Ultrafast synchrotron X-ray imaging and tomography of solidification microstructural evolution in external fields

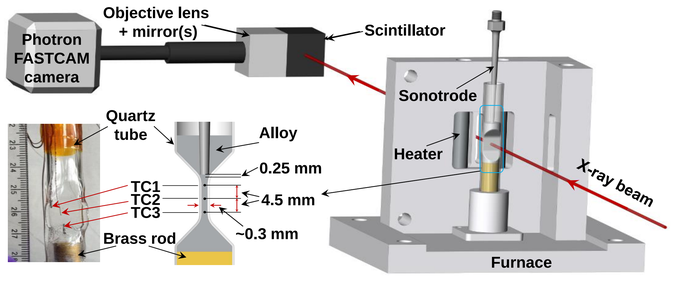
Contributing authors and the institutions

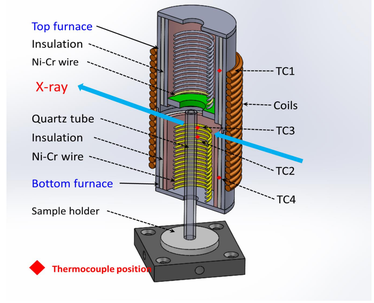
W. Du [1], B. Wang [1,2], T. L. Lee [1,3], J. C. Kong [1,4], B. Koe [1,5], D. Tan [1], W. Zhang [1], C. Wang [1], Y. Zhao [1] T. Manuwong [1], A. Sumayli [1], T. Connolley [5], A. J. Bodey [5], J. Fife [6], K. Fezzaa [7], A. Rack [8], J. Mi [1*]

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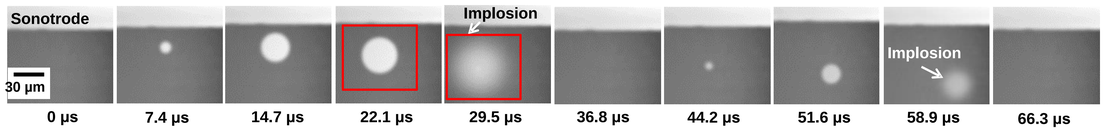
The apparatus used for the ultrafast synchrotron X-ray imaging & tomography experiments



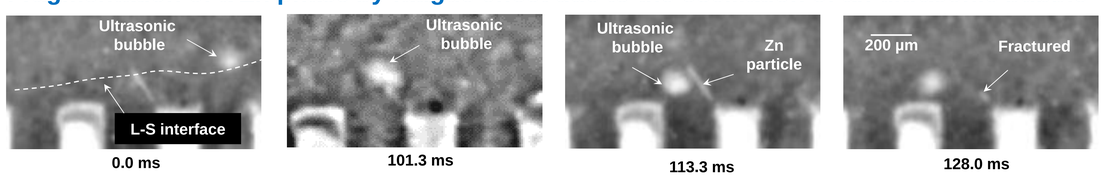


Ultrasonic bubble implosion, oscillation, acoustic flow & interactions with solidifying metal

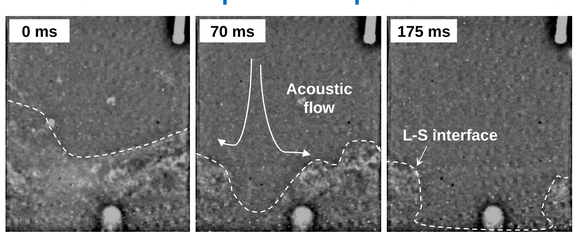
Bubble oscillation & implosion in liquid Bi-8%Zn alloy[1] (135,780 fps @ Sector 32-ID-B of APS



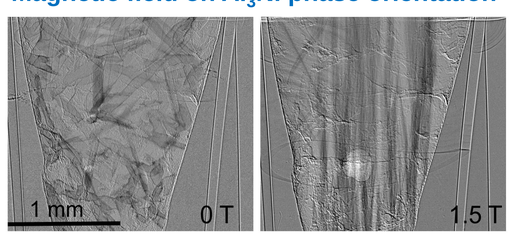
Fragmentation of a Zn phase by fatigue effect due to the oscillation of an ultrasonic bubble[1]



Ultrasonic flow impacts on liquid-solid interface[1]



Magnetic field on Al_3Ni phase orientation[3]

