2nd Year Report- Hafiz Mansoor ul Hassan (S5502806)

Study and development of Ba_122 superconductor for Applications.

My PhD thesis is funded by the PNRR - Research Infrastructure (Missione 4, Componente 2) Project "IRIS – Innovative research Infrastructure on Applied Superconductivity" and it is devoted to "Study and development of Ba_122 superconductor for Applications". The activity is done at the Institute CNR_SPIN and it is done within the Work Package 3 in collaboration with DIFI and INFN. Moreover the activity on Ba122 superconductors is in the framework of a collaboration agreement between CNR.-SPIN and CERN for the development of Iron Based superconductor for high magnetic field applications. The objective of this agreement is the fabrication of multi-filamentary wires realized with the powder in tube (PIT) method with Jc at least 105 A/cm2 at 16T at the temperature of interest.

Currently, iron-based superconductors (IBSs) have reaped significant consideration within the international superconducting community. Unlike traditional low-temperature superconductors, IBS materials exhibit convincing advantages, including higher upper critical fields H_{C2}, boosted critical current densities (J_c), and high transition temperatures T_c and as compared to other HTS like copper oxide and BISCO have less anisotropy. This is proving that they are very promising for fusion magnets and accelerators. Iron-based superconductors (IBS) open up new avenues for experimental research and potential applications, particularly under high magnetic fields. While sharing some commonalities with other high-temperature superconductors, IBS stand out due to their distinct pairing symmetry and superior grain boundary transparency. These unique properties present both challenges and opportunities for practical applications. These indicators highlight the practical capability of IBSs. There are different IBS families, each deriving from a common parent material. $KBaAs_2Fe_2$ (so-called 122 family) is very interesting after the preparation of Long-length BaK122 superconducting wires fabricated using the cost-effective powder-in-tube (PIT) method. This approach has enabled the preparation of high-performance (Ba,K)122 PIT samples, achieving transport critical current densities J_c of up to 1.5 × 10^5 A/cm² in tapes and 4.4 × 10^4 A/cm² in round wires. These results were obtained for samples annealed at ambient pressure, measured at 4.2 K and 10 T.

The aim of this research to develop Ba_122 superconducting wires realized with the powder in tube (PIT) method The PIT method consists of tube filling, drawing and heat treatment. Superconducting powder filled inside the Silver tube. The filled tube is then subjected to a drawing or extrusion process. This involves reducing the diameter of the tube and simultaneously elongating it. Then heat-treated to enhance its superconducting characteristics.

1st Year overview:

My 1st year was focused on the powder preparation with the purpose to increase grain size and get pure and homogenized powder. 5 different batches of 2g powder of Ba_122 were prepared with access of Potassium of 20%, 15%, 10%, 5% and 00% in [K=0.0870g, Ba=0.4583g, As=0.8335g and Fe=0.6212].So required grams of material (K, As, Ba and Fe) were mixed together homogeneously with the help of Ball milling process at 650 rpm for 15 and 15 hours in Glove Box. Transfer this powder into niobium tube with a diameter of 10 mm and pinch both sides put this tube into steel crusible diameter of 15 mm and weld both sides carefully. After welding the steel container containing the niobium crucible and the precursors, it is placed inside the oscillating furnace with a ramp of 50°C per hour up to 750°C for 50 hours. The powder was ground using an agate mortar and then analyzed using XRD measurements, SEM imaging, and SQUID magnetometry. And results were declared that

20% access K sample is good as compared to others in term of Purity, Homogeneity and gran size.

