Supplementary Material for:

Emerging opportunities in manufacturing bulk soft magnetic alloys for energy applications – A review

Andrew B. Kustas*, Donald F. Susan, Todd Monson

Material, Physical, and Chemical Sciences Center, Sandia National Laboratories, Albuquerque, NM, USA, 87185

* - corresponding author email: akustas@sandia.gov

Table S1 – Summary of high-pressure torsion studies on soft magnetic alloys.

Ref.	WP	initial grain size (μm)	HPT strain; temp.	Grain size after deformation (micron)	Magnetic Characterization Method	Full-field induction: Initial; post-HPT	Coercivity: Initial; post-HPT	Hardness
Vorhauer, 2006	Fe-Co based	10	32; 293-723 K	0.05-0.27	SQUID	2.10; 2.7-2.9 T	56; 517-2149 A/m	N/A
Scheriau, 2008	Fe-Si, Fe-Co (P800), FeNi	20-50	32; 77-293 K	0.04-0.15	SQUID	0.5-1.6; 0.0.4-1.6 T	12-159; 72-1592 A/m	N/A
Scheriau, 2010	Fe, Ni, Fe-17Co, Fe-3Si, Fe-6.5Si	20	42; 77 K-0.4 T_{hom}	0.072-0.270	B-H Tracer	~2.0 T; 1.9-2.0 T	Fe: 150; 1035-1870 A/m	Fe: ~225 to 525 HV
							Ni: 1806; 1856-3816 A/m	Ni: N/A
							Fe17Co: 349; 1403-2492 A/m	Fe17Co: 525 to 600 HV
							Fe3Si: 47; 385-842 A/m	Fe3Si: 450 to 600 HV
							Fe6.5Si: 60; 386 to 465 A/m	Fe6.5Si: 625 to 750 HV
Glezer, 2009	$B_{10}Co_{15}Fe_{29}Ni_{44}Si_2$, $B_9Cu_1Fe_{74}Nb_3Si_{13}$, $B_{17.5}Fe_{57.5}Ni_{25}$,	N/A	8 rotations; Ambient and 77 K	N/A	VSM*	N/A; 1.4-2.3 T	N/A; 5 to 45 A/m	N/A

	$B_{17.5}Fe_{49.5}Ni_{33}$ and $B_{15}Fe_{70}Cr_{15}$							
Glezer, 2016	Equiatomic FeNi;	50	4 rotations; Ambient	0.055-0.06	VSM*	108; 112-120 Gcm^3/g	80; 119-557 A/m	N/A
Glezer, 2018; Glezer, 2018	Fe-24 at.% Al	N/A	5-9; Ambient	0.15-0.3	VSM*	160; 177 Am^2/kg	N/A	N/A
Glezer, 2019; Glezer, 2021	Fe-Co-V	100-150	5-9; Ambient and 77 K	0.05-0.25	VSM*	230-240; 220-240 Am^2/kg	40-70; 70-100 A/m	550 to 650 HV
Abrosimova, 2013	FeSiB	N/A	5 rotations; ambient	Amorphous + 0.006 crystallite	VSM*	1.2; 1.25-1.75 T	N/A	N/A
Aronin, 2010	FeSiB	N/A	4.5 strain; ambient	Amorphous + 0.005-0.015 crystallize	VSM*	180; 200 Am^2/kg	~64-80 A/m	N/A
Hosokawa, 2014	Fe, FeCo, $FeNi_3$	N/A	10 rotations; ambient	0.15-0.39	VSM*	Fe: 239-249 Am^2/kg	~1000 A/m	~ 70-400 HV
						FeCo: 249-261 Am^2/kg	$10^3 < H_c < 10^4$ A/m	~ 300-550 HV
						$FeNi_3$: ~120 Am^2/kg	$10^2 < H_c < 10^3$ A/m	~ 150-450 HV
Stückler, 2021	Fe-Co-Cu	N/A	50-150 rotations, ambient-500 °C	0.066 (single alloy)	SQUID	~145-175 Am^2/kg	< 800, up to 3183 A/m	~220-780 HV

*VSM: vibrating-sample magnetometer

Table S2 – Summary of metal injection molding studies.

