CHALMERS
UNIVERSITY OF TECHNOLOGY

Design of Z-phase strengthened steels

KME-710

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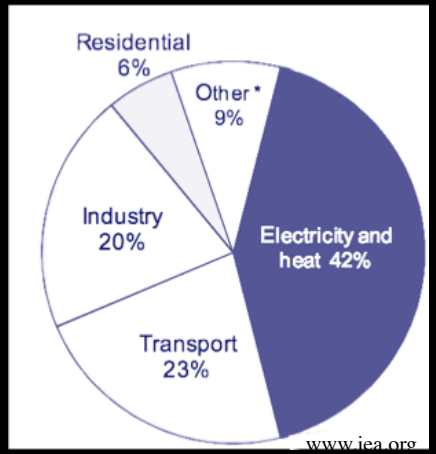
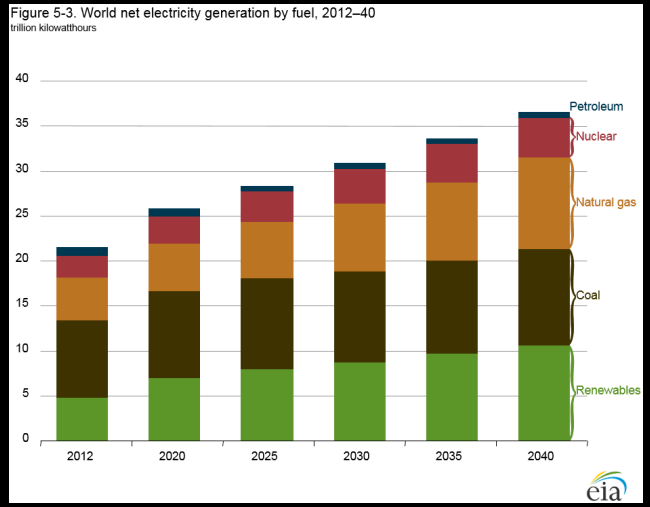
Outline

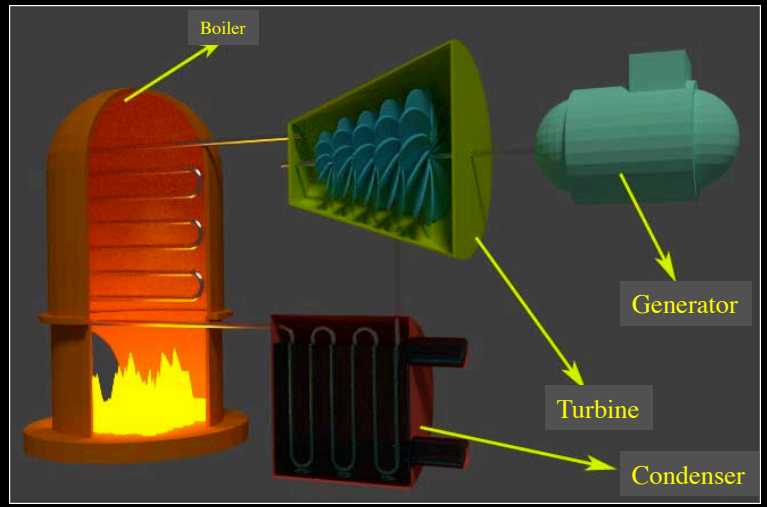
- Motivation
- Overview of Z-phase strengthened steels
- Core-shell structure of intermediate precipitates
- Effect of C on Z-phase formation

