Mechanochemical Synthesis of Pnictide Compounds

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Introduction

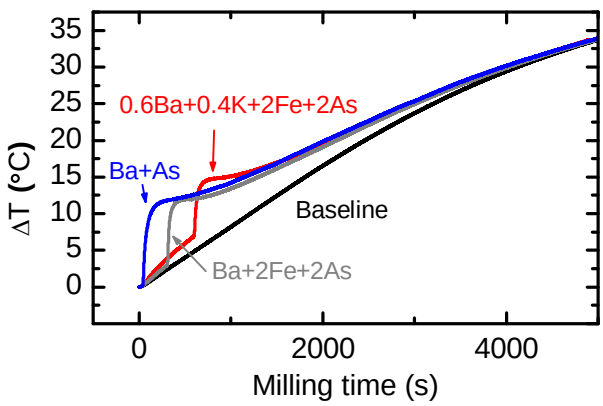
Superconducting materials are needed in high current applications such as power transmission lines and high field magnets used in industry (e.g. MRIs in hospitals). Pnictide superconductors show a lot of promise for applications, but synthesis of the pure material needed to carry current is difficult by traditional methods since the elements are volatile. We have developed ways to synthesize pnictide compounds from the elements using high energy milling techniques to drive chemical reactions.

Experimental

Ba, As, Fe, and K metals were combined in an argon filled glove box at the NHMFL. The mixture was then reacted using high energy ball milling. The reaction was monitored by a thermocouple placed on the milling vial. X-ray diffraction (XRD) was used to analyze the phases present before and after reaction. The powders were then consolidated by heat treating in a furnace or a hot isostatic press (HIP) to obtain a bulk material. The bulk material phase purity was characterized by XRD and SEM. Superconducting properties were characterized at the Applied Superconductivity Center by SQuID magnetometry, vibrating sample magnetometry, and magneto-optical imaging.

Results and Discussion

During milling distinct exothermic events occur as a result of a chemical reactions taking place as seen in the figure. XRD analysis before and after the reactions confirmed that the intended compounds were obtained immediately after the reaction. After the HIP heat treatment, very high density and purity were obtained. The high purity and density of the material greatly improves the superconducting properties of the $Ba_{0.6}K_{0.4}Fe_2As_2$ bulks. This technique has been used to synthesize powders for wires that carry large currents [2].



Milling vial temperature as a function of milling time for three different pnictide reactions and a baseline in which inert powder is milled and no reaction occurs [1].

Conclusions

When the elements are combined to make pnictide compounds they are at a very high energy state. Like gunpowder, they can ignite during handling and processing steps which can be dangerous. Graduate student Jeremy Weiss, undergraduate Ben Hainsey, and scientists at the Applied Superconductivity Center have successfully demonstrated this tendency for the elements to react can be exploited by using mechanical impacts to ignite the material in a controlled way. The resulting material is easier to handle and results in high quality samples that can be put into wires that carry over 160,000 A/cm^2 in self-field at 4.2 K.

Acknowledgements

We would like to thank W L Starch and V S Griffin for technical support. This work is supported by NSF DMR-1006584 and by the National High Magnetic Field Laboratory, which is supported by the National Science Foundation under NSF DMR-1157490 and by the State of Florida.

References

[1] Weiss, J. D., et al., SUST, **26**, 074003 (2013).
[2] Weiss, J.D., et al., Nature Materials, **11**, 682-685 (2012).