

SUPPLEMENTARY Materials for

Utilizing local phase transformation strengthening for nickel-based superalloys

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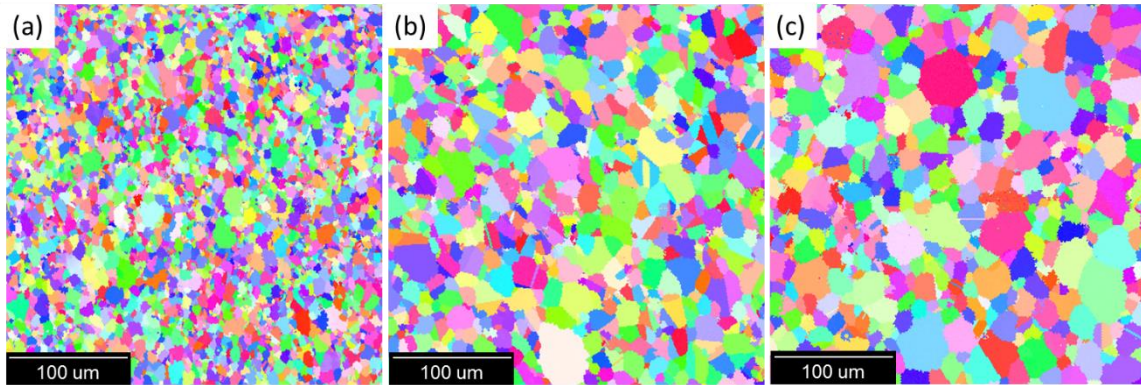
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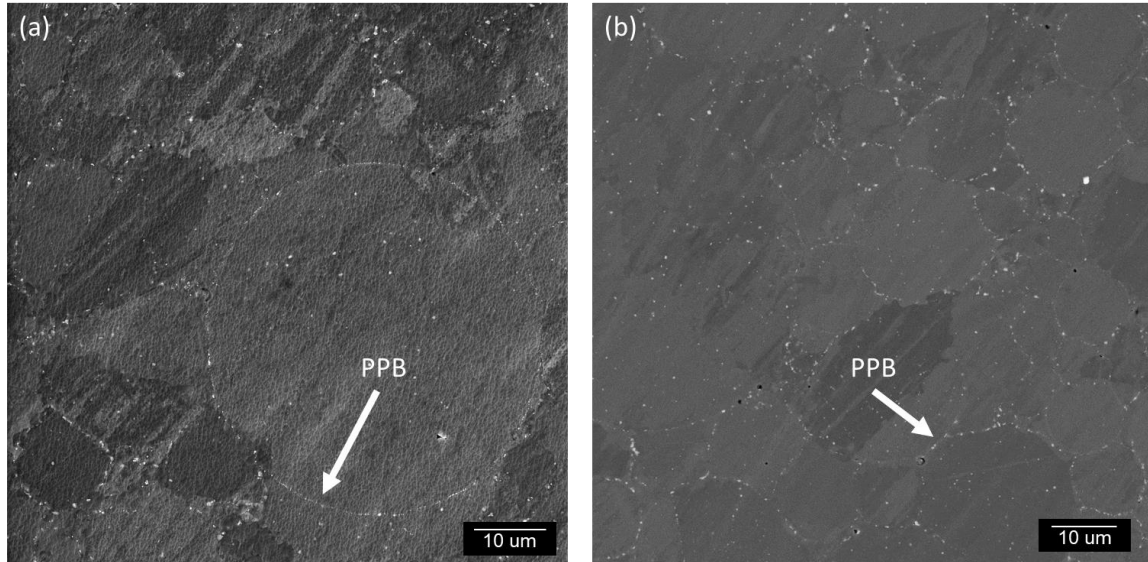
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Supplementary Table 1: Measured TSNA-1 compositions in weight percent using ICP and LECO from consolidated billet.

