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Microscopic densification mechanisms of metallic systems by spark plasma sintering

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MICROSCOPIC DENSIFICATION MECHANISMS OF METALLIC SYSTEMS BY SPARK PLASMA SINTERING

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This study reports on the microscopic mechanisms accounting for the fast densification kinetics of metallic materials processed by spark plasma sintering (SPS). Metallic systems have been chosen in reason of their elevated electric conductivity. Hence, an important fraction of the electric current of the SPS passes through the powder, and electrically induced new mechanisms, or acceleration of conventional ones (e.g. plasticity, diffusion), can be expected. TiAl powder and Ag-Zn diffusion couple have thus been chosen to study the influence of the electric current on plasticity and on diffusion, respectively.

An originality of this work was to observe by transmission electron microscopy (TEM) the phenomena occurring at the necks between TiAl powder particles during densification. For this purpose, a method of extraction of TEM thin foils at the necks by focused ion beam (FIB) has been developed (Figure 1). High dislocation densities and recrystallization mechanisms have been observed at these locations. The influence of the electric current on the densification kinetics and on the superplastic behavior of the TiAl powder has been evaluated by comparisons between the SPS and hot pressing techniques.

The influence of the current on diffusion has been studied with Ag-Zn diffusion couples by carrying out experiments with and without the SPS current, using in the last case special setups to electrically insulate the couples. Though diffusion in this system has been previously shown to be sensitive to current densities above 200 A/cm2 in dedicated diffusion experiments, by SPS, no influence of the current was observed. This was also the case if the SPS current density was artificially increased, using special devices, to ≈1000 A/cm2, that is, five to twenty times the values obtained in typical SPS conditions (50-200 A/cm2).

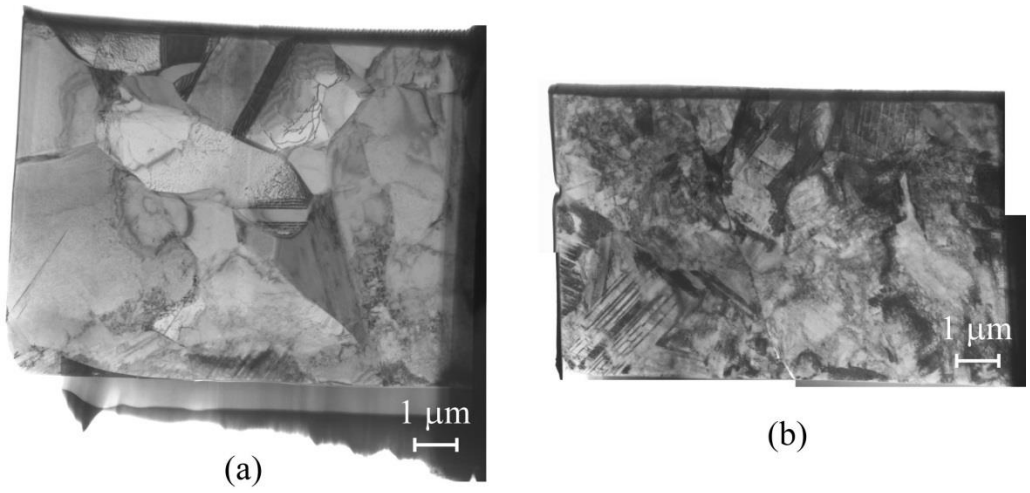

Figure 1 – Thin foils extracted by FIB at the center of a TiAl particle (a) and the neck between two particles (b) observed by TEM at the same magnification. The neck region is strongly deformed, whereas the center is undeformed.