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MODIFICATION OF THE INTERDIFFUSION PROCESS IN THE IRON-ALUMINUM SYSTEM VIA SPARK-PLASMA SINTERING / FIELD ASSISTED SINTERING

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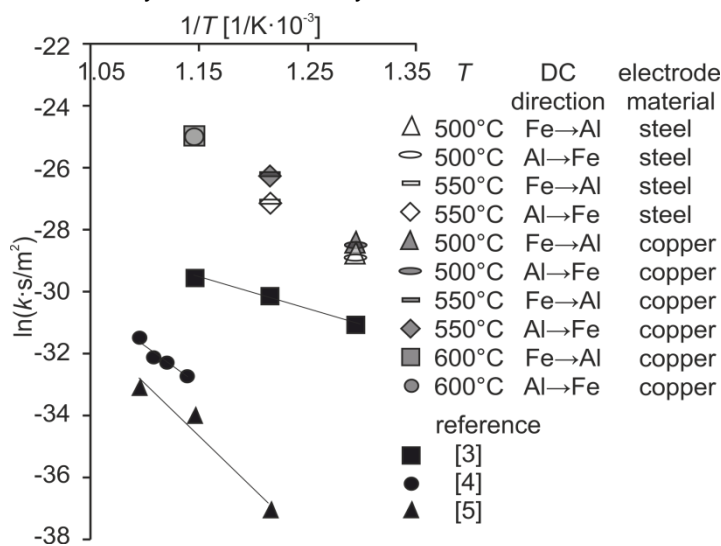
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Utilizing the Spark Plasma Sintering (SPS) / Field Assisted Sintering Technology in electrically conductive samples, the pulsed direct current (DC) induces primarily Joule heating. Nevertheless, the applied DC is frequently reported to accelerate diffusion processes as compared with the conventional heating in a furnace [1]. Thereby, after SPS treatment, the microstructural evolution is changed against the conventional heat treatment even if the diffusion processes run at the same temperature [2]. These differences are attributed to various phenomena, whose characteristic significance depends on the material system. The present study of the reactive diffusion in the binary system Al-Fe aims at contributing to the discussion of the above phenomena.

Diffusion couples Al-Fe-Al were treated at temperatures between 500°C and 600°C for 15 min to 120 min applying a SPS facility working alternatively with steel and copper electrodes. The temperature was controlled at the top of the Al-Fe-Al stacks by a thermocouple. This temperature range was connected with average (root-mean-square) current densities up to 129 A/cm². Scanning electron microscopy including electron backscatter diffraction and transmission electron microscopy were employed to identify the sequence and growth of intermetallic phases in the Al-Fe system and to analyze the microstructural features in the interdiffusion zone.



Additional to the occurrence of Al₅Fe₂ as in conventional heat treated solid Fe - solid Al diffusion couples, the Al₁₃Fe₄ phase was detected. The morphology of the Al₅Fe₂ phase was not altered compared to literature [3, 4, 5]. The layer-growth kinetics was parabolic. The growth rates of the intermetallic were remarkably enhanced in comparison to the conventional heat treatment experiments [3, 4, 5], while the DC direction had no effect on the growth of intermetallic phases. However, the electrode materials affected the resulting rate constants. At the same preset temperature, which was specified at one end of the Al-Fe-Al stack, the growth of intermetallic phases was faster with copper electrodes than with steel electrodes (Figure 1).

It is proposed that the enhanced diffusion is connected with temperature gradients existing in

Figure 1 – Natural logarithm of the parabolic rate constants in dependence on the reciprocal temperature for different annealing conditions including the DC direction and electrode material in comparison to the data from literature.

the samples between the position of temperature measurement at the edge of the sample and the center. Therefore, the true temperature in the diffusion couple is likely higher than the measured temperature, explaining the enhanced diffusion to

some extent. This temperature difference is likely larger in the case of use of the thermally well conducting copper electrodes, which well complies with the larger growth rates upon use of copper electrodes. Moreover, possible effects of thermomigration and electromigration are discussed.

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