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New hierarchy of solute architecture breaks strength ceiling in a nanocrystalline aluminium alloy

Introduction

Our 7075 Al alloy prepared through high-pressure torsion (HPT) breaks the strength ceiling for wrought Al alloy property space (Fig. 1).

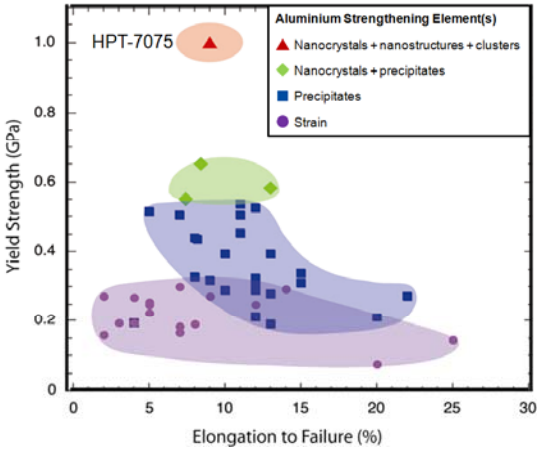


Figure 1 – Record strength exhibited by HPT-7075 Al alloy

Characterisation

Conventional and high resolution transmission electron microscopy reveals an average grain size of **26 nm** (Figs. 2a + b). This nanocrystalline grain size creates extremely challenging imaging and analytical conditions.

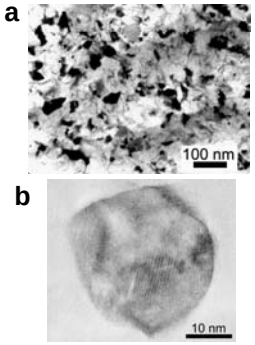


Figure 2a, b – 26 nm average grain size

We have specifically developed **new techniques** in atom probe tomography to characterise the structure, chemistry and texture with atomic resolution (Figs. 3-4).

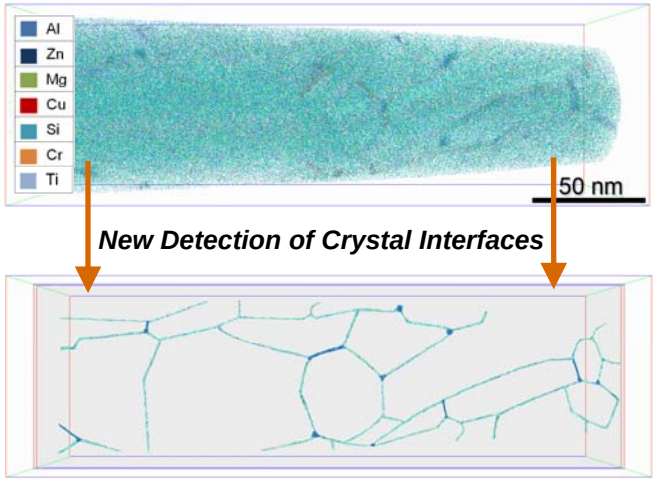


Figure 3 – Grain-boundary detection (5 nm slice)