Ref.	WP	Sintering Temp.	Relative Density	WP Final grain size (micron)	Magnetic Characterization Method	Full-field induction	Coercivity	Hardness/ Yield Strength	Ductility
Barrow, 1988	Fe-2%Ni, Fe-50%Ni, Fe-3%Si, Fe-6%Si	All 2400 F, except one Fe-3%Si at 2250 F	Fe-2%Ni: 97% Fe-50%Ni: 94% Fe-3%Si: 98% Fe-6%Si: 99%	N/A	N/A	Fe-2%Ni: 1.5 Fe-50%Ni: 1.3 Fe-3%Si: 1.4-1.5 Fe-6%Si: 1.3 and 1.3 T	Fe-2%Ni: 82 Fe-50%Ni: 16 Fe-3%Si: 45-60 Fe-6%Si: 46 A/m	N/A	N/A

Merhar, 1990	Fe-2%Ni, Fe-3%Si	N/A	Fe-2%Ni: 95% Fe-3%Si: 99%	N/A	N/A	N/A	N/A	Fe-2%Ni: 95 HV/207 MPa Fe-3%Si: 162 HV/345 MPa	Fe-2%Ni: 25% Fe-3%Si: 25%
Miura, 1996	Ni-Fe, Si-Fe; 0-9 mass% for Ni and Si, respectively	Ni-Fe: 1573 K Si-Fe: 1523 K	Ni-Fe: 88-96% Si-Fe: 80-96%	N/A	N/A	0.75-1 T	398-875 A/m	N/A /Ni-Fe: 200-500 MPa Si-Fe: 200-750 MPa	Ni-Fe: 5-35 % Si-Fe: 0-30%
Miura, 1999	Fe-9.5Si-5.5Al	1473-1543 K	86-99%	12-60	B-H tracer	0.75-1.1 T	5.6-32 A/m	361-505 HV/ N/A	N/A
Miura, 2013	6.5Si-Fe; 50Ni-Fe	1423-1623 K	Si-Fe: 68-99% Ni-Fe: 90-96%	20-500 N/A	B-H tracer	Si-Fe: 0.8-1.5 T Ni-Fe: 1.3-1.55 T	Si-Fe: 127-32 A/m Ni-Fe: 20-32 A/m	N/A	N/A
Ma, 2013 [no HIP]; Ma, 2013 [HIP]	50Ni-Fe	1110-1360 C; 1360 C	91.3-97.2%; 94.5-97%	N/A; Up to 200 (500 post HIP + heat treat)	B-H tracer	1.24-1.48 T; 1.4-1.48 (1.56 post-HIP) T	25.9-6.8 A/m; 11-6.8 A/m	N/A	N/A
Ma, 2014	4Mo-79Ni-Fe	1240-1360 C	92.1-97.2%	20-246	B-H tracer	0.78-0.83 T	2.6-1.1 A/m	N/A	N/A
Ma, 2016	Fe-xP; x= 0-1.2 wt.%	1100-1450	79-99%	59-350	B-H tracer	1.41-1.77 T	~260-21 A/m	N/A	N/A
Páez-Pavón, 2016	Fe-3.8%Si	1350 C	97.3-98.4%	21.4-99.1	Hall Effect sensor	N/A (reported residual induction)	N/A	227 HV; N/A	N/A
Páez-Pavón, 2017	Fe-3.8%Si Fe-6.5%Si	1300-1400 C	~93-99.5%	152-278	SQUID	~1.6-2.3 T	N/A	129-285 HV; N/A	N/A
Zhang, 2020	Fe-35%Co	1275-1375 C	7.523-7.670 g/cm^3	19.62-34.1	B-H tracer	2.065-2.152 T	293.7-171.7 A/m	N/A	N/A