On the three-dimensional atomic scale characterisation towards understanding the sequence of nano-scale B2 phase evolution in Ni-alloyed Fe-Mn-Al-C low-density steel

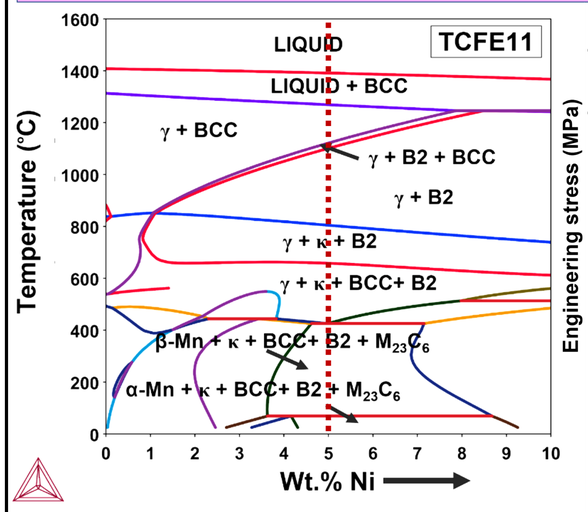
Reg code: EMSI2023-0320

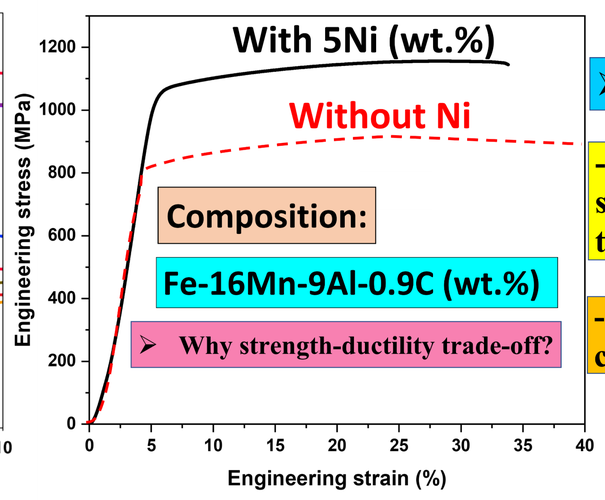
Mainak Saha, M. Sadhasivam, M.B. Ponnuchamy, K.G. Pradeep

Correlative Microscopy Laboratory, Department of Metallurgical and Materials Engineering, IIT Madras, Chennai - 600036

Introduction and objectives

- **Design of Ni-alloyed Fe-Mn-Al-C low-density steel**





Composition:

Fe-16Mn-9Al-0.9C (wt.%)

