Superconductors are emerging technology with transformative potential in various fields, including energy-efficient power grids, high-speed maglev trains, medical imaging systems like MRI, nuclear magnetic resonance (NMR), particle accelerators, fusion generators, and advanced high-field magnet applications for research and industry. Since discovery in 2006, Fe-based superconductors have drawn significant interest in high field magnet applications. The K-doped Ba-122 (Ba0.6K0.4Fe2As2) is a promising Fe-based superconductor candidate to be utilized as a technological conductor due to its high intragranular critical current density *Jc* of 106 Acm-2 at 5 K and 1 T field in single crystal, high upper critical field, and very low critical field anisotropy. Although the single crystal possesses a very high supercurrent, the polycrystalline K-doped Ba-122 is severely restricted by grain-to-grain connectivity at the grain boundaries (GB).

Weiss et al. demonstrated that *Jc* of ~105 Acm-2 at self-field is achievable in polycrystalline K-doped Ba-122 bulk, which paved the way for further research efforts in this material. Weiss’ approach of mechanical alloying enhanced the activity of the precursor powder and controlled the phase purity. Besides, the high-pressure heat treatment enabled densification of the structure. However, the *Jc* obtained is one order of magnitude lower than the single crystal. Many previous works on K-doped Ba-122 indicated that presence of oxide impurities and K segregation at GBs and presence of secondary non-superconducting phase can act as extrinsic current limiters.

To minimize the current limiting factors, Pak et al. adopted a very clean synthesis technique, utilizing highly pure elemental materials and facilitating clean environment of a high-performance glovebox. His work eliminated the impurity at GBs, however, presence of nanoscale cracks at GBs were observed. Although the *Jc* was doubled from Weiss et al., the nanocracks still present an obstruction to current flow.

The goal of my research was to understand how synthesis approach influences the superconducting properties of K-doped Ba-122 and how synthesis parameters can control the extrinsic current limiting factors. I adopted the approach of milling energy density of the high energy ball milling reported by Tokuta et al. for the synthesis of Co-doped Ba-122. His work on varying ball milling parameters to obtain high *Jc* could potentially be applied in K-doped Ba-122 too. I also maintained the same clean environment Pak et al. adopted, so that impurities are minimized, and I can investigate the influence of milling parameters on superconducting properties, especially how supercurrent is limited with respect to changing synthesis conditions.

In my work, I varied the milling parameters to vary the milling energy density exerted on the elemental materials and varied the heat treatment (HT) temperature. I varied the 1st milling energy density and 1st HT temperature of a two-stage synthesis process, where 2nd stage HT was performed in high pressure. Variation of various structural parameters like lattice parameters, dopant K-content, impurity phase, amorphous phase were observed, along with variation in superconducting properties like critical temperature and *Jc*. The work indicates that any detrimental effect in the 1st stage synthesis cannot be recovered even after the 2nd stage. Despite using clean synthesis and high-pressure sintering, traces of secondary phases and amorphous phases were present. However, the synthesis was optimized with the minimal impurity phase and a high *Jc* comparable to Pak et al. was obtained. A key finding was that despite having very similar impurity phase and dopant content, there is large *Jc* variation, indicating that the supercurrent is influenced by many factors still unknown to us.

My work on remnant magnetization and analysis of microstructures further elucidates the current limiting nature of K-doped Ba-122. As remnant magnetization is effective in revealing superconducting granularity for the cases of weakly coupled GBs, this technique was adopted to investigate connectivity variation in down selected samples. The remnant magnetization results showed size dependence of the specimen, which indicated that intergrain properties are defying the current loop in the bulk. electron microscopic analysis demonstrated that nanoscale defects are ubiquitous, even in the best *Jc* sample, which implies extrinsic current limiter present. However, no indication of intrinsic weak linking of GBs were observed. Based on the remnant data, it is proposed that the bulk is segmented to multi-domain current loops. Further *Jc* improvement is possible by controlling extrinsic defects at GBs.