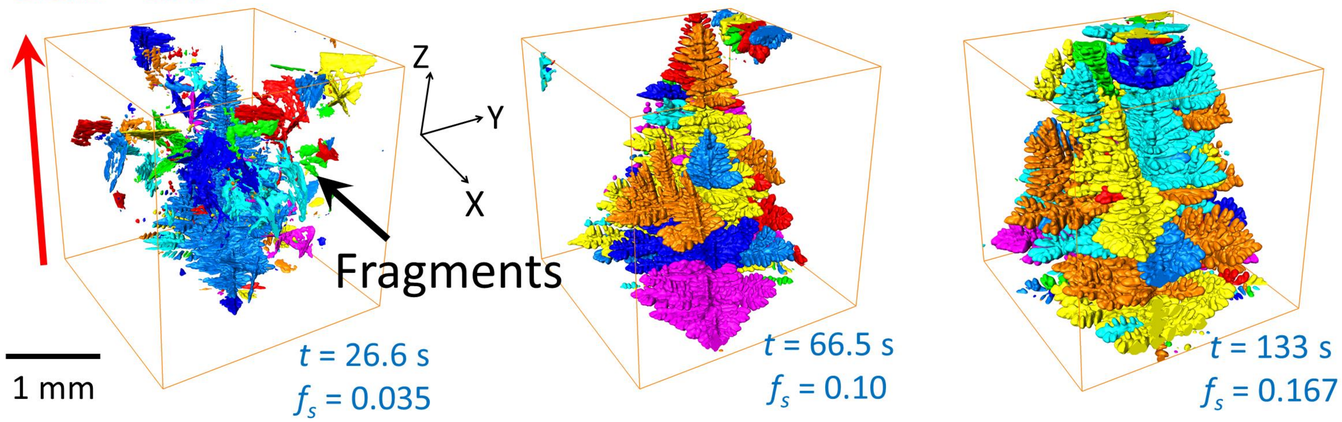


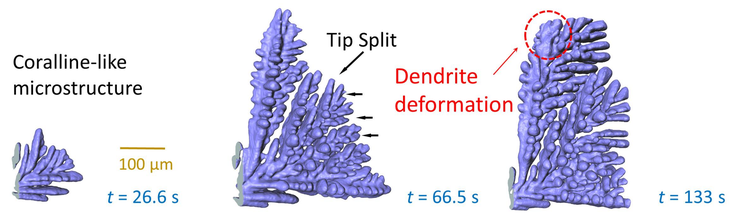
The highlight of our real-time and in-situ synchrotron X-ray research

We present a number of highlight cases in our recent projects funded by the Royal Society and the EPSRC. Our focus is to study in real-time and in-situ the dynamic evolution of solidification microstructures under ultrasonic waves [1, 2] and pulse magnetic fields [3]. We have used the speciality beamlines from the Diamond Light Source, Advanced Photon Source, European Synchrotron Radiation Facility, and Swiss Light Source for our studies and worked closely with the relevant beamline scientists when did the work. We also used the high performance supercomputer, Viper, housed at Hull University to process and analyze the many hundreds of TB data acquired from the experiments. Our research demonstrates that real-time and in-situ visualisation of the dynamic microstructural evolution is absolutely essential for elucidating some of the ambiguities or missing links in the classical theories concerning the solidification processes of metal alloys. Real-time evidence shows that the shock wave created at ultrasonic bubble implosion and the pinch stresses produced by the electromagnetic pulse are very effective in causing the fragmentation of dendrites or intermetallic phases, promoting greatly the grain multiplication effect, and therefore enhancing grain refinement.

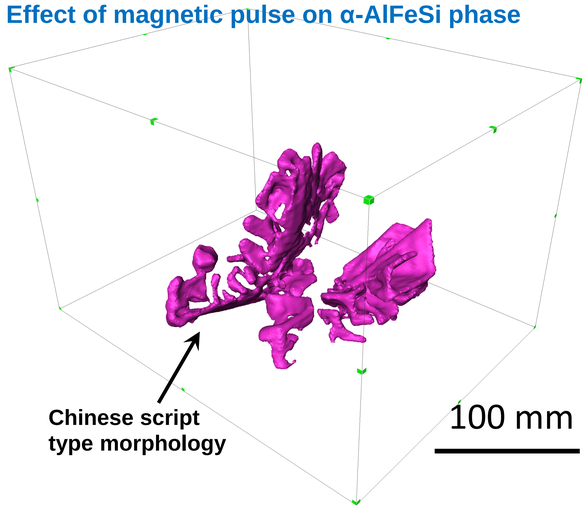
3D and 4D synchrotron X-ray tomography of solidification structure in a pulse magnetic field

Fragmentation of Al dendrites by magnetic pulse and the subsequent growth[3]

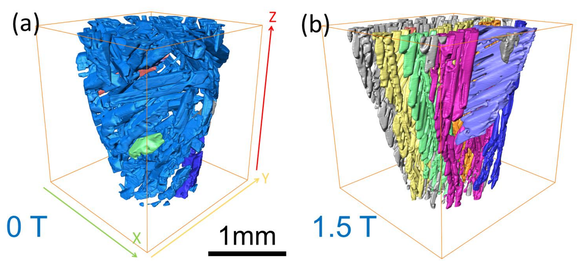




Effect of magnetic pulse on α-AlFeSi phase



Effect of magnetic field on Al_3Ni phases & orientation[3]



Acknowledgements & the selected relevant publications

We would like to acknowledge the relevant grants awarded by the Royal Society and EPSRC (EP/L019965/1, EP/L019884/1, EP/L019825/1), and the X-ray beam times given by DLS, SLS, APS, and ESRF. The PhD Studentships that have contributed to the research are also gratefully acknowledged, including Hull University bursary to Du, Lee, and Khong, Hull-DLS to Koe, Hull-CSC to Tan and Zhang, Thai and Saudi Government award to Manuwong and Sumayli respectively.

[1] B. Wang & **J. Mi** (2018) *Ultrafast synchrotron X-ray imaging studies of microstructure fragmentation in solidification under ultrasound*, **Acta Materialia**, Vol.144, 505-515
[2] F. Wang & **J. Mi** (2017) *A synchrotron X-radiography study of the fragmentation and refinement of primary intermetallic particles in an Al-35 Cu alloy induced by ultrasonic melt processing*, **Acta Materialia**, Vol.141, 142-153
[3] W. Du & **J. Mi** (2018) *Real-time synchrotron X-ray imaging and tomography studies of the dynamic evolution of intermetallic in solidification under pulse electromagnetic fields*, **Acta Materialia**, submitted in June 2018