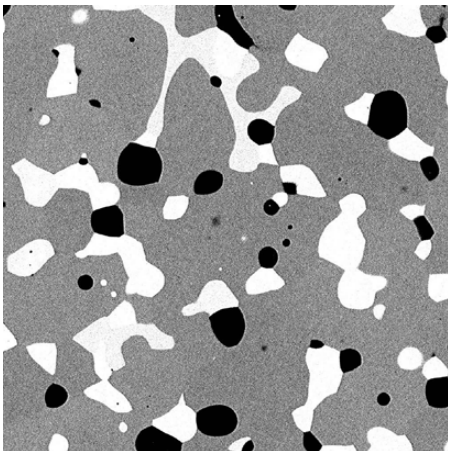

Figure 1. Phenom desktop SEM BSD image of an advanced ceramic. heating element material.

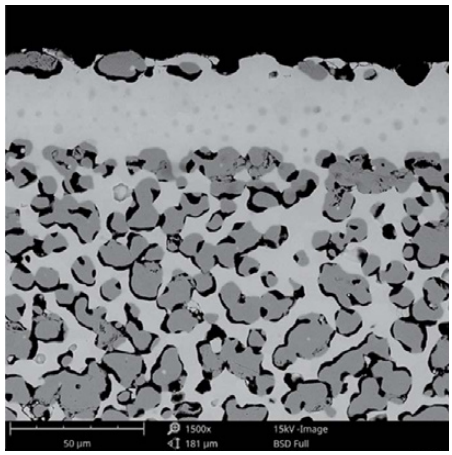

Figure 2. Phenom desktop SEM BSD. *Image courtesy of CoorsTek.*

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Grain size distribution

Many ceramic materials are sintered to produce the required mechanical properties. Grain size and coverage can be quantified using BSD images. Using Automated Image Mapping with the Thermo Scientific™ Phenom™ desktop SEM, data acquisition can be automated for maximium workflow with statistical analysis. This is illustrated with a tiled image comprised of 30 individual SEM images (Figure 3). Total acquisition time was less than 3 minutes. The tiled image was then analyzed using a threshold effect, indicating 5% black, 78% gray, and 17% white for this ceramic sample (Figure 4). The grain distribution data can be used to optimize processing conditions to meet product requirements. SEM imaging with material contrast using a BSD also provides a visual understanding of ceramic particulate morphology for insight into the final material properties and structure (Figure 5).

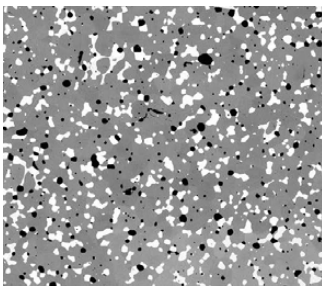


Figure 3. Tiled composite of 30 Phenom desktop SEM images.

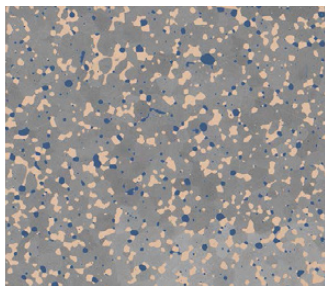
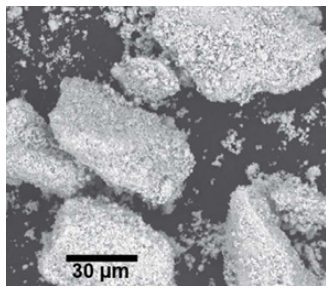


Figure 4. Threshold image for analysis of an advanced ceramic material.



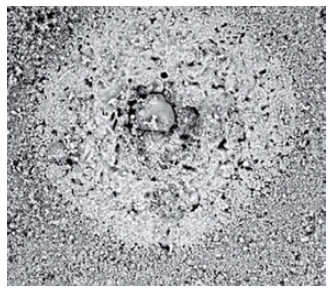


Figure 5. SEM images using a BSD of (left) ceramic powder agglomerates and (right) their effect on the ceramic microstructure. *Image/data courtesy of CoorsTek.*

Elemental identification

Elemental analysis using EDS with SEM provides material information correlated to structure for ceramic materials. Processes can be evaluated to optimize the best composition for desired mechanical properties and product performance. EDS can be done at a point, across a line or over an area. This data can be used in ceramic research and development to chart nanoparticle diffusion through a porous ceramic, to identify second phases on ceramic surfaces (Figure 6) or to analyze agglomerates or contamination. An EDS map can correlate phase morphology to composition for ceramic materials.

Benefits of the Phenom desktop SEM

The Phenom desktop SEM was designed to bring high-quality SEM imaging into environments where a traditional SEM was not manageable or practical. The Phenom desktop SEM does not require a dedicated operator or additional infrastructure. The Phenom desktop SEM uses an extremely long life source, providing more than one year of continuous uptime.

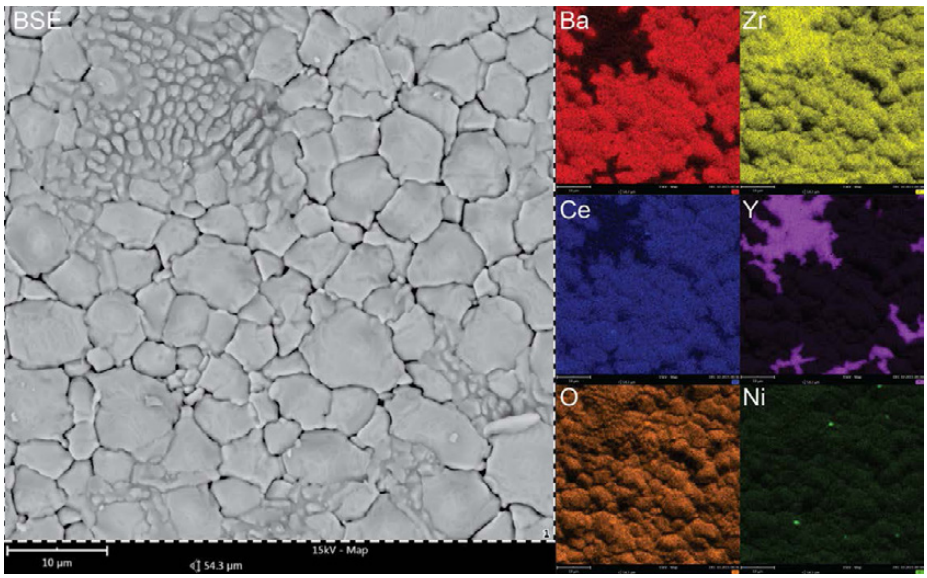


Figure 6. BSD image (left) and corresponding EDS maps (right) used to identify second phases on ceramic surfaces. *Image/data courtesy of CoorsTek.*

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