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Influence of Process Parameters on the Thermal Plasma Driven Aluminothermic Processing of Manganese Ore

Manganese (Mn) is a critical component in the production of ferrous and non-ferrous alloys. It is primarily sourced from high-grade ores (>40% Mn) typically containing Fe, Al, and Si oxides [1]. While conventional hydrometallurgical and carbothermal reduction methods generate toxic secondary waste, the aluminothermic process offers an environmentally friendly alternative. However, standard aluminothermic reduction often requires significant external energy to initiate the reaction and achieve efficient metal–slag separation. This study investigates the recovery of Mn and associated metals using a thermal plasma-assisted aluminothermic process. The starting ore composed of $MnAl_2(SiO_4)_3$, SiO_2, and Fe_3O_4 phases with oxide concentrations of MnO (36%), SiO_2 (21%), Al_2O_3 (22%), and FeO (17%). TG-DSC analysis revealed that the aluminothermic reaction between molten Al and solid metal oxides initiates at approximately 960 ℃. Consequently, the thermite mixture was treated using a transferred arc plasma (at 3, 5, and 7 kW) under Ar, Ar + H2, and air atmospheres to optimize recovery. The plasma successfully initiated and sustained the reaction, generating a molten product that facilitated clean separation between the metal and oxide phases. The resulting products included a Mn-rich metal fraction that containing Fe, Si, and Al, suitable for steelmaking applications and a slag fraction that composed of Al_2O_3, Mn_2SiO_4, $FeSiO_3$, and Al_2SiO_5, with potential utility as a refractory material in the cement industry. Residual Mn in the slag suggests insufficient aluminium addition or high slag viscosity. These limitations can be mitigated by reducing ore particle size, improving the wettability between liquid Al and the ore, or adding fluxes to decrease viscosity. With further parameter optimization, this scalable, non-toxic approach may provide a commercially viable pathway for large-scale Mn ore processing.

References

[1] Liu, B., et al., Extraction and separation of manganese and iron from ferruginous manganese ores: A review. Minerals Engineering, 2019. 131: p. 286-303.

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