Severe Plastic Deformation as an Innovative Method to Enhance Magnetic Properties in Bulk Materials

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The research on permanent magnetic materials resulted in a steadily increase of essential magnetic properties (e.g. maximum energy product BH_{max}) in the previous century. This development originates in the findings of novel material combinations such as the SmCo-phases during the early 70's and the Nd-based alloys later on, but was also concomitant by an incredible microstructural optimization process. However, within the last decades no completely new permanent magnetic material, that could compete with the already existing ones in terms of processing and commercial usage was found[1].

Motivated by a strongly increasing global demand on high BH_{max} permanent magnets (PM), the research nowadays is widely spread. For instance, one focus is placed on processing routes, another one is the search for novel material phases. While increasing magnetic performance and decreasing the usage of critical materials (e.g. rare earth elements), magnetic coupling effects such as exchange bias or exchange coupling are getting more and more attention. These effects provide the basis for a novel type of magnets, so called spring magnets. So far, interesting findings on spring magnets are mainly made for thin films or powders, where the production and a proper microstructural tuning on the nanometer scale is possible. But these promising results are always combined with one essential problem for PM applications: hard magnets have to attain dimensions of at least the millimeter regime.

To overcome these limitations, we are using a top-down approach: Severe plastic deformation by high-pressure torsion (HPT) is a highly versatile processing route where starting materials and processing parameters can easily be adjusted. The resulting mm-sized bulk samples can be microstructurally tuned, as the microstructure exhibits nanocrystalline or ultrafine-grained grain sizes[2]. Additionally, nanocomposites of phases with different magnetic behavior can be formed. They show global magnetic properties as have been observed for thin-films[3].

Within this study, we emphasize the capability of HPT for nano-scaled microstructural tuning to obtain PMs. Magnetic properties examined by SQUID magnetometry are combined with microstructural findings obtained by synchrotron X-ray diffraction experiments and electron microscopy. First, we show the successful generation of a SmCo-based spring magnet by HPT-deformation. Second, we discuss the importance of novel rare earth free PM based on the MnBi system. Third, thermodynamically metastable FeCr alloys are processed, where the existence of a large exchange bias is presumed.

This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 757333).

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