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► **To cite this version:**

Ryan Sedek, Gabriel Gomez Eslava, Patricia de Rango, Sorana Luca. Sintering of Nd(Fe,Mo)₁₂ tetragonal compounds for permanent magnets applications. REPM2023 - 27th international workshop on rare earth and future permanent magnets and their applications, Sep 2023, Birmingham, United Kingdom. cea-04850131

HAL Id: cea-04850131

<https://cea.hal.science/cea-04850131v1>

Submitted on 19 Dec 2024

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Sintering of Nd(Fe,Mo)₁₂ tetragonal compounds for permanent magnets applications

Ryan Sedek^{1,2}, Gabriel Gomez-Eslava¹, Patricia De Rango², Sorana Luca¹

¹ Univ. Grenoble Alpes, CEA, Liten, DTNM, 38000 Grenoble, France

² Univ. Grenoble Alpes, CNRS, Institut NEEL, 38000 Grenoble, France

Over the last 12 years, a lot of scientific effort has been made for the development of new materials for high performance permanent magnets with reduced or none rare earth (RE) content. Nd(Fe,Mo)₁₂N compounds have been considered as good candidates, due to their excellent intrinsic magnetic properties at room temperature: $T_c = 320^\circ\text{C}$, saturation magnetization $M_s = 1.3\text{T}$ and large anisotropy field $\mu_0 H_a = 11\text{T}$ [1]. Despite these relatively high intrinsic magnetic properties, achievable coercivity is still low for permanent magnet applications ($< 0.6\text{T}$) [2]–[4]. Single-phase material and proper nitrogenation is a prerequisite to increase the intrinsic magnetic properties. In addition, proper microstructure, formed by single crystalline 1-12 grains magnetically separated by non-magnetic intergranular phases, is necessary to achieve high extrinsic magnetic properties, namely remanence and coercivity. Furthermore, maximum performances are expected from fully dense magnets. Nevertheless, nitrided compounds are not stable at conventional densification temperatures, limiting their use as bonded magnets.

This study focuses on the development of dense Nd(Fe,Mo)₁₂N compounds by low temperature sintering process. Alloys with Nd_{1.25}(Fe,Mo)₁₂Cu_{0.1} (wt.%) composition were prepared by strip casting, allowing to obtain more than 96% of 1-12 phase. Liquid phase sintering at low temperature is promoted by the addition of Cu in the Nd(Fe,Mo)₁₂ alloy composition, allowing also the formation of a eutectic Nd-Cu grain boundary phase that should magnetically decouple the 1-12 grains.

The SPS (Spark Plasma Sintering) was implemented in order to permit low temperature sintering assisted by the grain boundary liquid phase. The SPS makes possible to apply a homogeneous pressure during the thermal cycle and thus to reduce the densification temperature. Following this procedure, we obtained high densification rates ($>98\%$). Microstructural analysis will allow us to establish the limitations of the process, regarding the desired magnetic performances.

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