CONCLUSION

9.1. Summary and conclusion

Doping study in HTS materials is an active area of superconductivity research since it represents an easily controlled, non destructive and efficient method for improving their structural, superconducting and mechanical properties. In Bi-based systems even though Bi-2223 phase has the highest $T_c$, it is difficult to synthesize in pure form comparing with Bi-2212. Moreover higher levels of RE doping are not possible in Bi-2223. Previous works on RE doping in Bi-2212 report only marginal improvements in $T_c$ and flux pinning properties while no report was available on the effect on $J_c$. Solo doping of RE may be the reason for the insignificant results.

This thesis first reports that addition of REs in bulk (Bi,Pb)-2212 highly enhances the $T_c$, $J_c$ and flux pinning properties. Doping of RE modifies the system morphologically as seen in XRD and SEM. EDX results show that the added REs go into the cationic sites such as Sr, Ca and Bi in general, but predominantly being substituted for Sr. Improvement of superconducting properties depends on the RE, especially its valancey and concentration and site of substitution. This is clearly evident from the addition of Ce in (Bi,Pb)-2212 which is in the tetravalent state whereas other RE ions are mainly in the trivalent state. The present results also show that the enhancement in $J_c$ in the self field and infield is not due to RE doping alone but due to co-doping of RE and Pb. The RE doping decreases the charge carrier concentration in the Cu-O$_2$ planes and RE at the cationic sites acts as point like defects and hence as flux pinning centers. Pb doping in the Bi site of RE-modified Bi-2212 decreases the anisotropy of the system also. Results show that all the superconducting properties can be improved upto an optimum value of RE and above this value the superconducting properties deteriorate due to different reasons.

Substitution of different RE atoms at the Sr site of (Bi,Pb)-2212 shows remarkable improvements in the superconducting properties upto an optimum level of RE. At higher levels of substitution, superconductor to insulator and metal to insulator (MI) transitions occur. But these changes vary with the RE chosen for doping. Site selective doping studies of RE show that the superconducting and flux pinning
properties vary with the site selected for substitution. The results in general show that at an optimum level of RE doping the superconducting properties enhance to a maximum and thereafter the properties deteriorate. At the optimum condition the hole concentration in Bi-2212 changes to ‘optimally doped’ regime from ‘over-doped’ regime (when it is without RE), which improves the $T_c$ of the system, because in high-$T_c$ superconductors $T_c$ mainly depends on charge carrier concentration in the Cu-O$_2$ plane, and the carriers are supplied by the charge reservoirs. This improvement of $T_c$ enhances $J_c$ also. The point like defects produced due to the replacement of cations by RE ions act as flux pinning centers and hence the infield $J_c$ also improves. Thus REs in the cationic sites such as Sr and Ca play a duel role in such a way by optimizing the charge carrier concentrations and by acting as flux pinning centers. At higher levels of doping the system shifts to ‘under-doped’ condition and hence the superconducting properties decrease. The secondary phase formed due to heavy doping of RE also affects superconducting properties.

9.2. Scope for future work

The experiments described in the thesis are limited to RE and Pb co-doped bulk polycrystalline samples prepared by conventional solid state method. This co-doping technique needs to be studied in single crystals and melt processed samples for better understanding and application point of view. The oxygen stoichiometry plays a vital role in determining the superconducting properties of HTS materials. In this work we have not studied the variation of the oxygen content in the RE modified system. In this study, even though the processing temperature chosen is around the optimum for pure sample, we get improved superconducting properties for the doped samples for which the processing temperature is slightly higher. If temperature optimization studies are done for doped samples one can further improve the properties of the system. HTS materials show interesting properties such as MI transition in the normal state. A systematic study of MI transition will certainly give more information about the system. The results obtained in this study are highly useful for the development of superconducting wires and tapes with high $J_c$ s in self field and infield.