New solute nanostructures in 7075 Al alloy

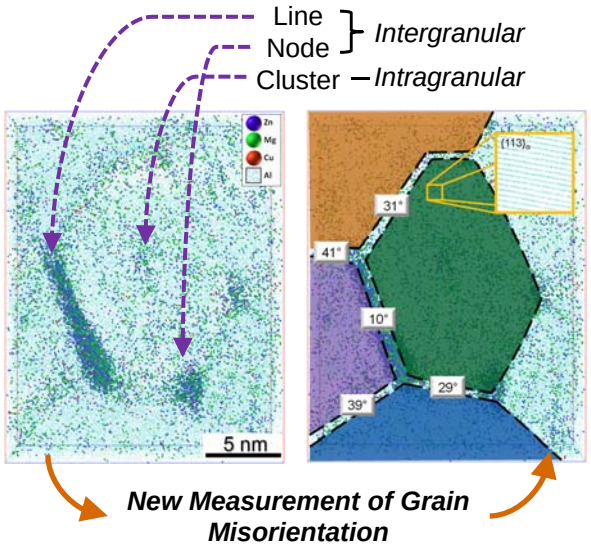


Figure 4 – Nanocrystalline structures and texture

Results

Novel line, node, and cluster nanostructures represent a **new hierarchy of solute architecture**. Figs. 5-8 describe them quantitatively using the core linkage clustering algorithm; 3.0 p. d., 0.6 d-link & enveloping.

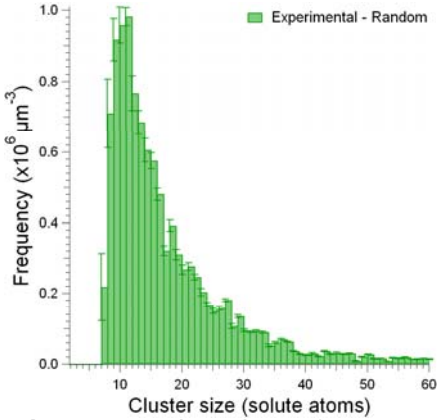
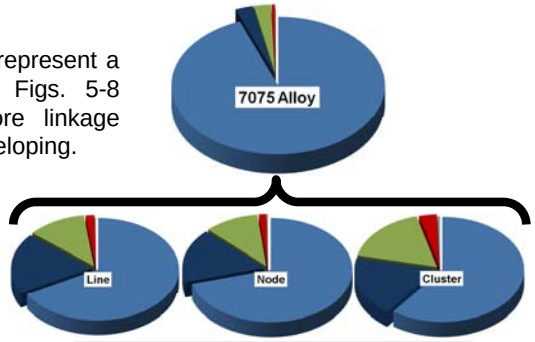


Figure 5 – Solute cluster frequency

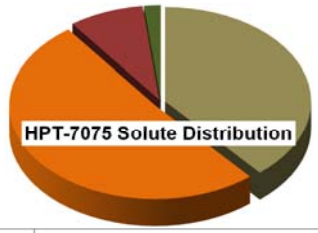


At. %	7075 Alloy	Line	Node	Cluster
Al	93.6	66.55	70.19	59.68
Zn	2.55	19.11	16.80	18.07
Mg	2.89	11.69	10.77	18.16
Cu	0.61	1.73	1.41	3.63
Si	0.11	0.11	0.15	0.31
Cr	0.10	0.18	0.16	0.17
Ti	0.01	0.46	0.35	0.08

Figure 6 – Nanostructure compositions

Conclusion

Novel techniques in atom probe tomography reveal a new hierarchy of solute architecture around and within the 7075 Al nanocrystalline grains. Only ~36% of the solute remains in the matrix. We propose the record strength is a result of restricted dislocation generation and mobility, cluster strengthening, and plastically mediated grain-boundary migration and slide.



At. %	Fraction of total solute in structures
Matrix	38.78
Line	8.31
Node	1.84
Cluster	51.07

Figure 7 – Solute distribution in alloy

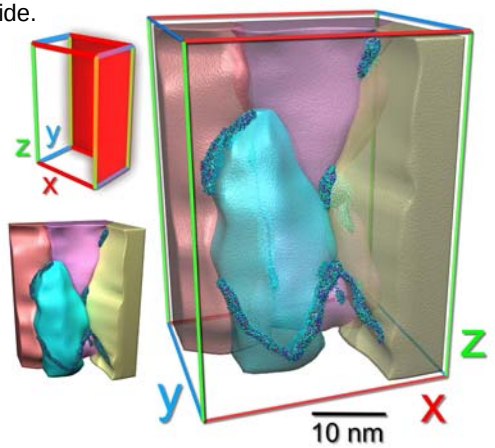


Figure 8 – Nanostructural architecture