Poster Presentation

Rapid Preparation of $Sm_2Fe_{17}N_3$ Fine Powder by Cryo-milling

Qiang Gao, Dong Liang, Hui-Dong Qian, Tao Zhu, Jingzhi Han, Changsheng Wang, Wenyun Yang, Jinbo Yang

Beijing Key Laboratory for Magnetoelectric Materials and Devices, Beijing 100871, China.
Institute of Condensed Matter and Material Physics, School of Physics, Peking University, Beijing, 100871, China
E-mail: yangwenyun@pku.edu.cn

Introduction

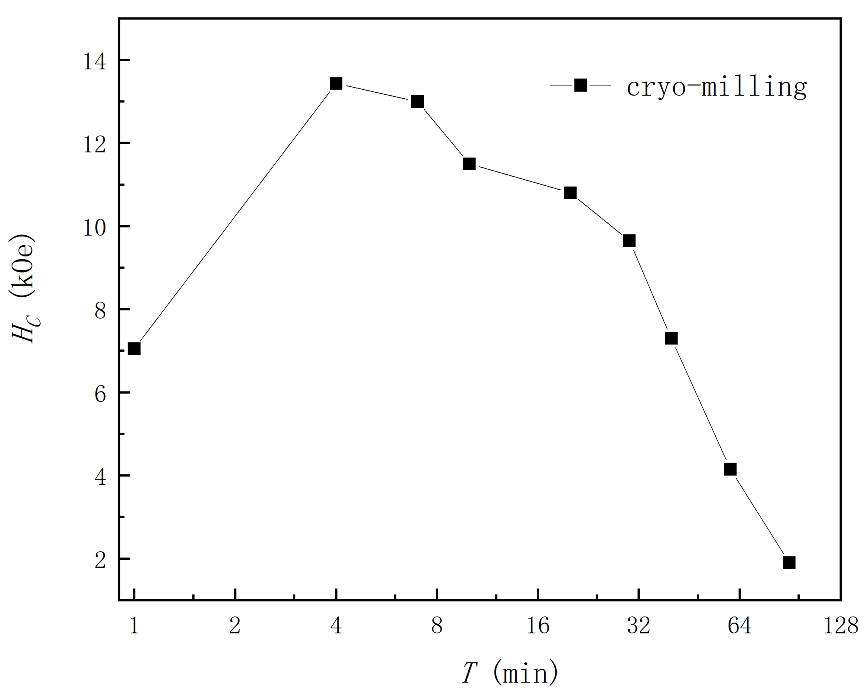
- Samarium iron nitride ($Sm_2Fe_{17}N_3$) permanent magnetic materials possess excellent intrinsic magnetic properties, including a saturation magnetization of 1.54 T. To reach the full potential, the key is to increase the coercivity of the powder. Since the coercivity mechanism of $Sm_2Fe_{17}N_3$ is nucleation-controlled, reducing the grain size through grinding is a necessary step in preparing high-performance powders for $Sm_2Fe_{17}N_3$ magnets.
- Due to the high chemical reactivity, $Sm_2Fe_{17}N_3$ readily oxidizes during ball milling, forming Sm_2O_3 and soft-magnetic Fe that degrade the magnetic properties. Meanwhile, the localized high temperatures generated during milling can decompose $Sm_2Fe_{17}N_3$ into SmN and Fe, thereby compromising the magnetic performance.

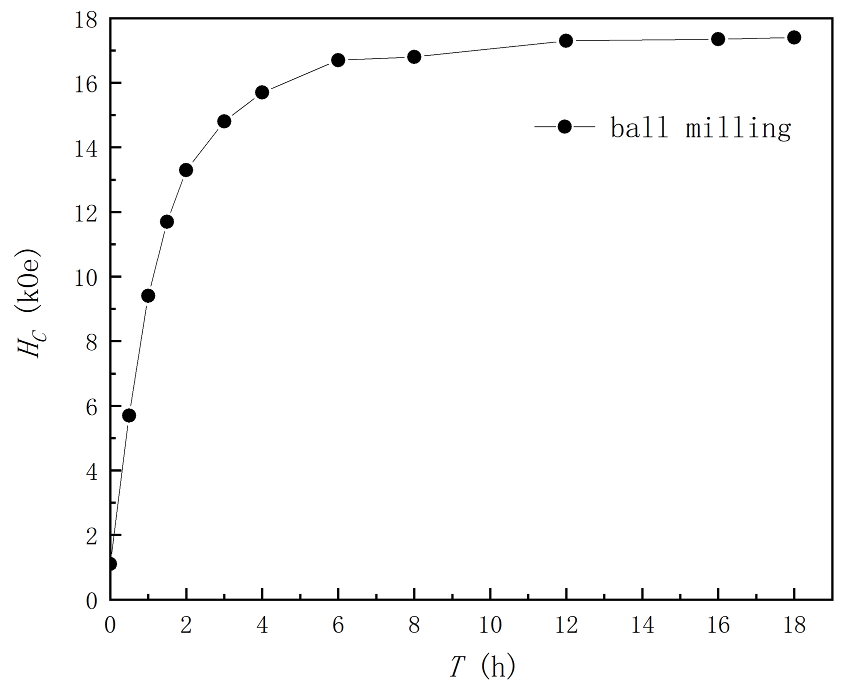
This Work

- **Here**, we therefore investigate a liquid-nitrogen-cooled milling process (cryo-milling) for rapidly producing high-coercivity $Sm_2Fe_{17}N_3$ fine powder, which significantly boosts production efficiency and ensures superior batch-to-batch quality stability.

