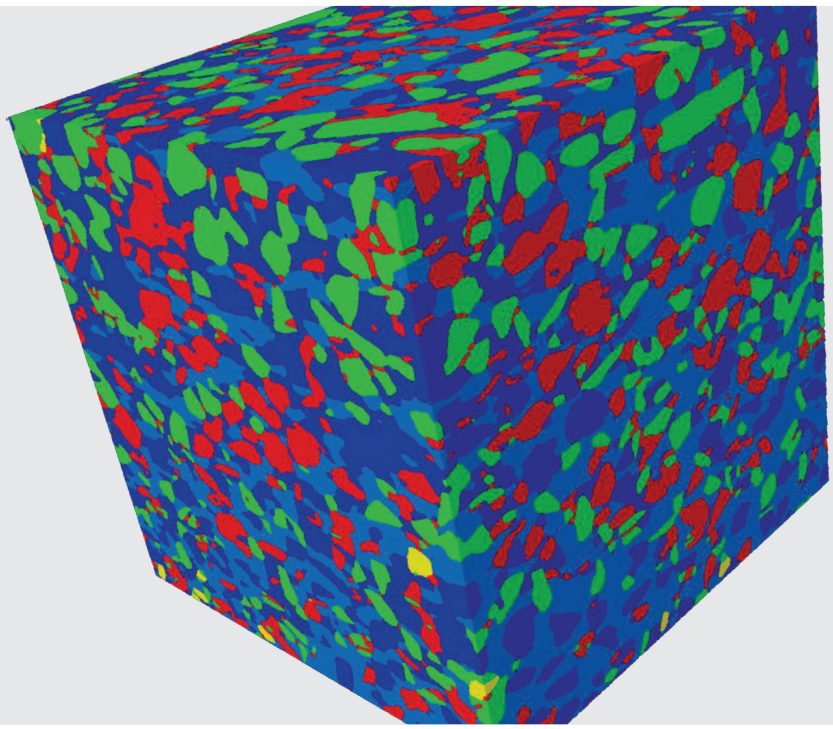
Application Note

Mineral Processing with 3D X-ray Microscopy

Precious Metals, Base Metals, Industrial Metals, and Coal



ZEISS

Seeing beyond

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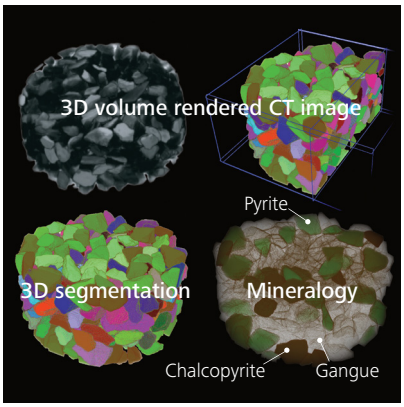
3D X-ray microscopy (XRM) is an emerging complementary method to 2D SEM-EDS techniques for volumetric analysis at submicron resolution of mining ores. This tomographic technique achieves rich statistics on size, shape, liberation and exposure, providing basic mineralogical discrimination that opens up a wide range of application possibilities.

It is possible to provide improved analytical information throughout the life of a mine. The opportunity exists for rapid 3D characterization of ores for geometallurgy, feed and tailings characterization, plant design and optimization, leaching operations (or circuits), pyro and hydrometallurgical applications. This non-destructive X-ray tomographic technique does not require complex preparation of polished sections typical of SEM-EDS techniques. XRM complements existing techniques by providing 3D information of multi-phase particles using significantly larger volume statistics within a much shorter turn-around time.

Unique Advantages of XRM in Mineral Processing

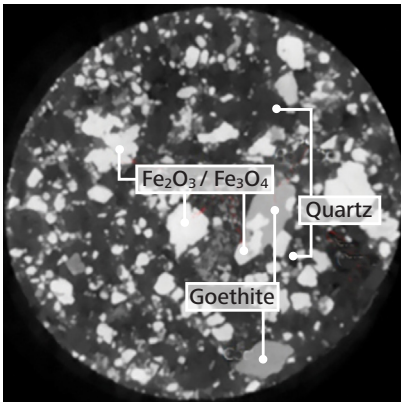
- Rapid 3D mineralogy, exposure and liberation analysis
- Minimal sample preparation
- Large volume statistics for high resolution characterization of tailings of base and precious metals
- Dual energy for mineralogical distinction between common mineral pairs such as chalcopyrite and magnetite, or galena and platinum
- Non-destructive measurements of grain dissolution over time during heap leaching
- Coal washability analysis
- Correlate to SEM-based mineral analysis

Mineralogy

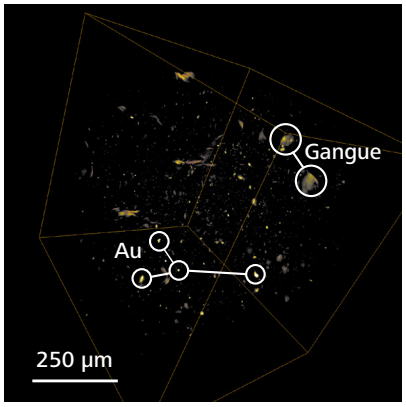


3D segmentation and characterization of Cu ore. Samples scanned in a packed particle bed, 5 mm in diameter. > 30,000 multiphase particles can be analyzed rapidly.

