Densification Behavior of Passivated Nanoscale Metal Powders (Al, Cu, Ni, Fe) during Spark-Plasma Sintering

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Spark-Plasma sintering (SPS) is a novel sintering method which is particularly useful for sintering of hard-to-sinter materials, amorphous materials, metallic and ceramic compounds etc. In addition to mechanical pressure, a DC voltage pulse is applied to the sample during SPS, which is inserted between a conductive die and punch.
This causes a spark-plasma between powder particles and their resistive heating and leads to enhanced densification. Even at lower sintering temperature and for shorter holding time conventional methods such as hot pressing and hot isostatic pressing, higher sintered densities of the compacts without grain growth can be achieved. In the present work, Cu, Ni, Fe and Al nanopowders produced by wire electric explosion (WEE), were spark-plasma sintered.
Wires with diameters ranging from 0.3 to 0.35 mm with length of 65 mm were used for the WEE process. WEE was carried out at voltages between 26 and 28kV under an 1.5 atm Ar atmosphere. The produced powders were subsequently passivated in air for 24 h. Particle size analyses, by laser diffraction, revealed mean particle sizes of 110~160nm. SPS was carried out, using graphite dies with an inner diameter of 15mm, at a heating rate of 100 K/min, an applied pressure of 50MPa and under a vacuum of 10^{-3} torr. Depending on the powder, the sintering temperature was 600(Al), 950(Cu), 1100℃(Ni and Fe). Relative density and densification rate were determined from the SPS data. Using SEM and EDS, the microstructure and chemical distribution the SPS compacts were analyzed. Crystallite sizes were determined by XRD line broadening method. Vacuum in the SPS chamber during sintering was carefully monitored and oxide contents in initial and sintered compact were measured with EPMA.