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The mechanisms of field assisted sintering in metallic systems

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Using the advantages of Spark Plasma Sintering to produce superior materials, e.g. with potentially new phases, first requires a profound understanding of the densification mechanisms that are active during the process. The research presented contributes to this understanding by connecting temperature and pressure distribution in the particles with rate and activation energy of densification in pure copper.
Activation energy (Q) has been determined using a method originally developed by J. E. Dorn. Therewith, the activation energy for diffusion controlled processes can be extracted from densification rate measurements without the results being influenced by errors in measuring the density of the specimen nor the thermal expansion of specimen or sintering equipment.
Various particle sizes, externally applied pressures and different temperatures have been studied. Values for Q of about 100 kJ/mol in all cases show grain boundary diffusion, i.e. coble creep to be main cause of densification up to theoretical densities of at least 90 percent.
The measured densification rates correspond to this finding and match those calculated by a densification model developed incorporating surface tension and externally applied pressure as driving forces.
In this model, the temperature and pressure distribution in the particles obtained from previous experimental work as well as to be presented new FEM simulations for different process conditions are considered.
KOSSEL method was used to obtain the dislocation density throughout single crystal particles. Optical microscopy of the etched samples was performed to measure the grain size. Up to 700 °C no recrystallization occurred. The densification rates as well correspond to temperature and effective pressure without further changes in the microstructure. By using single crystalline powder, the densification rates decreased as expected and confirmed the dominance of the grain boundary diffusion controlled densification.

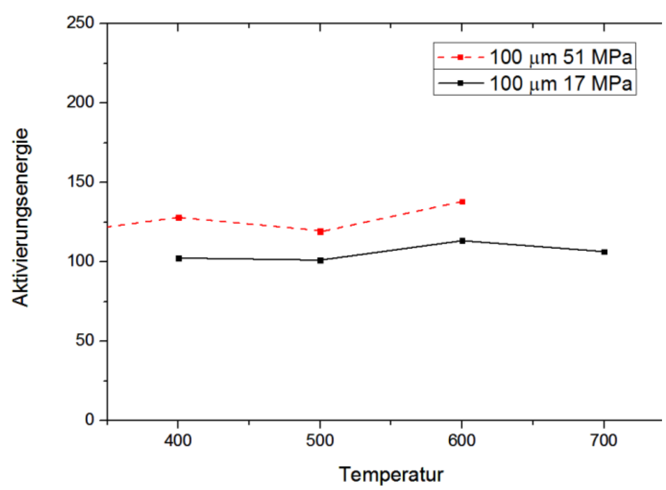

Figure 1: Activation energy for the densification of copper with different temperatures and pressures

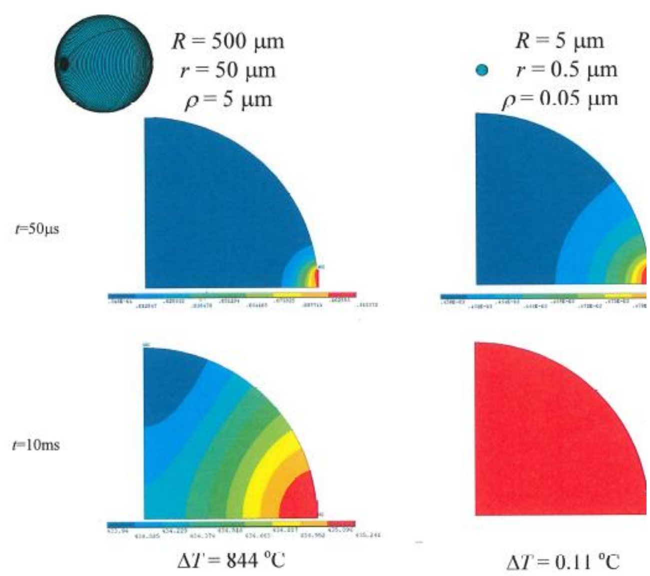

Figure 2: Microscopic temperature distribution in the beginning and end of a 10 ms pulse for very large and small particles