Chalcopyrite	*0.49%*
Pyrite	*12.75%*
Gangue	*86.76%*



Low grade Iron ore. CT slice showing discrimination of valuable metal ore (Fe_2O_3 / Fe_3O_4) versus Goethite (FeO(OH)) and Quartz (SiO_2) (Particle size range – 0.3 mm + 0.1 mm, image Field of View: 5 mm)



Rapid detection of Gold, Silver, or Platinum Group Metals (PGMs) in feed, concentrates, or tailings. Large number of particles can be scanned in 3D to detect rare phases. Image: Scanning for Au particles (bright particles) in 3D at 1 µm voxel within a 3 mm packed bed tube

Cover Image *Segmentation and quantification of non-graphite materials in square mount. Light Blue – Epoxy, Deep Blue – Silicate, Red – Intergrowths, Green – Hematite, Yellow – Ba Sulfate*

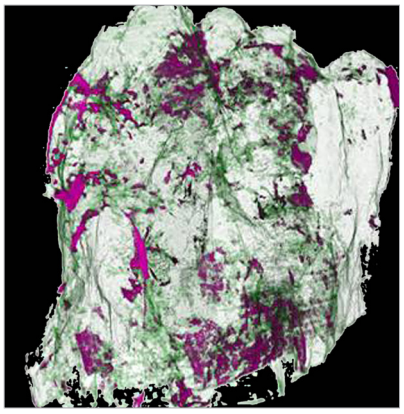
ZEISS Xradia Versa 3D X-ray Microscopes for Mineralogy

Xradia Versa 3D X-ray microscopes operate on the principle of computed tomography, similar to those used in medicine for human body scanning, by taking X-ray radiographs of a sample at a number of rotational angles.

However, unlike conventional medical CT, industrial CT or desktop microCT, which use a simple geometric magnification principle to achieve resolution, Xradia Versa solutions rely on an architecture that is derived from technology originally developed for synchrotron radiation facilities. They feature a unique two-stage magnification imaging technique based on proprietary detector and optics that enable 0.5 µm spatial resolution (<150 nm voxel) on relatively large samples. In addition, ZEISS Xradia Versa optics employ advanced contrast mechanisms that uniquely allow for the discrimination of valuable mineral phases from the gangue materials. The DSCoVer module on ZEISS Xradia 620 Versa uses dual energy information to distinguish between minerals with similar X-ray attenuation such as platinum and galena (in PGMs) and chalcopyrite and magnetite (in certain Cu ores). Enhanced contrast capabilities on the XRM also enable difficult-to-image internal fracture networks, optimizing comminution processes.

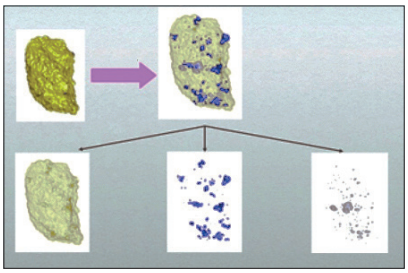
X-ray microscopy volumetric datasets enable a large number of particles in 3D to be rapidly characterized. XRM studies provide 3D liberation and exposure analysis, volumetric particle shape analysis and grouped mineral classification.

Comminution



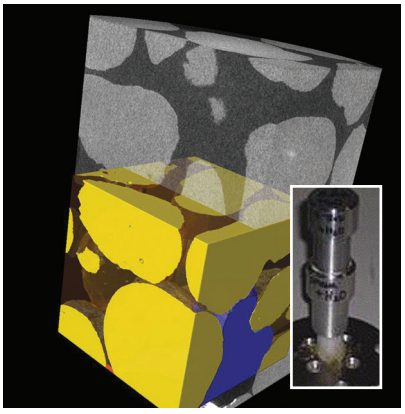
Comminution & Particle Damage Assessment. The understanding of fracture networks within particles can determine the energy required for comminution and predict the efficacy of liberation techniques, as fracture networks provide pathways for leachants and flotation chemicals to reach interior locked particles. With high resolution X-ray microscopy, detailed 3D analysis of fracture networks can be performed before and after comminution to establish fracture mechanisms: transgranular random breakage or preferential breakage [Garcia 2009].

Flotation



Exposure Analysis in 3D for Mineral Liberation. With XRM and software, 3D analysis enables the determination of Size Fraction vs Locking Class over a large number of particles [Miller et al; SME 2009].

Leaching



In situ *Observation of Particle Dissolution. Due to the non-destructive nature of X-rays, particles within a mini leaching cell can be repeatedly monitored over time and under environmental conditions as to their dissolution behaviors during leaching [Kodali 2011].*

References:

[1] D. Garcia, C.L. Lin, J.D. Miller, Quantitative analysis of grain boundary fracture in the breakage of single multiphase particles using X-ray micro-tomography procedures,Minerals Engineering, Vol. 22, No. 3, 2009

[2] High Resolution X-ray Micro CT (HRXMT) - Advances in 3D Particle Characterization for Mineral Processing Operations, J.D. Miller, C.L. Lin, in Recent Advances in mineral Processing Plant Design, D. Malhotra, P.R. Taylor, E. Spiller, and M. LeVier, eds., SME, Littleton, Colorado, pp. 48-59. Published, 12/2009.

[3] http://www.sciencedirect.com/science/article/pii/S0892687511002731

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