

**PREFACE**

Even after a century of its discovery, superconductivity is one of the captivating topics of modern science with its extensive range from the most elementary aspects of physics to hands-on applications. Significant progress has occurred in the field of superconductivity and the improvements are being sensibly incorporated into the new generation wires, tapes and cables that are being used in a broad range of prototype devices. These devices include NMR magnets, MRI instruments, magnets for fusion power experiments, high field accelerators, motors, generators, and power transmission lines.

Though there are thousands of superconducting materials, only a few of them are suitable for practical applications. The discovery of high temperature superconductors with critical temperature ($T_C$) above 77 K stimulated the development of superconductors for power applications, yet the most widely used commercial superconductors are NbTi and Nb$_3$Sn, the two low temperature superconducting materials. The discovery of superconductivity in MgB$_2$ in early 2001 with relatively higher $T_C$ (39 K), simpler structure, lower anisotropy and nearly transparent grain boundaries spurred renewed interest due to its potential for magnetic applications. The material has already been studied in terms of its crystal structure, thermal and electrical conduction, specific heat, isotope effect and doping effects. Though its $T_C$ is lower than high temperature cuprates, MgB$_2$ is an intermetallic with very low contact resistance between the grain boundaries, eliminating the weak-link problem that has plagued widespread commercialization of the cuprates. Further, relatively higher coherence length of MgB$_2$, in comparison to HTS compounds, permits the use of nano particles of various compounds as additives to act as effective pinning centers and thereby enhance its critical current. These superior properties in
comparison to the so called intermetallic BCS type superconductors and HTS cuprates provide MgB₂ an edge over the other superconductors. In addition, the conduction electron density and normal state conductivity are about two orders of magnitude higher for MgB₂ than the cuprates used in present day wires. These features, combined with the low cost, lightweight, and easy fabrication of wires and thin films, make MgB₂ attractive for many applications such as MRI, transformers and generators especially on board in air and sea, where weight is a concern. It is a strong competitor for the currently used NbTi and Nb₃Sn conductors because it can be operated around the 20-30 K temperature range, above the range of current use of LTS. In this range the expensive liquid helium can be avoided and liquid hydrogen or cryocooler can be used. Hence, among the superconducting materials discovered so far, MgB₂ seems to be a potential candidate for the next generation superconductor applications.

The thesis ahead focuses on the establishment of enhanced superconducting properties in bulk MgB₂ via nano particle doping and its conversion into mono/multifilamentary wires. Further, an attempt has also been made to develop prototypes of MgB₂ coil and conduction cooled current lead for technological applications. The thesis is configured into 6 chapters. The opening chapter gives an idea on the phenomenon of superconductivity, the various types of superconductors and its applications in different fields. The second chapter is an introduction on MgB₂ superconductor and its relevance which includes crystal and electronic structure, superconducting mechanism, basic superconducting properties along with its present international status. The third chapter provides details on the preparation and characterization techniques followed through out the study on MgB₂. Fourth chapter discusses the effect of processing temperature and chemical doping using nano sized dopants on the superconducting properties of MgB₂. Fifth chapter deals with the optimization of processing parameters and novel preparation techniques for
wire fabrication. Sixth chapter furnishes the preparation of multifilamentary wires with various filament configurations, their electromechanical properties and it also incorporates the development of an MgB2 coil and a general purpose conduction cooled current lead. The seventh chapter summarizes the major findings and conclusions of the entire work and also provides the scope for future studies.

MgB2 bulk superconductor is synthesized using a simple Powder-In-Sealed-Tube (PIST) method wherein Mg and B powders were filled in stainless steel tubes and heat treated in atmospheric condition after sealing the ends. The method is simple and cost effective, as it avoids the demand for vacuum or inert atmosphere during synthesis. The in-field current density of the pristine MgB2 is enhanced using various nano sized dopants. Among the different dopants tried, burned rice husk (BRH), an inexpensive natural material is found to be one of the best additives for enhancing the in-field critical current density of MgB2. By selecting suitable combinations of additives a significant enhancement of the critical current density around two orders of magnitude was achieved at higher fields. Later, the focus was on the translation of these properties in mono/multifilamentary wires with various configurations. The influence of sheath material reactivity on the superconducting properties of MgB2 was studied first which was followed by process optimization studies. Further, the influence of typical nano dopants on the in-field transport $J_C$ of multifilamentary MgB2/Fe/Cu/Ni wires was examined. It was observed that the in-field $J_C$ of doped MgB2 multifilamentary wires showed excellent performance, relatively better than the corresponding bulk samples. Another achievement in conductor fabrication was the lowering of the processing temperature of MgB2 wires using nano Cu as an additive. It was found that the MgB2 can be synthesized at around 550 °C with minor Cu addition, which offers a substantial reduction in the processing temperature. In addition, Fe sheathed in situ MgB2 superconducting tapes with high densities were prepared by hot-
pressing of electrically self-heated PIT wires. The method comprised heating of the PIT wires by passing a suitable current, followed by pressing in hot conditions with the help of a hydraulic press. The other highlights of the thesis are the development of a prototype MgB$_2$ coil having an overall homogenous $J_C \sim 10^5$ A/cm$^2$ at 4.2 K and a general purpose conduction cooling type current lead based on MgB$_2$/Fe/Cu/Ni with rating 1000 A at 20-37 K.

In brief, the work compiled in this thesis brings out the influence of nano particle doping in both bulk as well as wire forms of MgB$_2$. Moreover, the development of prototype for coil and conduction cooled current lead shows the potential of MgB$_2$ for technological applications. It is expected that the findings in the thesis can contribute much towards further development in MgB$_2$. 