Phase evolution of Strontium hexaferrite Sintered by Pressureless Spark Plasma Sintering (PSPS)

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Permanent magnets (PM) play an important role in enabling technologies and modern devices of today [1]. Ba- and Sr-ferrites are most-produced permanent magnetic materials in the world [2]. Although ferrite magnets are inferior in performance to rare-earth magnets, the harmful environmental impact of production, uneven distribution, and increasingly questionable supply chain force us to look for alternatives. One of the possible candidates comes from the group of hexagonal ferrites [3]. M-type ferrite magnets generally do not contain critical raw materials [4].

In our study we tested pressurless spark plasma sintering (PSPS) on strontium hexaferrite using graphite die in spark plasma sintering (SPS) device, that enabled to isolate radiation as a sintering mechanism. Although ceramic magnets and radiation assisted sintering process have been known for some time, this is a less commonly used approach to sintering this widely used magnetic material. This research focuses mostly on analysis of phase evolution during PSPS sintering of Sr-ferrite where we tried to determine newly formed phases in the sample. The samples were extensively analysed on a scanning electron microscope (SEM) where, with the help of energy dispersive spectroscopy (EDS) and electron backscatter diffraction (EBSD) techniques, we were able to determine the segregation of the base material and the new arrangement of grains. In addition, we analysed the diffractions with the help of transmission electron microscopy (TEM) and thus tried to determine the crystal phases of the newly formed phases. Additionally, we confirmed our results with X-ray diffraction analysis (XRD) and thermogravimetry differential thermal analysis (TG/DTA) analysis. We found that ferrite reduction occurs in the sample due to a slightly reducing atmosphere, which is caused by a combination of vacuum and carbon sputtering. This causes the appearance of strontium depleted and enriched phases.

Key words: Strontium hexaferrite, magnets, graphite die, sintering, PSPS

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[1] Global market insights: Permanent Magnet Market size to exceed USD 50 Bn by 2024. (2019). Available at: https://www.gminsights.com/pressrelease/permanent-magnet-market. (Accessed: 9th January 2021

[2] KOLAR, D. *Tehnična keramika 2 knjiga.* Ljubljana : Zavod Republike Slovenije za šolstvo in šport, 1993, 455 str.

[3] Riba, J.-R., López-Torres, C., Romeral, L., & Garcia, A. (2016). *Rare-earth-free propulsion motors for electric vehicles: A technology review. Renewable and Sustainable Energy Reviews, 57, 367–379.* doi:10.1016/j.rser.2015.12.121

[4] Nordelöf, A., Grunditz, E., Lundmark, S., Tillman, A.-M., Alatalo, M., & Thiringer, T. (2019). *Life cycle assessment of permanent magnet electric traction motors. Transportation Research Part D: Transport and Environment, 67, 263–274.* doi:10.1016/j.trd.2018.11.004