Experiments performed in 2nd Year:

My Second year of PhD mostly focused on the preparation of optimized Ba122 phase in terms of purity (free impurities) homogeneity, and optimized critical field and critical temperature and then preparations of wires. This year, we prepared 4 batches of a large amount of powder (each 6g) with 20% and 0% access of potassium K. The $(Ba_{0.6}K_{0.4})Fe_2As_2$ powder were synthesized through a solid-state reaction using high purity metallic elements: Fe 99.99% powder; K 99.99% solid; Ba 99.25% (+ 0.75%Sr) and Arsenic As 99.99% chunks. The resulting mixture is encapsulated in a Niobium (Nb) tube and subsequently sealed in an Argon (Ar) atmosphere in a stainless-steel crucible using tungsten inert gas (TIG) welding. The entire process is performed in a glove box with an Ar controlled atmosphere containing less than 0.5 ppm of O2 and 0.5 ppm of moisture. The sealed crucible is finally heated around 850°C for 20 hours while continuously rotating off-axis to optimize the elements mixing during the reaction. After getting powder of 20% and 0% access again ball milling process was performed on two batches at the end we get 4 following batches. 1 with 20% access of K + Ball milling, 2 with 20% access of K without Ball milling, 3 with 0% access of K + Ball milling and 4 with 0% access of K without Ball milling. The purpose of ball milling to enhance grain size and improve homogeneity. XRD and SEM analysis performed and results will be discussed in PPT presentation. Mostly work done with the help of group members.

Preparations of Tapes:

To test the impact of the different powders on the transport properties of conductors, four tapes were fabricated using the PIT technique. Each tape was filled with one of the four different powders and all the samples were processed in the same way. A pure Ag tube, with a starting outer diameter (OD) / inner (ID) diameter of 8/5 mm, was filled with powder and processed down to 1.8mm diameter wire through wire drawing and groove-rolling with reduction of 10% every time in order to achieve a better compaction of the powder inside the tube. Flat rolling steps were performed on the resulting wires to obtain a tape with a final thickness of 0.4mm again with the reduction of 10% every time. Then prepared tapes treated with 750^0C, 800^0C and 840^0C at 5 and 10 hours in the presence of argon environment. Following samples are prepared.

Sr. No	Sample Name	Potassium K Access
1	Ba017T08B_750C_10h	+K 20% Milled
2	Ba017T08B_800C_5h	
3	Ba017T08B_840C_5h	
4	Ba018T09B_750C_10h	+K 00% Not Milled
5	Ba018T09B_800C_5h	
6	Ba018T09B_840C_5h	
7	Ba018T09B_840C_10h	
8	Ba019T10B_800C_5h	+K 00% Milled
9	Ba019T10B_750C_10h	
10	Ba021T11B_750C_10h	+K 20% Not Milled
11	Ba021T11B_800C_5h	
12	Ba021T11B_840C_5h	
13	Ba021T11B_840C_10h	

SEM, I_c and XRD analysis were performed on the prepared tapes. In this section I focused on XRD, texturing and orientation analysis of tapes and other work done with the help of group members. Results will be discussed in PPT presentation.

Supervisors:

- Dr. Andrea Malagoli (CNR-SPIN)
- Prof. Marina PUTTI (Università degli Studi di Genova)

Courses attended:

- Design of Superconducting Magnets (Pass)
- Applied Cryogenics (Pass)
- Technology of wires, tapes and superconducting cables
- Superconductivity (Master's Course) (Pass)

Summer School:

- CONECTUS Summer School, 24-28 June 2024, Prague, Czech Republic

Conferences attended:

- EUCAS 2023, 3-7 September 2023, Bologna, Italy

Short Courses:

- "Materials" in EUCAS 2023, 3-7 September 2023

Publications:

- **"Impact of powder granulometry on the transport properties of $Ba_{0.6}K_{0.4}Fe_2As_2$ superconducting tapes.** Andrea Traverso, Matteo Bordonaro, Hafiz M. Hassan, Alessandro Leveratto, Federico Loria, Emilio Bellingeri, Cristina Bernini, Valeria Braccini, Amalia Ballarino and Andrea Malagoli"

- "**Development of a scalable method for the synthesis of pure (Ba,K)-122 superconducting powders.** Andrea Malagoli, Andrea Traverso, Cristina Bernini, Federico Loria, Alessandro Leveratto, Emilio Bellingeri, Matteo Bordonaro, Hafiz M. Hassan, Valeria Braccini, and Amalia Ballarino"

Submitted to ASC-2024.