Superconductor Design Choices for a 1.4 GHz (32.9 T) High Resolution NMR Magnet at the NHMFL

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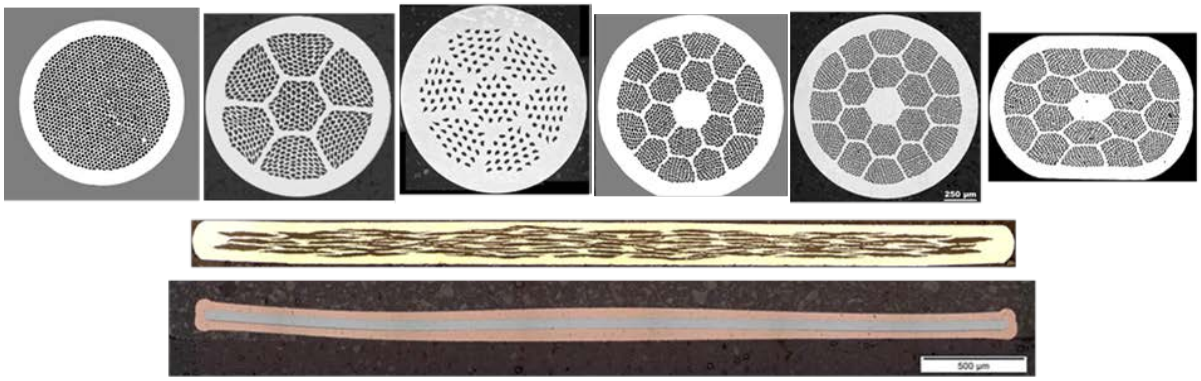
The goal of building a >30 T high resolution NMR spectrometer was first advocated by the Committee on High Magnetic Fields in 2005 and reinforced a decade later by MagSci. Progress towards the 30 T class NMR magnets has however been slow, indicating that the goal is not easy. So far Bi-2223 and REBCO coated conductors have been the conductors of choice but both are high-aspect ratio tapes with significant magnetizations that complicate attainment of high field quality. The high irreversibility temperature T_{irr} of REBCO greatly complicates quench protection , which has been a challenge for several significant REBCO magnets. At the magnet lab we have been developing Bi-2212 as a round wire, with macroscopically isotropic critical current density, a truly multifilamentary architecture and the ability to twist the filaments so as to reduce coupling losses during charging. In all of these respects it is like the Nb-Ti and Nb_3Sn conductors from which all present NMR magnets are built. Bi-2212 is now reaching current densities of 5000 A/mm^2 at 30 T, with whole wire current densities of order 1000 A/mm^2 fortunately with the Bi-2212 embedded in a high purity Ag matrix that has residual resistivity ratio >100, making it very suitable for quench protection. By contrast to REBCO, where the 30 T irreversibility temperature T_{irr} is ~55 K, T_{irr}(30T) for 2212 is ~15 K, making the quench protection much easier.



Top row shows various Bi-2212 wires displaying a wide variety of filament architectures. Note the very strong contrast with the Bi-2223 flat tape (~0.2 x 4 mm – middle row) made by Sumitomo Electric Inc. in only one single architecture and the flat SuperPower REBCO coated conductor (bottom row) made for the NHMFL 32 T user magnet (~0.14 x 4 mm).

The complication of Bi-2212 is that, like Nb_3Sn, it must be wound and then reacted in place. Bi-2212 reaction technology is more complex, however, requiring a 50 bar over pressure (OP – 1 bar O_2 balance Ar) at a peak temperature of 890 C. After some years of development, supported also by the Accelerator Physics Community, we believe that Bi-2212 is now ready for large magnet projects. Furnace technology (we note that all Bi-2223 is processed at 200 bar and about 840 C), insulation technology and coil-strengthening technology have all had to be developed but solutions for each of these challenges are now in hand. We are accordingly now developing larger scale coils which will be tested in large-bore LTS coils to demonstrate fields in the 30 T range with safe mechanical and quench properties. Capitalizing on its multifilamentary, fine filament and macroscopically isotropic properties, we plan coils with sub ppm and low screening current magnitudes.