Element	TSNA-1 - Top	TSNA-1 - Bottom	Average
Al	2.9	2.89	2.895
Co	18.93	18.99	18.96
Cr	10.91	10.92	10.915
Hf	0.38	0.36	0.37
Mo	2.62	2.6	2.61
Nb	1.47	1.45	1.46
Ni	50.46	50.55	50.505
Ta	4.83	4.8	4.815
Ti	2.98	2.96	2.97
W	4.22	4.19	4.205
B (ppm)	230	260	245
Ca (ppm)	1	1	1
Fe (ppm)	150	160	155
Na (ppm)	12	12	12
P (ppm)	not detected	not detected	N/A
Si (ppm)	430	460	445
Zr (ppm)	460	500	480
C	0.0522	0.0513	0.05175
S	0.0006	0.00045	0.000525
N	0.0237	0.00605	0.014875
O	0.0271	0.0255	0.0263



Supplementary Fig. 1: EBSD grain structure maps of TSNA-1 after varying solution heat treatments. EBSD maps of TSNA- 1 after solution heat treatment at (a) 1170 °C/1 h (b) 1180 °C/1 h and (c) 1190 °C/1 h. Only the solution heat treatment at 1190 °C successfully removed all the bulk η phase.



Supplementary Fig. 2: Micrographs of TSNA-1 post heat treatment. (a) Secondary and (b) back-scatter detector images of the microstructure of TSNA-1 after heat treatments. Prior particle boundaries can be observed in both images.

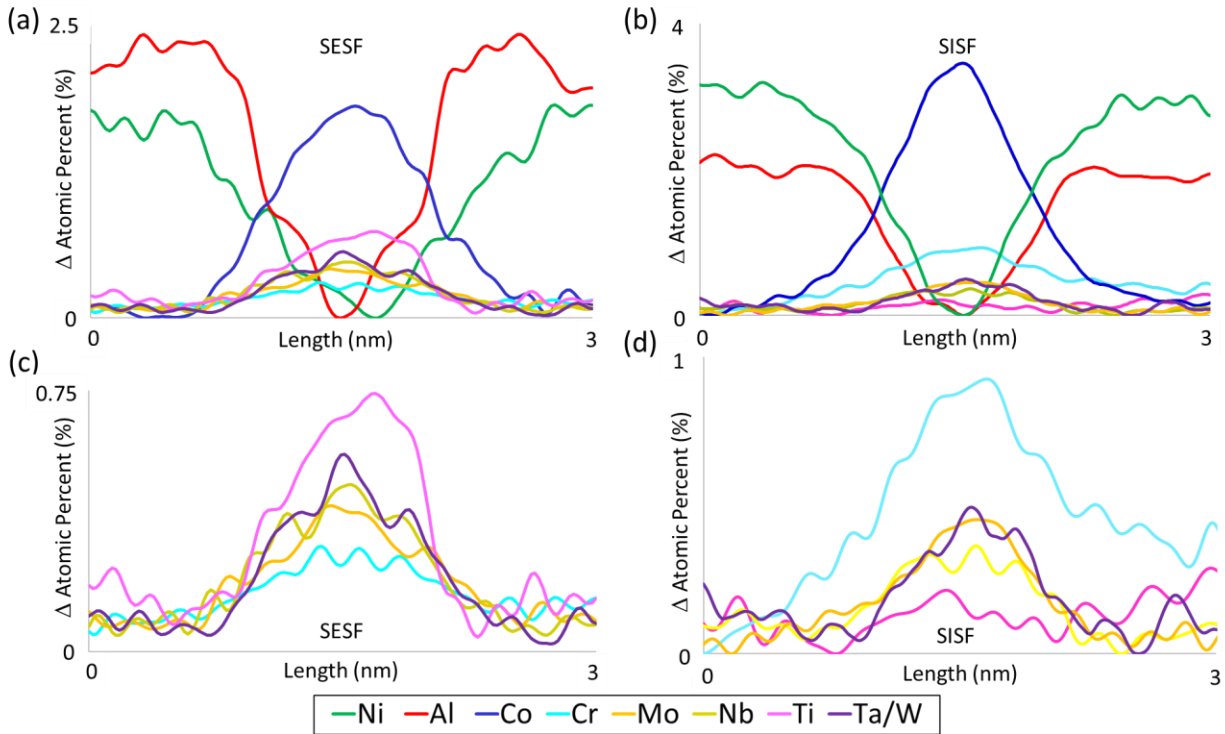
Supplementary Table 2: Tensile properties of ME3, LSHR, and TSNA-1 at (a) room temperature and (b) 760 °C

a. Tensile tests at room temperature.

