High-Entropy CuCrFeTiNi Alloy Produced by High-Energy Ball Milling and Spark Plasma Sintering: Structural and Magnetic Characterization

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Newly developed high-entropy alloys (HEAs) are receiving much attention for their unique structures and excellent properties [1-3]. Two groups independently proposed the study of HEAs containing multiple elements (at least 5) in equiatomic or nearly equiatomic concentrations (ranging between 5 and 35 at. %). These alloys are stabilized by the increase of the mixing entropy which is thought to suppress the formation of metallic phases and thus favors the formation of simple solid solutions with a *fcc* or *bcc* or *bcc+fcc* structures.
HEAs have been fabricated by several methods, including arc melting and casting, mechanical alloying, and laser cladding. Among these, especially promising seems to be high-energy ball milling (HEBM) in planetary ball mills that can yield stable microstructures and nanocrystalline alloys of better homogeneity compared to other non-equilibrium processes. In this communication, we report the first preparation of equiatomic CuCrFeTiNi HEA particles by short-term (30 min) HEBM and spark plasma sintering (SPS) and provide a structural and magnetic characterization.
Our structural and chemical analysis showed that micron sized particles of *bcc* CuCrFeTiNi consisting of nanosized crystalline grains (~6 nm) could be obtained after 30 min of HEBM. The HEA powders were thermally stable up to 500°C by DSC. The HEA powder was subsequently consolidated by SPS at 700°C resulting in a consolidated bulk HEA with co-existing *bcc* and *fcc* phases. The as-milled CuCrFeTiNi powder blend contained a solid solution with *bcc* (*Im*3*m*) structure. Annealing at 600°C (*t*=180 min) increased the crystallinity of the α-phase (*bcc*) and gave rise to formation of the γ-phase (*fcc*, *Fm*3*m*) whose amount grew with increasing dwell time. Between 800–1000°C, a tetragonal intermetallic σ-phase – most likely FeCr - appeared and subsequently vanished. At 1000°C, the final product was found to contain two solid solutions based on the γ-phase (*fcc*). The Vickers hardness H_v^{HEBM} = 7.7 GPa of the SPS consolidated CuCrFeTiNi alloy (milled for *t* = 180 min) was markedly higher than the one of SPS-produced ones without HEBM (H_v= 2.1 GPa). Paramagnetic behavior at room temperature with a small ferromagnetic contribution at low fields was observed for as-milled powder after 180 min of HEBM. A small magnetic hysteresis was observed at 5K and 300K with a coercive field of around 16 kA/m. Above 100K, the inverse susceptibility of a HEA powder ball-milled for *t*=240 min showed a clear paramagnetic response. The Curie temperature T_C ~ 50 K was found.

References
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