Visualization of microstructure in advanced porous materials by X-ray CT

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Introduction: The porous aluminum as advanced structural materials has complicated shapes and the 3D analysis is one of the major roles in order to progress the mechanical qualities. In this study, the in-situ compressive tests with reflective contrast imaging apply to investigate the microstructure and fracture behavior in Al foams. Moreover, the method of liquid metal doping was carried out for the visualization of the grain boundaries.

Experiments: The experiments were performed at BL47XU beam line using X-ray CT with the energy 20keV. The combination of the CCD detector (1000×1018 pixels, 12×12 μm^2) and the optical lens has a voxel size $1\mu m^3$. The CT scan of a sample with 750 transmitted images was done during a 180° rotation and the total scanning time was 90min. The radiographs were reconstructed by the method of convolution back projection. The samples for in-situ compression testing were the pure Al foam "ALPORAS" and two Al-Zn-Mg alloy foams. The material test rig was specially designed for CT experiments using a poly-carbonate tube as a load frame.
The actuator consists of an air pressure cylinder and an air servo valve. The max compression is 2kN and the max tension is 1kN. Due to the extremely precise sample stage, the weight of the rig is about 6kg.

Results: The microstructural features, such as micropores and particles were visualized in Fig.1. From 3D quantitative analysis, the volume rate and the mean diameter of the micropores in the AlZnMg1 sample are higher than the pure Al. In the AlZnMg1, there are large micropores distributed as destructive starting points. The many large TiH_2 particles un-foamed can be seen in the AlZnMg2. The liquid metal doping has been done in the Al foams. The doping alloy including Zn and Sn elements was diffused to the grain boundaries and the grain boundaries were 3D-visualized by X-ray CT. Due to the measurable region $1mm^2$, the compression test was done using the method of local tomography. The foam samples for compression tests with three loads are cylinders with the height 7mm and the diameter 7mm. The reconstructed volumes within $1mm^2$ have about 7000 micropores and the distribution of the micropore's center of gravity has been fallen down as increasing loads. From the results, the 3D quantitative analysis of the microstructures in the cell walls has been performed using the method of local tomography.

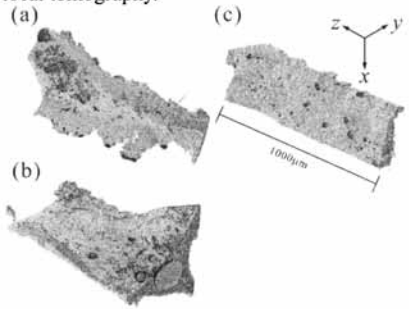

Fig.1. 3D reconstructed volumes and corresponding micropore and particle distribution in samples (a) Pure Al , (b) AlZnMg1, and (c) AlZnMg2

Visualization of sophisticated 3D structure of advanced Micro-Electro-Mechanical-System (MEMS) device by X-ray CT

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Currently, the efforts to use the MEMS (micro electromechanical system) with the more complex shapes (e.g. micromotors, microturbines, microoptical components and etc) have been attempting. In these MEMS, assuring reliability of their mechanical behaviors is important due to their complicate 3D deformation. However, 3D deformation assessment using the MEMS of actual size does not have established concretely up to now even if indirect evaluation using test specimens of prototype, and 2D deformation of the MEMS such as laser or confocal microscopy, AFM and so on have been developed, In the research project, therefore, measurement technique to evaluate 3D deformation of the MEM devices i.e. synchrotron X-ray microtomography technique was used using high–resolution X-ray CT (BL47XU of Spring-8). An in-situ static/dynamic compatible tester was developed for the research. Metallic particles with different X-ray absorption coefficients from matrix material of the MEMS were stuck on the surface of the MEMS as marker particle to grasp 3D deformation easily. As prior step to apply this technique to evaluate 3D deformation of the MEMS, 3D deformation of a pure Al thin film (purity is 99.6%) was evaluated. The size of the specimen used was 18mm (L) x 1mm(W) x 0.3mm(t). Fe powders with 3~5 μm in diameter were stuck on the surface using general-purpose liquid epoxy resin as marker particle. Coating thickness of the epoxy resin was controlled below 1 μm. The in-situ tensile tests were performed under four different stroke levels - 0.104, 0.218, 0.285 and 0.344mm because stroke mode controls piston of the in-situ tester more precise than load mode does. Volume rendering (3D image) and center positions of the marker particles in the region of interest were calculated by marching cube algorithm. In addition, 3D deformation of micro epicyclic gears with marker particles (0.55mm in diameter) were assessed in the loading condition. Figure shows variation of center positions of the marker particles when increasing of the stroke from 0.104 to 0.344. In the plot, black, red, green and blue solid circles were for 0.104, 0.218, 0.285 and 0.344 stroke conditions respectively. Mean Strain of the pure Al thin film calculated in each stroke condition was 0.107, 0.245, 0.329 and 0.415 respectively. It was possible to evaluate the 3D deformation of the region of interest as well as the whole. It was confirmed that synchrotron X-ray microtomography is useful technique for 3D deformation assessment of the MEMS with complex shapes. We are now planning next test using MEMS with complex shapes for instance, micromotors, microturbines and so on.

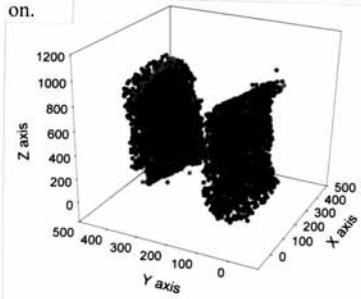

Fig. Variation of center positions of the marker particles in the pure Al thin film