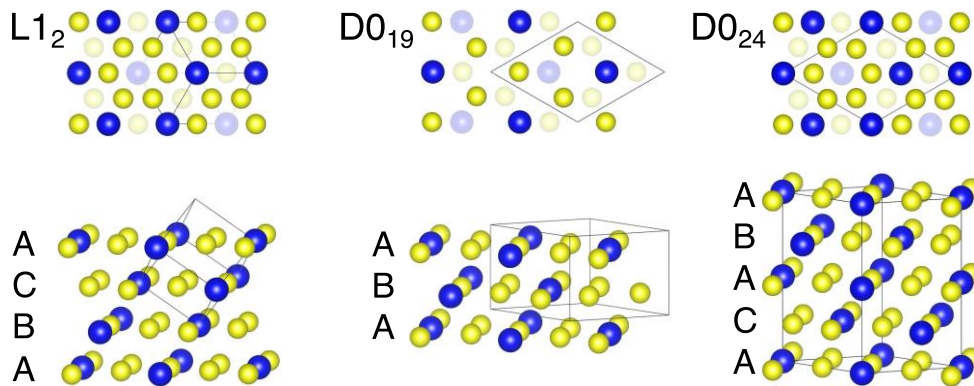
Alloy	0.2% Yield Strength (MPa)	Ultimate Strength (MPa)	Elongation (%)	Reduction of Area (%)
ME3 - CG	1096	1579	16	18
LSHR - CG	1110	1565	16	19
LSHR - FG	1123	1627	20	35
TSNA-1 - FG	1151	1696	16	15

b. Tensile stress relaxation tests at 760 °C.

Alloy	0.2 % Yield Strength (MPa)	Initial Stress at 1 % Strain (MPa)	0.01 h Relaxed Stress at 1 % Strain (MPa)	1 h Relaxed Stress at 1% Strain (MPa)	100 h Relaxed Stress at 1 % Strain (MPa)
LSHR - FG	982	1003	848	604	369
LSHR - FG	981	1009	860	616	380
TSNA-1 - FG	1102	1061	924	676	424



Supplementary Fig. 3: Segregation of elements to faults. Integrated line scans of all elements across the (a) SESF in TSNA-1 and (b) SISF in TSNA-1. Zoomed in graphs of the same integrated line scans for Cr, Ta/W, Nb, Mo, and Ti across the (c) SESF and (d) SISF in TSNA-1.



Supplementary Fig. 4: Atomic arrangements in L1₂, D0₁₉, and D0₂₄ structures. The upper row shows the (111) plane projection of the L1₂ cubic crystal structure and hexagonal 001 projections of D0₁₉ and D0₂₄ structures, with shaded atoms in the lower half of the unit cell. The lower row shows the stacking of triangular atomic layers in each structure (distorted 110 cubic or hexagonal view).

Supplementary Table 3: Composition of superalloys. Average alloy compositions in weight percent. Ni is balanced (Bal)

Alloy	Cr	Co	Al	Ti	Nb	Mo	Ta	W	Hf	B	C	Ni
LSHR	12.5	20.4	3.5	3.5	1.5	2.7	1.5	4.3	0	0.03	0.045	Bal
ME3	13	21	3.5	3.4	0.8	3.7	2.4	2.1	0	0.02	0.05	Bal
CMSX-4	6.5	9.6	5.6	1.0	0	0.6	6.5	6.4	0	0	0	Bal
TSNA-1	10.9	19	2.9	3	1.4	2.6	4.8	4.2	0.37	0.025	0.05	Bal