Coercivity Characterization

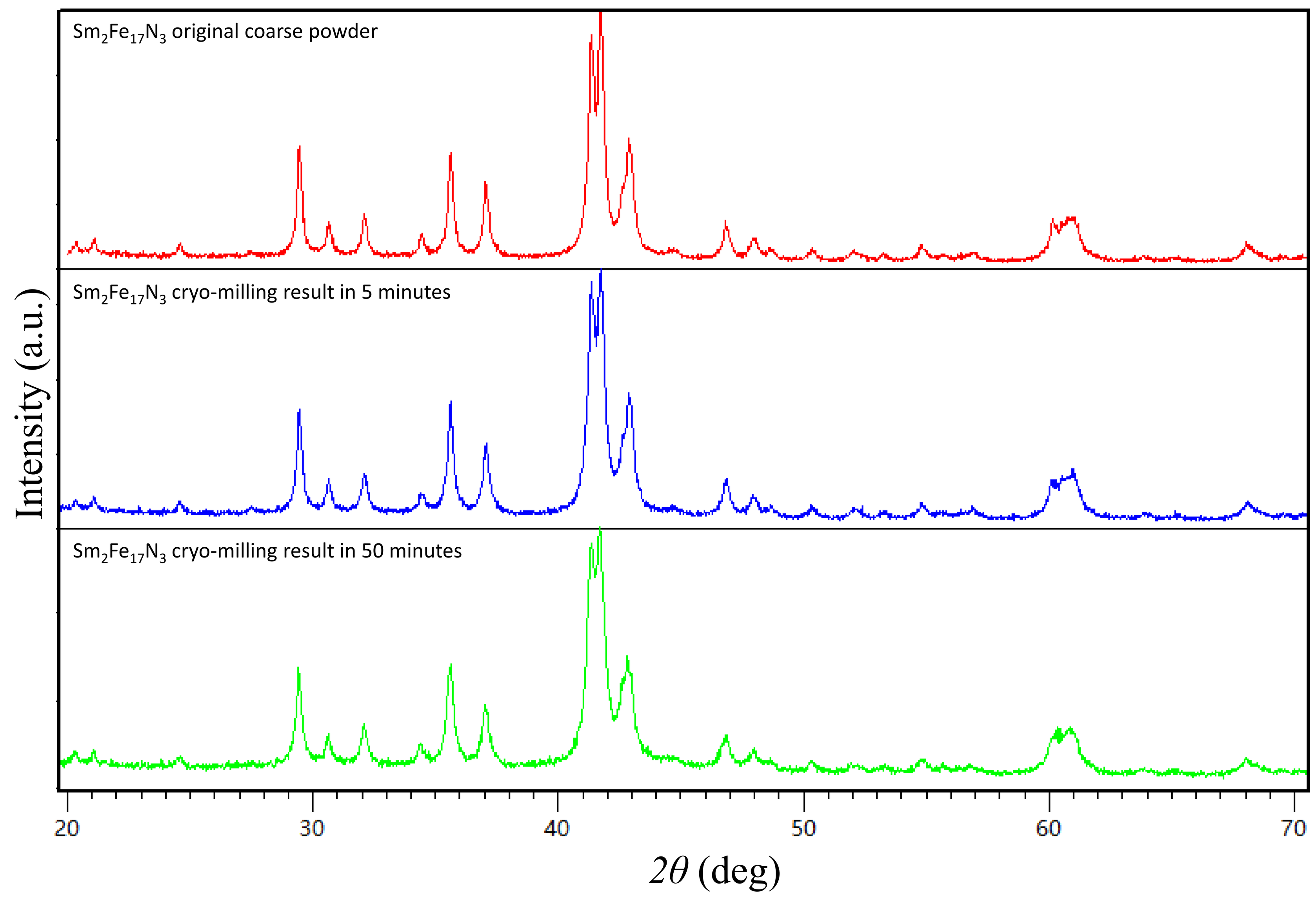
- By using the equipment named Freezer/Mill, the $Sm_2Fe_{17}N_3$ coarse powder was ground by cryo-milling method at liquid nitrogen temperature. After 1 minute of grinding, the coercivity of the $Sm_2Fe_{17}N_3$ powder went up from 1.5 kOe to 7.0 kOe, while after 4 minutes, the coercivity reached 13.4 kOe. However, as the grinding time increased further, the coercivity began to decrease.
- As a control experiment, we used conventional ball-milling: the same $Sm_2Fe_{17}N_3$ coarse powder was loaded into a jar together with stainless-steel balls and n-heptane acting as an oxygen and moisture barrier solvent. Only after a prolonged milling time of 120 min did the coercivity reach 13.3 kOe, comparable to the cryo-milling result in just 4 min.





