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Mechanochemical synthesis of nanostructured metal nitrides, carbonitrides and carbon nitride: A combined theoretical and experimental study Supplementary material

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1. DFT calculations

System	Symmetry	#Metal	#N	#C	KPT relax	KPT static	MaxForce (meV/Å)					
Aluminum												
Al	Fm-3m	4	0	0	15x15x15	21x21x21	0.00					
Al:N Sub	- 2x2x2	31	1	0	9x9x9	13x13x13	0.25					
Al:N Int T		32	1	0	5x5x5		2.05					
Al:N Int O		32	1	0	5x5x5		2.06					
Al:C Sub		31	0	1	9x9x9		0.52					
Al:C Int T		32	0	1	5x5x5		0.48					
Al:C Int O		32	0	1	5x5x5		1.10					
AlN	P6 ₃ mc	2	2	0	15x15x15	21x21x21	0.04					
AlN:C Sub	3x3x2	36	35	1		11x11x11	0.29					
AlN:C Int H		36	36	1	3x3x3		1.84					
AlN:C Int T		36	36	1			0.85					
Al ₄ C ₃	R-3m	12	0	9	15x15x3	21x21x5	0.19					
Al ₄ C ₃ :N Sub T	0.0.1	48	1	35	9x9x3	9x9x3	11.09					
Al ₄ C ₃ :N Sub H		48	1	35		13x13x5	0.34					
Al ₄ C ₃ :N Int H	2X2X1	48	1	36	9x9x3		0.46					
Al ₄ C ₃ :N Int C		48	1	36			3.51					
Titanium												
Ti	P6 ₃ /mmc	2	0	0	15x15x15	21x21x21	0.00					
Ti:N Sub		35	1	0			0.28					
Ti:N Int H		36	1	0			0.46					
Ti:N Int C	32327	36	1	0	5x5x5	9x9x9	0.13					
Ti:C Sub	32322	35	0	1			0.20					
Ti:C Int H		36	0	1			0.15					
Ti:C Int cage		36	0	1			0.29					
TiN	Fm-3m	4	4	0	15x15x15	21x21x21	0.00					
TiN:C Sub	$\gamma_{v}\gamma_{v}\gamma$	32	31	1	5x5x5	13x13x13	0.06					
TiN:C Int		32	32	1			0.07					
TiC	Fm-3m	4	0	4	15x15x15	21x21x21	0.00					
TiC:N Sub	2x2x2	32	1	31	5x5x5	13x13x13	0.12					
TiC:N Int		32	1	32			0.19					
	•		Va	anadi	um							
V	Im-3m	2	0	0	15x15x15	21x21x21	0.00					
V:N Sub	- 3x3x3	53	1	0	5x5x5	13x13x13	0.11					
V:N Int		54	1	0			0.95					
V:C Sub		53	0	1			0.47					
V:C Int		54	0	1			0.63					
VN	Fm-3m	4	4	0	15x15x15	21x21x21	0.00					
VN:C Sub	- 2x2x2	32	31	1	5	13x13x13	0.15					
VN:C Int		32	32	1	JAJAJ		0.30					
VC	Fm-3m	4	0	4	15x15x15	21x21x21	0.00					
VC:N Sub	- 2x2x2	32	1	31	5x5x5	13x13x13	0.08					
VC:N Int		32	1	32			0.24					
Chromium												
Cr	Im-3m	2	0	0	15x15x15	21x21x21	0.00					
Cr:N Sub	3x3x3	53	1	0	5x5x5	13x13x13	0.11					
Cr:N Int		54	1	0			0.22					
Cr:C Sub		53	0	1			0.37					

Table S1. Crystallographic information and details of DFT calculations.

Cr:C Int		54	0	1			0.34
CrN	Fm-3m	4	4	0	15x15x15	21x21x21	0.00
CrN:C Sub	2x2x2	32	31	1	5x5x5	13x13x13	0.07
CrN:C Int		32	32	1			0.41
CrC	Fm-3m	4	0	4	15x15x15	21x21x21	0.00
CrC:N Sub	- 2x2x2	32	1	31	5x5x5	13x13x13	0.23
CrC:N Int		32	1	32			0.32
$Cr_{23}C_6$	Fm-3m	92	0	24	5x5x5	11x11x11	0.30
Cr ₂₃ C ₆ :N Sub	1x1x1	92	1	23	5x5x5	13x13x13	0.73
Cr ₂₃ C ₆ :N Int		92	1	24	5x5x5		0.12



Figure S1: Ball-and-stick representation of the Al (a), AlN (b) Al_4C_3 (c) and Ti (d) atomic structure. Different interstitial sites are indicated, as well as the two possible substitutional

sites in Al₄C₃.

2. XRD analysis



Figure S2. XRD patterns of a) Al-M, b) Ti-M, c) Cr-M and d) V-M powder mixtures milled for various milling times.

3. EDX analysis









c





d



Figure S3. Typical SEM image with corresponding EDX mapping analysis obtained from a, b) Al-M, c, d) Ti-M, e, f) Cr-M and g, h) V-M powder mixtures milled for 6, 30, 84 and 30 h, respectively.