➢ **Why strength-ductility trade-off?**

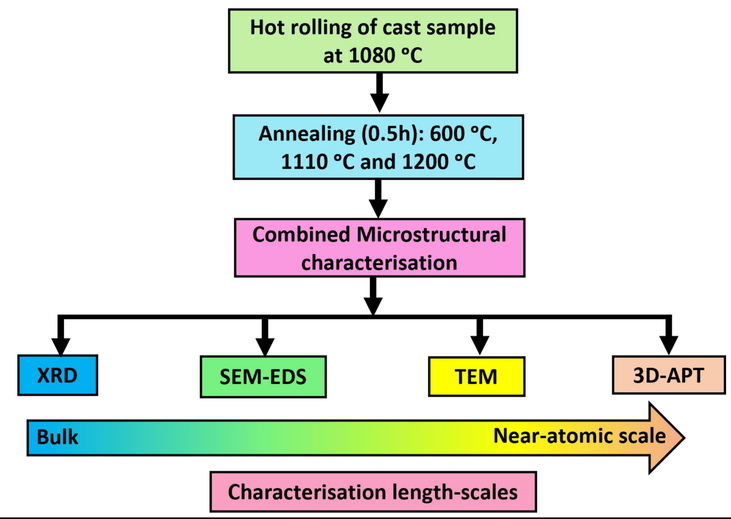
➢ **To investigate:**

- **Ni-induced B2 evolution sequence vs annealing temperature**

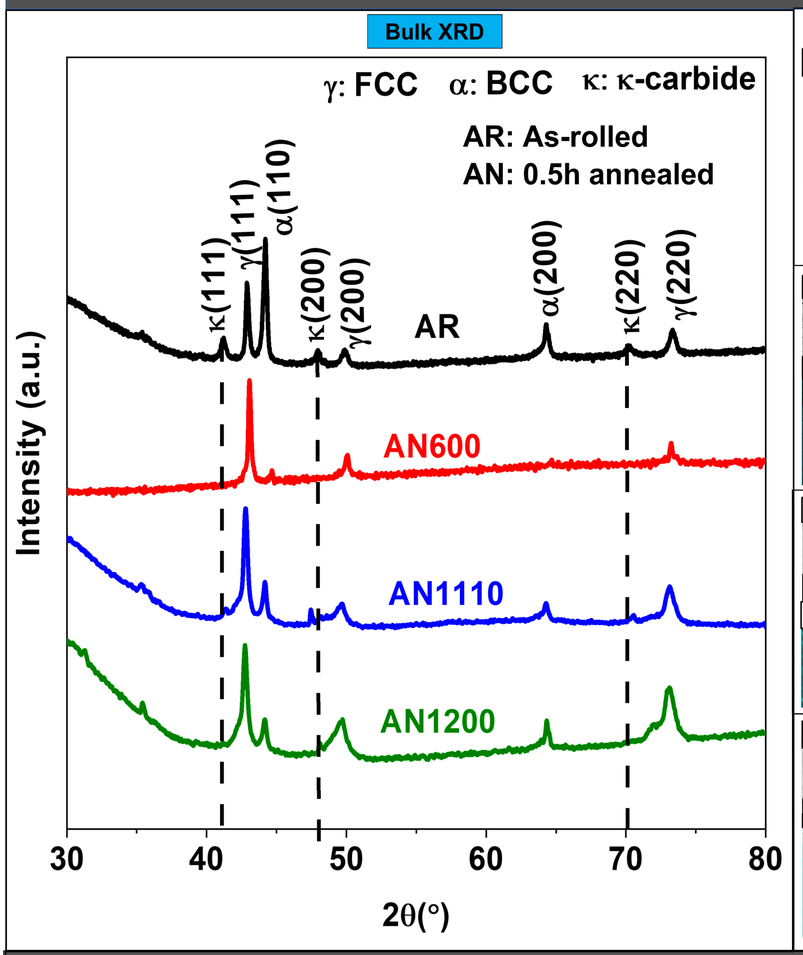
- **B2 stability and composition**

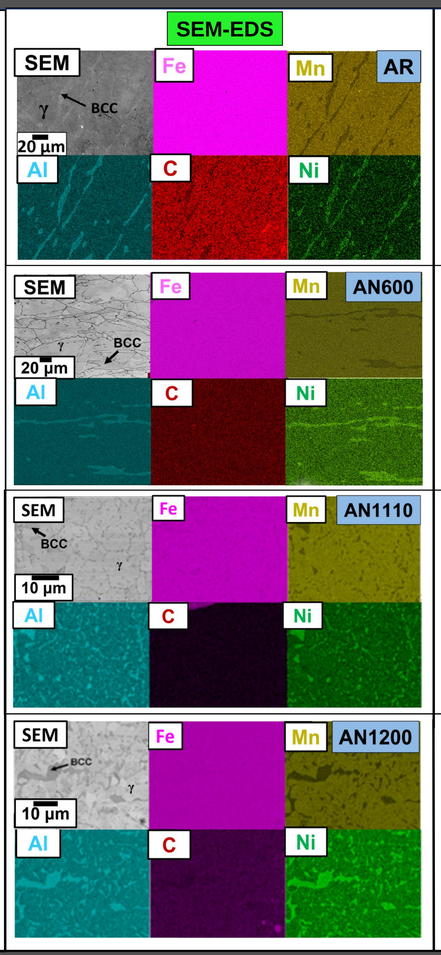
Methodology – Combined microscopy

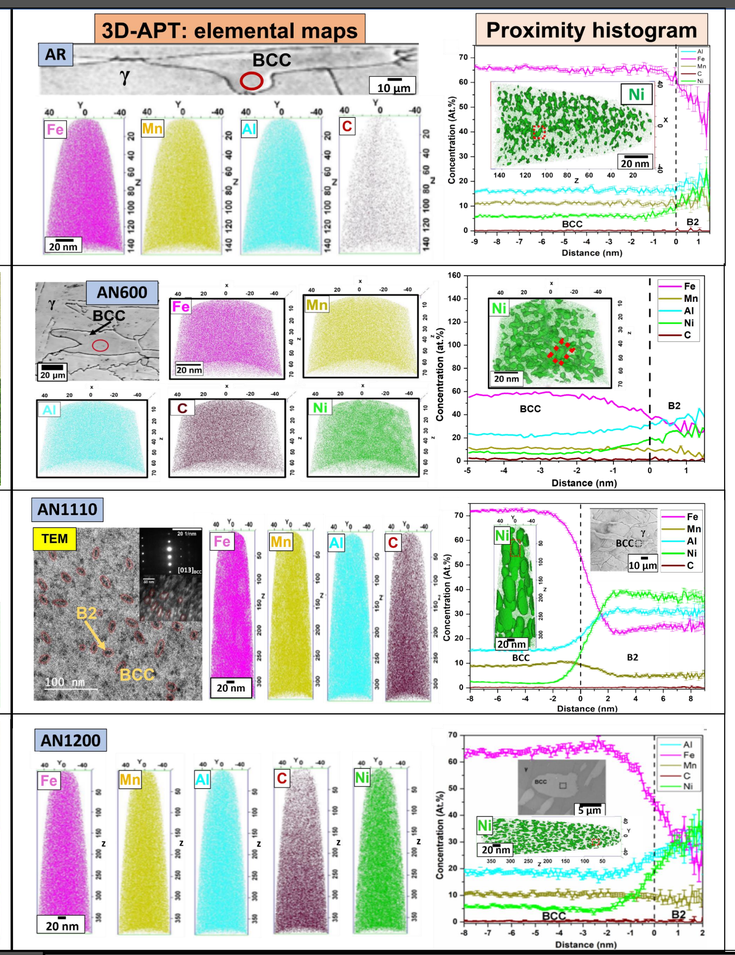
Fe-16Mn-9Al-0.9C-5Ni (wt.%)

