Chapter 6

Conclusions

In the present thesis, the microstructures of different nuclear structural materials have been studied using the XRD technique. The studies have been performed on different types of PHWR and FBR core structural materials under their deformed or irradiated conditions. In case of the Zr based alloys, the studies have been performed under heavily deformed and irradiated conditions. The heavily deformed powders of D9 alloy have been used to study the in-situ microstructural evolution during the early stages of annealing. Different model based techniques of XRDLPA have been used to analyze the XRD data obtained from the different samples. The microstructural information inside the different nuclear core structural materials could be extracted successfully using these model based techniques of XRDLPA.

The irradiation of Zr-1Nb alloy samples with 116 MeV O$^{5+}$ ions caused significant changes in their microstructure. The XRD data obtained from these samples have been analysed successfully to extract the different microstructural parameters like domain size, microstrain and dislocation density. These microstructural parameters have been found to vary significantly with the variation of the irradiation doses. Anomaly was found in the values of these microstructural parameters at a specific dose of irradiation ($2 \times 10^{18}$ O$^{5+}$/m$^2$) which proved that the post irradiated microstructure of Zr-1Nb alloys are very much dose dependent in the low dose regime.
The microstructural information of different Zr-based alloys under their heavily deformed powdered condition have been extracted successfully using different model based techniques of XRDLPA. The methods were found to be complementary to each other. However among the different model based techniques of XRDLPA, the Modified Rietveld Technique is the most reliable technique as it is based on the whole pattern fitting method. The domain sizes were found to be smaller in case of the Zr-2.5Nb and Zirlo compared to that of Zircaloy-2. The presence of Nb enriched β-phase in α-Zr matrix of Zr-2.5Nb and Zirlo was found to be responsible in controlling the domain growth, resulting in a smaller domain size compared to that of Zircaloy-2.

Beside the successful application of the different model based techniques of XRDLPA to study the deformed and irradiated microstructure of different reactor core structural materials, the techniques also have been used successfully to study the microstructural evolution of the heavily deformed D9 powder samples during the early stages of annealing, both with time and temperature. In this study, high temperature XRDLPA has been used successfully for the first time to know about the evolution of the lowest length scale dislocation substructures at the early stages of annealing. Systematic increase in the domain size have been observed with increase in the temperature. The kinetics of the microstructural evolution at the early stages of annealing was found to be controlled by two distinct mechanisms, one is the rearrangement of dislocations and another is their annihilation. The growth of these lowest length scale substructures during the early stages of annealing have been modeled successfully from the light of these two mechanisms. The climb process was found to become active at higher temperature which finally governed the kinetics of both rearrangement and annihilation of dislocations.