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Investigation on Material Properties by Synchrotron Radiation X-Ray Computed Tomography

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Summary

The Synchrotron Radiation X-ray Computed Tomography (SR-CT) technique is a non- destructive detection technology which can give the in-situ observation of microstructure evolution of materials under the external field (e.g., high pressure, high temperature, electromagnetic field, intense radiation, etc.), and it has a significant application in the area of plants and crops, advanced manufacturing, advanced materials, biomedicine, mechanics, archaeology and so on.

The application of the SR-CT technique in the research of sintering began in the 90s of last century by J. H. Kinney et al. Subsequently, researchers from France, Britain and other countries carried out the online observation of microstructure evolution of metal and ceramics during sintering by this technique. In China, We designed two special SR-CT technique-originated sintering furnaces to carry out the sintering experiments on Si3N4, BC, Al2O3, Zr2O, Al, SiC, etc.

From the reconstructed 2D and 3D images, various sintering phenomena during three sintering stages such as grain contact, grain growth, sintering neck growth, and pore spheroidization, are clearly observed. The growth kinetic curves such as the growth of grains, sintering necks were obtained. For example, in the study of alumina powders, the mean grain radius in the middle sintering stage shows a linear relationship with sintering time in double logarithmic coordinates. The grain growth exponent of 0.34 is extracted from linear fiting of the curve. For compacted bulk materials, the change in porosity is obtained as a function of logarithmic sintering time, showing different densification characteristics in three sintering stages, and linear relationship between porosity and logarithmic time in the middle stage of sintering. In the investigation of the silicon carbide, the process of sintering neck growth and material migration during sintering are clearly distinguished from the reconstructed images. The sintering neck size of the sample is presented for quantitative analysis of the sintering kinetics during solid state sintering. The neck size-time curve is obtained. Compared with traditional sintering theories, the neck growth exponent (7.87) obtained by SR-CT experiment is larger than that of the two-sphere model. Such condition is discussed and shown in terms of sintering neck growth, in which the sintering process slows down when the particle shape is irregular rather than spherical.

Recently, the SR-CT technique has also been successfully introduced into the mechanical field. It can not only give a direct and 3-D view of the microstructure

of the sample, but also provide a continuous observation of the micro-mechanical behavior during the loading process in a non- destructive and real-time way, which will offer an effective experimental support for the revelation of the damage mechanism. In our study of damage evolution of internal structure for Bi -2223/Ag HTS Tapes, it was found that the superconducting ability was related to the growth of micro-cracks in the core of superconductor. It is shown that superconducting ability was maintained when the material was in linear elastic state and that it would lose the ability when the material deformed plastically. In the study of the microstructure evolution of porous foamed aluminum in compression, the deformation and changes of pores were observed, it was shown that the internal closed-cell located at weak parts will be constantly knocked through during the compression process, and the larger pores formed. Recently, a force-loading-device that specially designed for Nano-CT has already been developed to study the damage mechanism in Nano-scale.