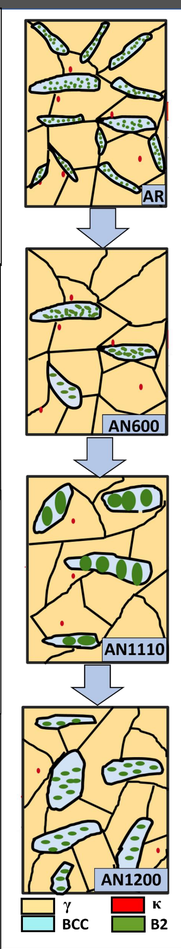


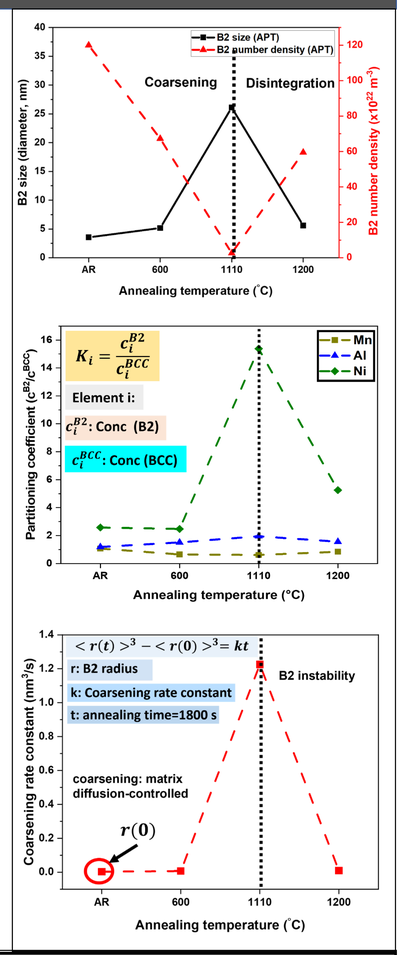
Results











Conclusions

1. **Near-atomic scale analysis using 3D-APT reveals the localized precipitation of nano-scale B2 precipitates within BCC phase.**
2. **B2 coarsening kinetics follows modified LSW model and hence is bulk diffusion controlled.**
3. **Partitioning of Ni between BCC and B2 phases controls the rate of B2 coarsening.**
4. **B2 disintegration at 1200 °C indicates its limited stability at elevated temperatures, as per thermodynamic estimates.**
5. **B2 localization within BCC phase in γ-based Ni-alloyed Fe-Mn-Al-C steel leads to enhanced strength-ductility trade-off.**

References

1. Saha, M., Ponnuchamy, M.B., Sadhasivam, M. *et al.* Revealing the Localization of NiAl-Type Nano-Scale B2 Precipitates Within the BCC Phase of Ni Alloyed Low-Density FeMnAlC Steel. *JOM* 74, 3181–3190 (2022).
2. Kim, S.H., Kim, H., and Kim, N.J. Brittle intermetallic compound makes ultrastrong low-density steel with large ductility. *Nature* 518 (7537), 77 (2015).
3. Park, G., Nam, C.H., Zargaran, A., and Kim, N.J. Effect of B2 morphology on the mechanical properties of B2-strengthened lightweight steels. *Scripta Materialia, 165,* 68-72 (2019).
4. Hwang, J.H., Trang, T.T.T., Lee, O. *et al.* Improvement of strength–ductility balance of B2-strengthened lightweight steel. *Acta Materialia, 191,* 1-12 (2020).
5. Sudbrack, C.K., Yoon, K.E., Noebe, R.D., *et al.* Temporal evolution of the nanostructure and phase compositions in a model Ni–Al–Cr alloy. *Acta materialia, 54*(12), 3199-3210 (2006).

Acknowledgements

We sincerely acknowledge Mr. K. Kumbhar (DMRL, Hyderabad) for providing the material, Mr. G. Vijayaragavan and Dr. D. Prabhu (ARCI, Chennai) for SEM analysis and are thankful to NFAPT, IIT Madras for 3D-APT analysis and to the Ministry of Education, Govt. of India for support with funds through Prime Minister Research Fellowship (PMRF).