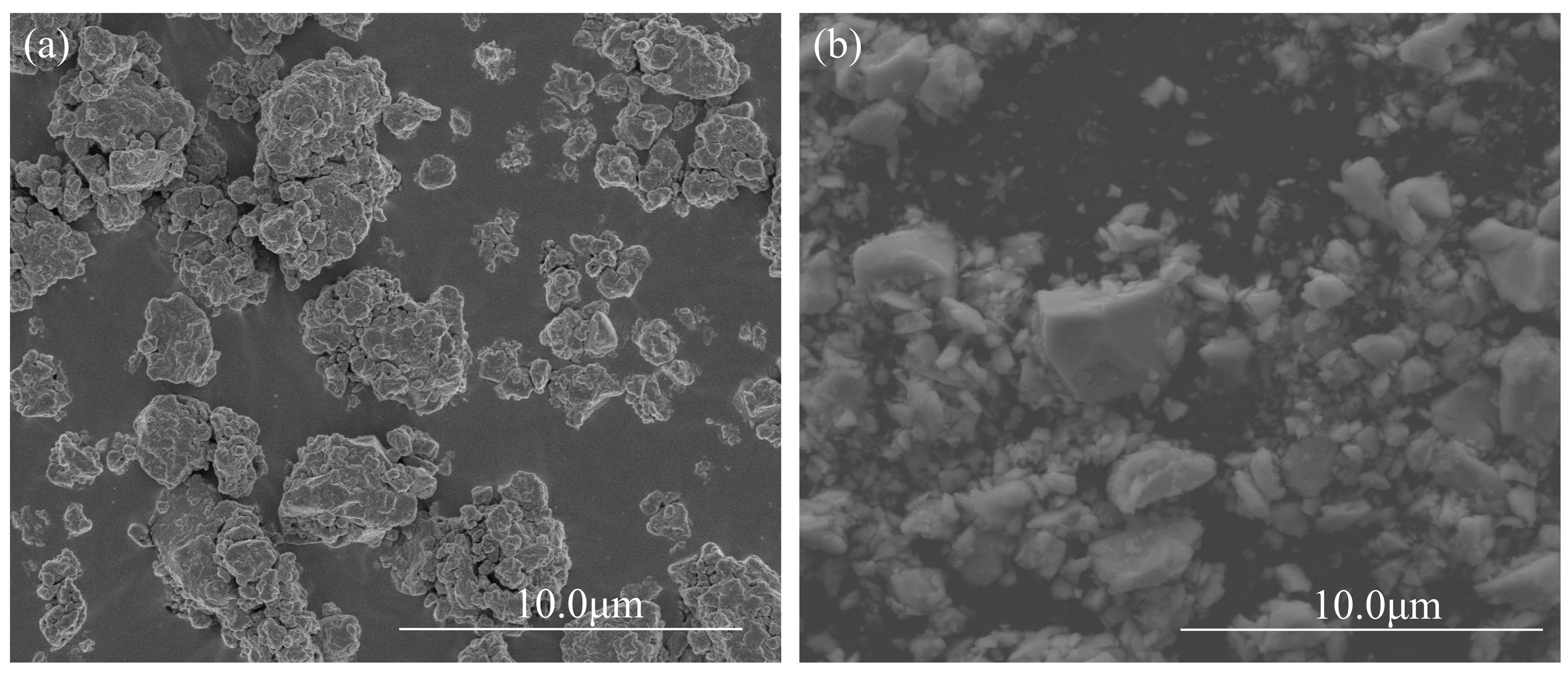
X-ray Diffraction Results

- X-ray diffraction (XRD) results indicated that no α-Fe phase was generated during the grinding process, and the $Sm_2Fe_{17}N_3$ diffraction peaks broadened continuously with increasing grinding time, showing that the liquid nitrogen conditions inhibit oxidation and thermal decomposition during the milling process of $Sm_2Fe_{17}N_3$, and as the grinding time increases, the grain size of the $Sm_2Fe_{17}N_3$ powder continuously decreases.



Microscale Morphological Features

- Scanning electron microscope (SEM) results showed that the sample ground for 4 minutes by cryo-milling (Fig. a) had a similar particle size to that of the sample ground for 120 minutes by conventional ball milling (Fig. b). This indicates that the material becomes more brittle at low temperatures, making it easier to break.



Conclusions

- Cryo-milling produce $Sm_2Fe_{17}N_3$ powder with similar coercivity and particle size to that obtained by conventional tumbling ball milling, yet in only 1/30 of the time—markedly faster and more efficient. It does not require the use of conventional solvents, is more efficient, and effectively avoids heat and oxidation issues during the grinding process. The cryo-milling method thus provides a promising approach to fabricate high-performance $Sm_2Fe_{17}N_3$ powder.