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Revealing the Complex Metal Carbide Morphologies of Cast Ni Superalloy by Synchrotron X-ray Microtomography

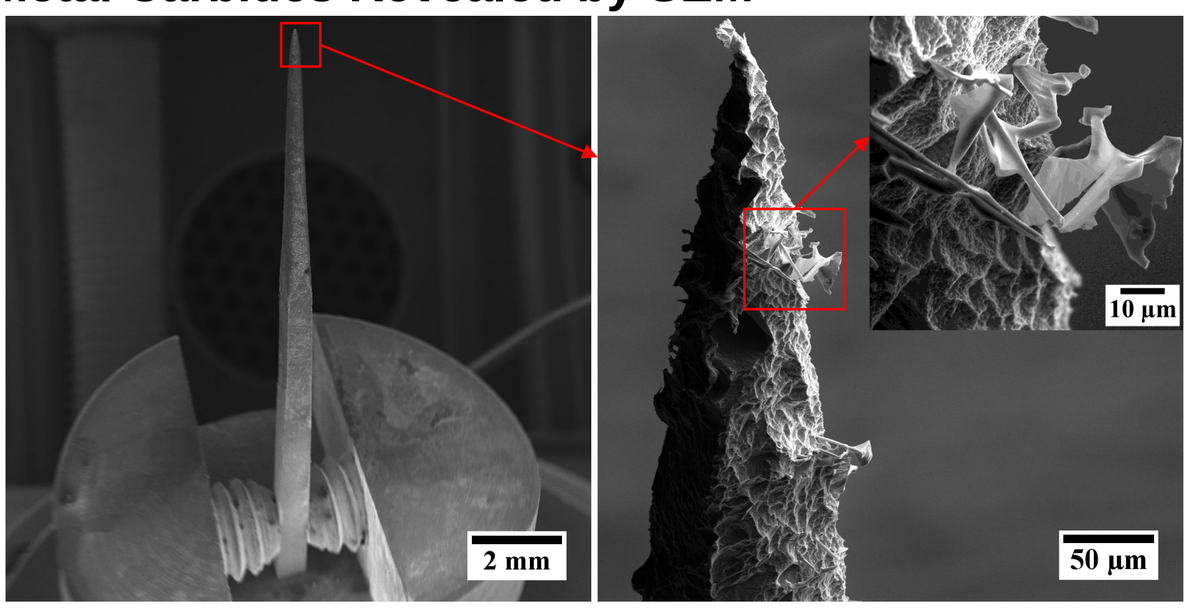
B. Koe[1, 2], J.C. Khong[1, 3], N. Green[4], A.J. Bodey[2], Z. Zhang[5], J. Gebelin[5], C. Rau[2], J. Mi[1]

[1] School of Engineering & Computer Science, University of Hull, Hull HU6 7RX, UK
[2] Diamond Light Source, Harwell Science and Innovation Campus, Didcot OX11 0DE, UK
[3] Department of Medical Physics & Biomedical Engineering, University College London, London WC1E 6BT, UK
[4] High Temperature Research Centre, University of Birmingham, Birmingham B15 2TT, UK
[5] Doncasters Group Technical Centre, George Baylis Rd, Droitwich WR9 9RB, UK

Introduction

Nickel-based superalloys are widely used in industry for high temperature applications because of their exceptional high-temperature strength, toughness, creep properties, and resistance to degradation in corrosive and oxidising environments [1, 2]. Metal carbides are the common strengthening phases in polycrystalline-type Ni superalloys. They are formed when carbons (up to 0.2wt% in the alloys) react with Ti, Ta, Hf, etc. [2] in the melt during solidification and any heat treatment afterwards. Although the structures and morphologies of these metal carbides were widely studied in the past by using electron microscopy, the true 3D structure and morphology have not been fully characterised and quantified.

