	Experiment title:	Experiment number:
	Measurement of stress partition in metal-matrix composites upon application of an external load	01-01-632
Beamline: **BM01B**	**Date of experiment**: from: 7.05.03 to: 13.05.03	**Date of report**: 17.04.04
Shifts: 6	**Local contact(s)**: Hermann Emerich	*Received at ESRF:* *15*

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Report:

This project deals with the aspect of load transfer between a soft metallic matrix and hard ceramic particles under an applied stress. The load transfer depends on the difference in the elastic modulus between the matrix and the particles and on the plastic deformation of the matrix, which induces additional stress on the particles. When such stress exceeds the fracture stress of the particles, damage of the material begins producing a back-stress on the metallic matrix. The project is made in the frame of a collaboration between EPFL and INSA Lyon, studying composite materials with an aluminium matrix reinforced by ZrO_2-30%SiO_2 spherical particles. The load is applied on dogbone shaped samples with a dedicated tensile test machine already conceived for tomography experiments at INSA Lyon. The samples are loaded by stepping motor inside a PMMA chamber.
Different particle size and matrix compositions are studied: a soft Al matrix with small particles, a hard aluminium alloy 2124 with small and large particles. In some samples, small copper particles that do not deform plastically are introduced in order to probe stresses in the metallic matrix. In the sample with large particles, stresses are measured on each particle by reducing the beam size to 0.5x0.5 mm. The behavior of seven particles and of the surrounding metal matrix are followed at different stages of the stress-strain curve of the composite.

Experimental results

Strain of polycrystalline materials are assessed by measuring the variations of the lattice parameters of the constituents and by comparing them with zero stress values and powder values according to the formula:

$$\varepsilon_{hkl}(T) = \frac{d_{hkl}(T) - d_{0,hkl}(T)}{d_{0,hkl}(T)}$$

The comparison with powders allows the assessment of residual stresses. The scattering angles are small, therefore the planes selected by diffraction are almost perpendicular to the tensile axis.
The evolution of local lattice strain (stresses) is reported in the figures below as a function of the applied stress. When load transfer occurs from one phase to another, strains tend to reduce. In fig. 1, a sample made with a pure aluminium matrix is shown. Strains in aluminium show a sigmoidal curvature. During the initial plastic yielding of the matrix some load is transferred to the ceramic particles. When damage occurs around ceramic particles, load is transferred back to the aluminium matrix.
In a second experiment, the stress distribution during loading in a composite containing 500 µm size ceramic particles is studied (fig. 2). As a result of residual thermal stress, a redistribution of stress within the aluminium matrix is observed upon the initial elastic loading. The matrix around the particles (fig. 3), which is in compression, undergoes larger strain than the matrix far from the particles (fig. 4). Plastic strain is associated with damage, which results in debonding of matrix from particles. This effect is evidenced by a drop of the load in particles at high stress (fig. 3). In the metal matrix, load transferred from highly loaded regions around particles to the matrix. Plastic yield of aluminium matrix is evidenced by load transfer to small copper particles.

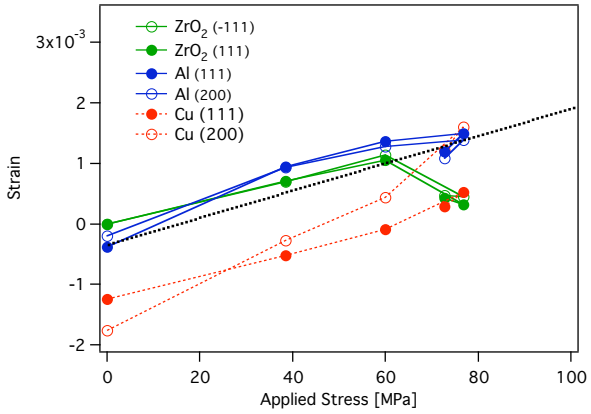

Fig. 1 Strain of lattice parameters as a function of applied stress in Al-ZrO_2 sample. The ceramic particles contain both monoclinic and tetragonal Al-ZrO_2. The slope of theoretical elastic loading of Al is shown in dotted line (as in other figures).

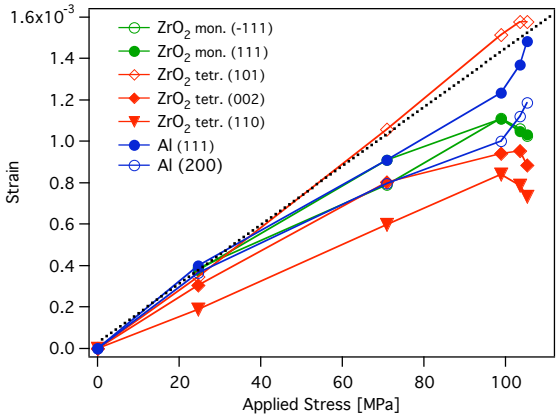

Fig. 3 Variations of lattice parameter in and around a ceramic particle. The drop in stress in the ceramic is due to damage. One can notice the load transfer from yielding Al matrix to hard copper.

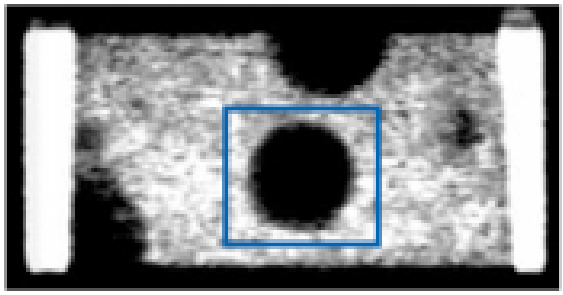

Fig. 2 Radiography of sample appearance. Ceramic rounded particles are clearly visible. The frame shows the area that is investigated after reducing the beam size.

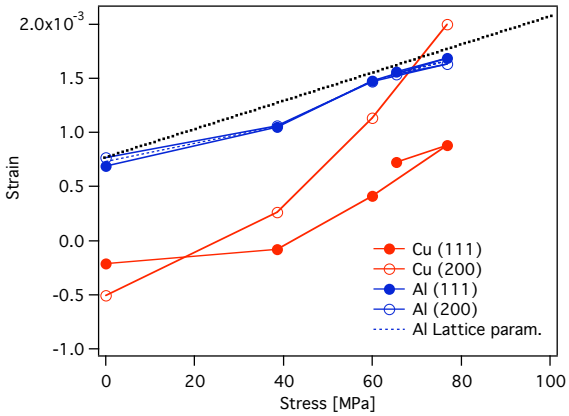

Fig. 4 Load in the aluminium matrix far from particles.

Remark: with this experiments we were able to show the feasibility of mapping local stress distribution in a composite material. However, the necessary reduction of the beam size leads to an increase of acquisition time and to loss in resolution. Using the same setup with microfocussing capability would produce much finer and convincing results.