A True-Color SEM-CT

W. Zhao, J. Liu, Y Wang, Y. Ma, L Han
Institute of Electrical Engineering, Chinese Academy of Sciences, Beijing 100049, China
zhaowx@mail.iee.ac.cn

G. Niu
University of Chinese Academy of Sciences, Beijing 100049, China

SEM-based Nano-CT (SEM-CT) is appropriate to generate a nanometer scale X-ray source by bombarding a target with electron beam of SEM.[1] Conventional SEM-CT cannot perform high-contrast imaging on materials and structures with small differences in X-ray absorption such as light element materials like carbon and hydrogen polymer with high-resolution.[2] Instead, color CT has become a hot spot in CT research due to its advantages of enhancing the discrimination of substances with similar linear attenuation coefficients but different atomic numbers. The current common method for implementing color CT is to use a photon-counting detector with multiple energy windows or several different X-ray filters,[3] yet those methods are not suitable for SEM-CT for its inevitable problem that the intensity of radiation is greatly reduced and the signal quality is difficult to guarantee. Therefore, we proposed a new true-color SEM-CT method with three different targets and applied to FEI Quanta 600 SEM successfully as shown in Fig.1. The resolution of SEM-CT is up to 500nm and has good application in biological detection as illustrated in Fig.2. By using three different targets, W, Cr, and Cu, to emit X-rays of different energies, the detector can count X-rays photons to obtain X-ray absorption values in different energy regions. The atomic number information and density information of the scanned object can be simultaneously acquired by data processing. Then the CT reconstruction results from three different energies are combined into color CT images as seen in Fig.3 by principal component analysis algorithm that is used to extract three principal components as color and the three primary colors of the image are combined to form a true-color image. At the same time, three-dimensional information inside the scanned object can be achieved through reconstruction of different faults with better imaging quality and detection accuracy. Compared with typical conventional SEM-CT, The true-color SEM-CT can perform high-contrast and high-resolution imaging of light element materials.

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[1] J. Liu, Y. Ma, W. Zhao, G. Niu, L. Han. X-ray microscopy using reflection targets based on SEM with tungsten filament. Proc. SPIE 9687, 96850I (2016)
[2] J. Yan, S. Jiang, M. Su, S. Wu, Z. Lin. Acta Phys Sin, 61, 068703 (2012).
[3] Z. Li, M. Yu, X. Jian. Energy calibration method of the photon counting detector based on continuous X-ray spectrum. CT Theory and Applications, 27(3), 363-372 (2018)

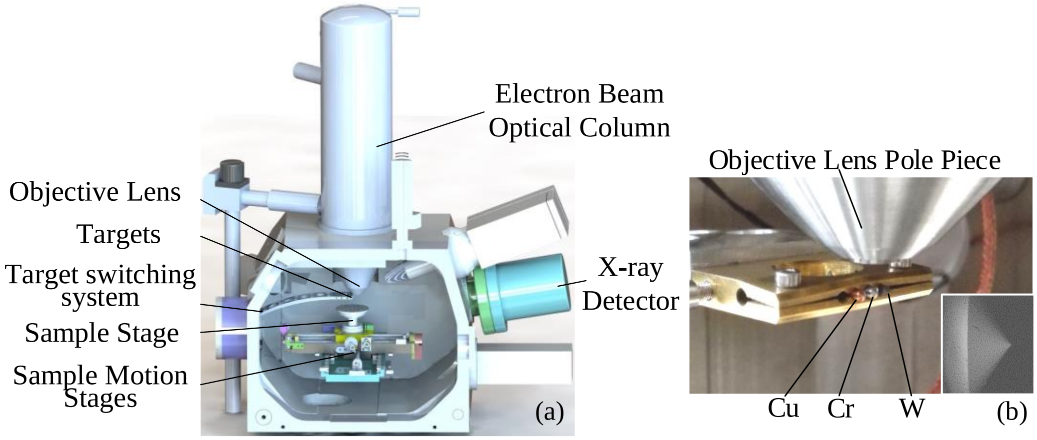

Figure 1: Schematic of true-color SEM-CT: (a) The system components of true-color SEM-CT. (b) The three target materials, Cu, Cr, and W.

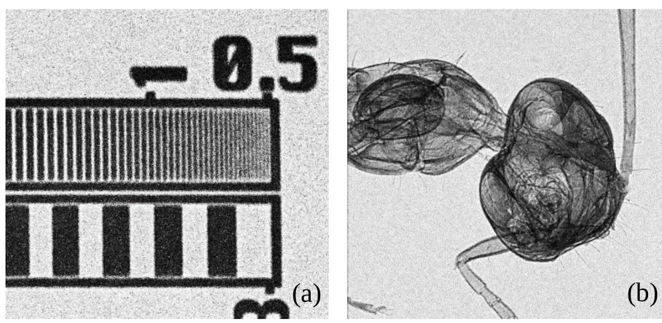

Figure 2: Schematic of projection data: (a) The 500nm slit width of JIMA RT RC-02B. (b) The head of an ant.

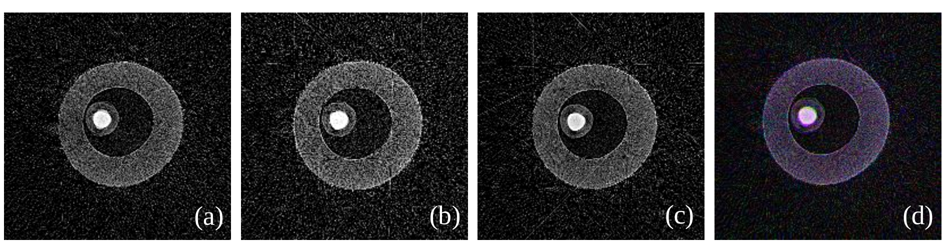

Figure 3: Reconstructed fault image of quartz glass fiber: (a) Fault image with Cr target. (b) Fault image with Cu target. (c) Fault image with W target. (d) The true-color CT image.