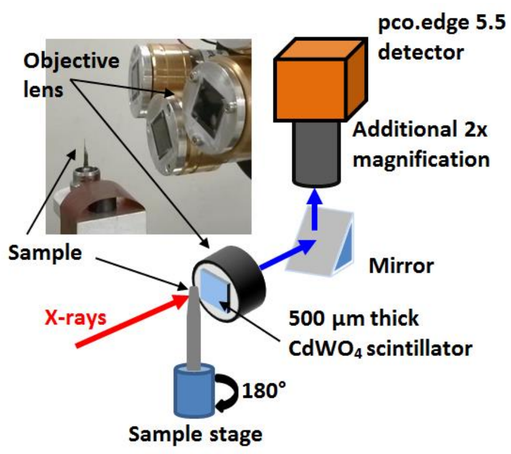
Metal Carbides Revealed by SEM



SEM SE micrographs of a deeply-etched needle-shaped sample exposing the metal carbides

Synchrotron X-ray Microtomography Experiment

Synchrotron X-ray microtomography experiments were conducted at the Diamond-Manchester Imaging Beamline (I13-2) of Diamond Light Source, UK. The key experimental parameters used are listed below.



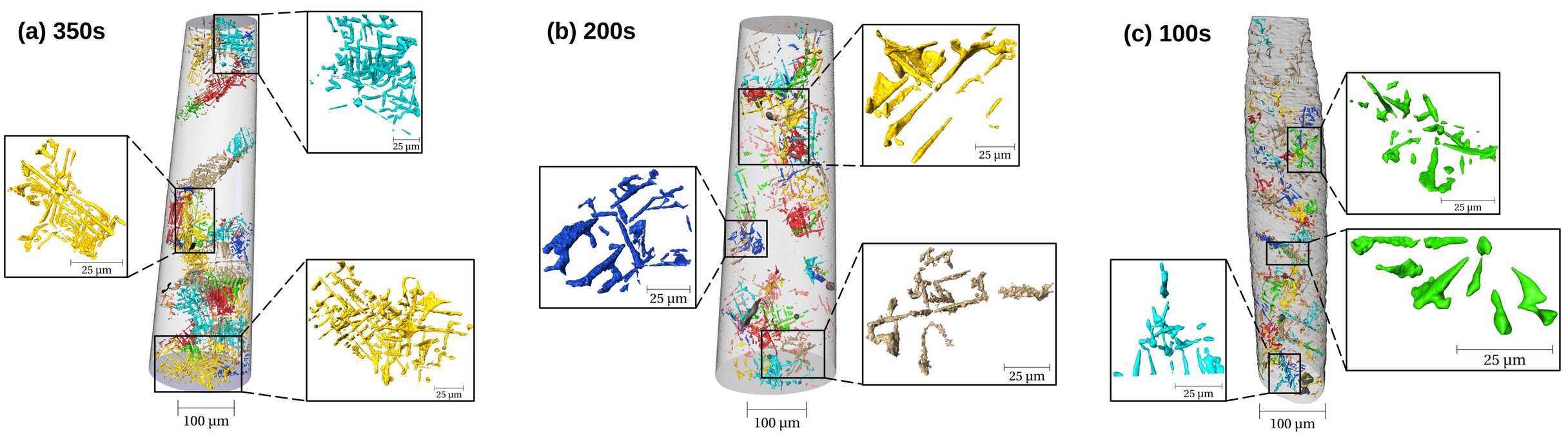
Experimental Parameters	
X-ray energy (keV)	18.5
Sample-to-detector distance (mm)	10
Scintillator	500µm $CdWO_4$
Total optical magnification	20×
Detector	pco.edge 5.5 (PCO AG, Germany)
Effective pixel size (µm)	0.33
Pixel array	2560 × 2160
Number of projections (180°)	2001
Exposure time (s)	1.9

The experimental setup and parameters used at beamline I13-2

Data Processing

Data processing was performed by using Viper [3], the University of Hull's newly established high performance computing cluster which is composed of 5,500 processing cores. It was used to process and visualise the graphics-intensive tomography datasets without any downsampling, hence high fidelity datasets were maintained. Avizo v9.2.0 (VSG, France) was used to perform the segmentation. Each individual metal carbide clusters were subsequently rendered into different colours for a better visualisation.

3D Structures, Morphologies and Networks of the Metal Carbides in Different Solidification Time



3D colour rendering illustrating the complex networks of metal carbides and the typical metal carbide clusters for the IN713LC Ni superalloy sample with the solidification time of (a) 350s, (b) 200s, and (c) 100s, respectively

Conclusion

The true complex 3D networks, structures, and morphologies of metal carbides under different solidification times were studied and revealed by using synchrotron X-ray microtomography, complemented by SEM observations. The solidification time of the sample was found to have very strong influences on the resulting structures and morphologies in terms of the size, length, tortuosity, sphericity and the interconnectivity of the metal carbide clusters.

Acknowledgements

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References

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