

Supplemental Materials

Table. S1 Parameters for example calculation of elastic modulus for the 28Ni alloy at 5K/sec

Phase	Volume fraction (%)	Young's modulus, E (GPa)	Bulk modulus, K (GPa)	Shear modulus, G (GPa)	Poisson's ratio, ν	Aspect ratio, ξ	CTE ($\times 10^{-6}/K$)
α -Al	36.57	79.95	83.28	29.83	0.34 [40]	-	24.6
Primary Si, Si _p	8.46	160.91	111.74	63.85	0.26 [41]	1.37	2.44
Eutectic Si, Si _e	18.97	111.46	77.40	44.23	0.26 [41]	1.63	2.44
Al ₃ Ni	17.68	158.62	80.11	67.79	0.17 [42]	2.61 (4-16Ni) 1.72 (20-22Ni) 1.92 (24-28Ni)	19.52
Al ₆ Ni ₃ Si	9.64	190.14	121.88	76.67	0.24	1.72 (20-22Ni) 1.92 (24-28Ni)	7.39
Al ₃ Ni ₂	8.68	235.16	186.63	91.15	0.29 [42]	1.92	7.21

Table. S2 Calculated values of the parameters used for the models of the 28Ni alloy at 5 K/s.

Model	Parameter		Value
Hashin-Shtrinkman	K_a , Bound of effective bulk modulus (for Upper)		95.18
	G_a , Bound of effective shear modulus (for Upper)		47.93
	K_a , Bound of effective bulk modulus (for Lower)		95.43
	G_a , Bound of effective shear modulus (for Lower)		46.98
Mori-Tanaka	K_a , Effective bulk modulus		91.83
	G_a , Effective shear modulus		45.20
Halpin-Tsai	η , Elastic modulus contrast parameter	Primary Si	0.31
		Eutectic Si	0.11
		Al_3Ni	0.19
		Al_6Ni_3Si	0.28
		Al_3Ni_2	0.29

The elastic modulus (E) was calculated based on various composite models using the parameters listed in Tables S1 and S2), as follows:

ROM (Voigt, upper): $E = 0.365 \times 79.95 + 0.085 \times 160.91 + 0.19 \times 111.46 + 0.177 \times 158.62 + 0.096 \times 190.14 + 0.087 \times 235.16 \approx 130.83$ GPa

ROM (Reuss, lower): $E = 1 / [0.377 \times 1 / 79.95 + 0.085 \times 1 / 160.91 + 0.147 \times 1 / 111.46 + 0.077 \times 1 / 158.62 + 0.196 \times 1 / 190.14 + 0.119 \times 1 / 235.16] \approx 116.79$ GPa

Hashin-Shtrikman (Upper): $E = 9 \times 95.18 \times 47.93 / [3 \times 95.18 + 47.93] \approx 123.12$ GPa

Hashin-Shtrikman (Lower): $E = 9 \times 95.43 \times 46.98 / [3 \times 95.43 + 46.98] \approx 121.07$ GPa

Mori-Tanaka: $E = 9 \times 91.83 \times 45.20 / [3 \times 91.83 + 45.20] \approx 116.51$ GPa

The Halpin-Tsai calculation is omitted here, as its multiphase extension involves a more complex procedure. The η values of each phase used in the Halpin-Tsai calculation are listed in Table S2.

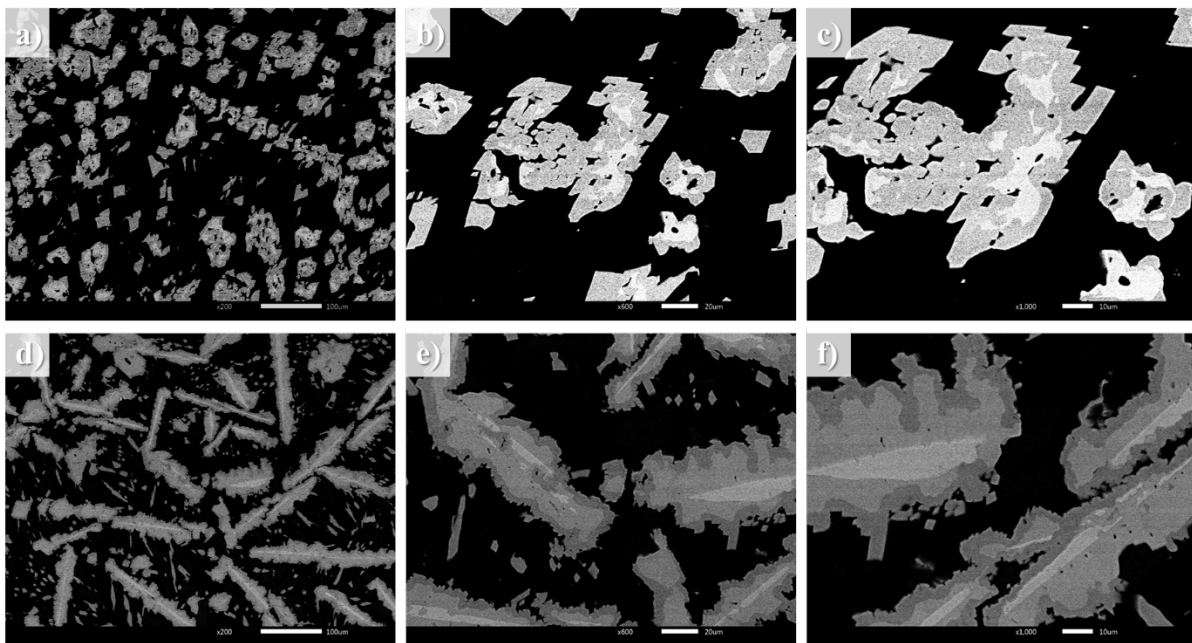


Fig. S1. SEM/BSE images at various magnifications showing the “cloud-like” and “needle-like” morphologies of Ni-rich intermetallic phases in (a–c) 20Ni and (d–f) 24Ni alloys.

Table S3. Variation of elastic modulus, density, and specific modulus with Ni content in Al-18Si-xNi

Properties		Al-18Si-xNi alloys								
		4Ni	8Ni	12Ni	16Ni	20Ni	22Ni	24Ni	26Ni	28Ni
Elastic modulus (<i>E</i> , GPa)	5 K/sec	86.21	90.11	97.92	103.63	109.81	114.68	118.57	119.35	123.51
	25 K/sec	86.04	91.72	97.45	100.82	111.69	115.82	117.37	117.67	118.74
Density of alloy (g/cm ³)	5 K/sec	2.71	2.77	2.88	2.97	3.07	3.17	3.20	3.19	3.22
	25 K/sec	2.71	2.79	2.87	2.94	3.10	3.19	3.19	3.21	3.23
Specific modulus (10 ⁶ m ³ /s ²)	5 K/sec	31.80	32.46	33.95	34.85	35.74	36.76	36.99	37.35	38.24
	25 K/sec	31.73	32.84	33.97	34.36	35.98	36.25	36.87	36.63	36.75

Table S4. Measured and calculated densities of Al–18Si–xNi alloys solidified at 5 K/s.

Properties		Al-18Si-xNi alloys (5K/sec)								
		4Ni	8Ni	12Ni	16Ni	20Ni	22Ni	24Ni	26Ni	28Ni
Density of alloy (g/cm ³)	Measure	2.71	2.77	2.88	2.97	3.07	3.17	3.20	3.19	3.22
	Calculate	2.68	2.72	2.79	2.82	2.93	3.01	3.11	3.17	3.21
Porosity (%)		1.10	1.81	3.12	5.05	4.56	5.05	2.81	0.63	0.31