Motivation

World CO_2 emission by sector







Efficiency $\eta = 1 - \frac{T_C}{T_H}$

Higher steam temperature and pressure →→→→ more efficient power plants

Current status

600°C

9% Cr steels

Creep

Corrosion

650°C

9% Cr steels

Creep

Corrosion

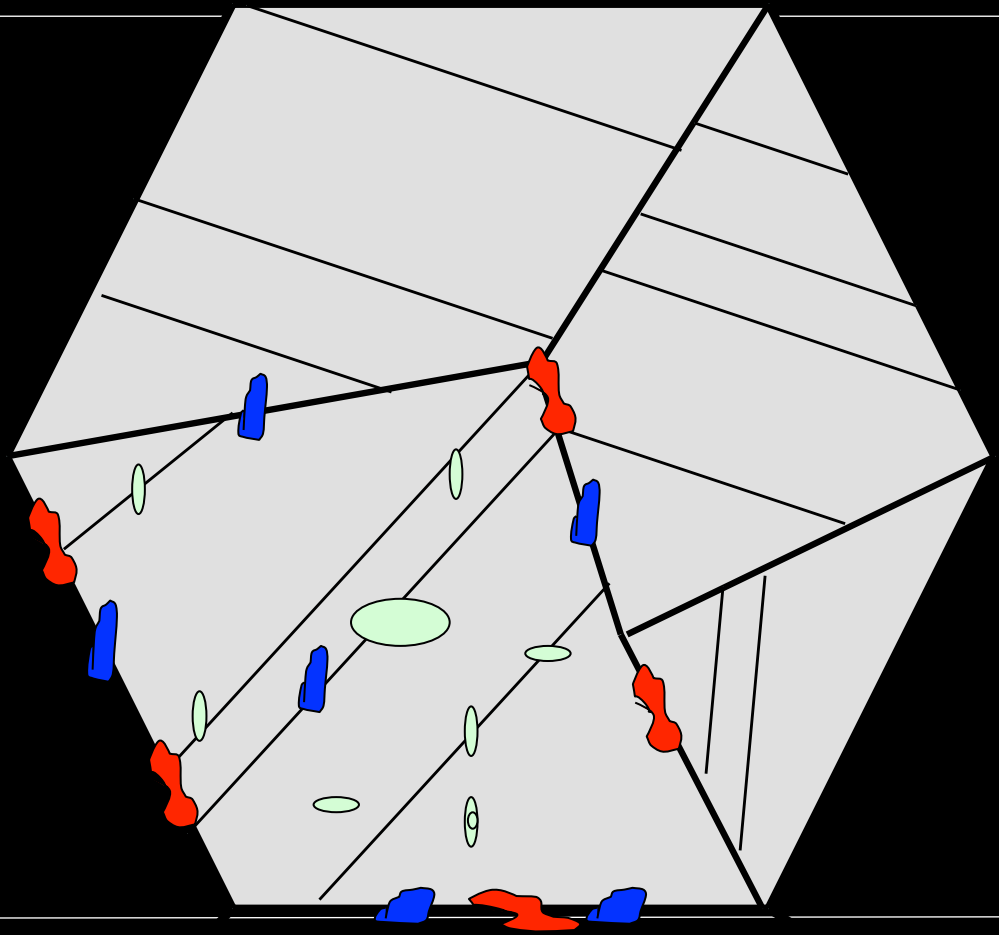
Aim

650°C

12% Cr steels

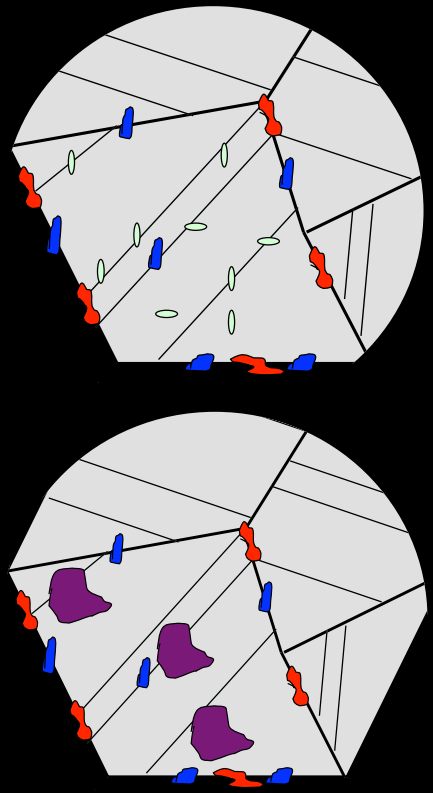
Creep

Corrosion



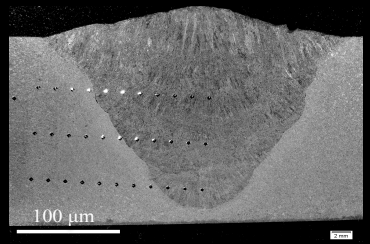
Traditional 12% Cr steels

Z-phase strengthened steels

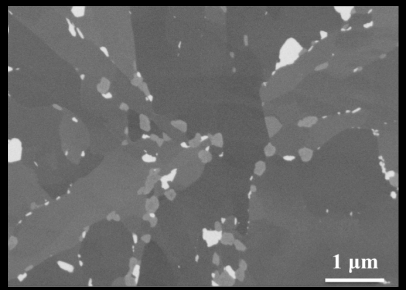


Microstructure characterization

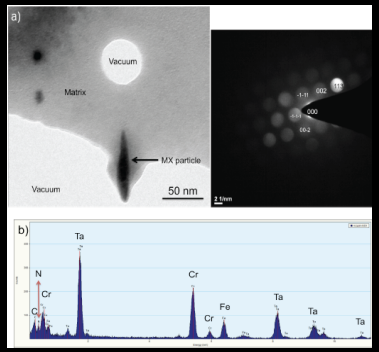
Light Optical microscopy



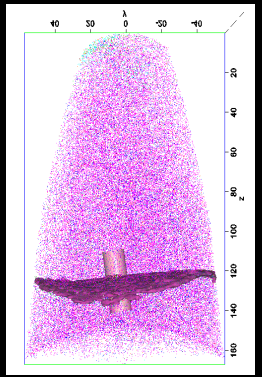
Scanning Electron Microscopy



Transmission Electron Microscopy

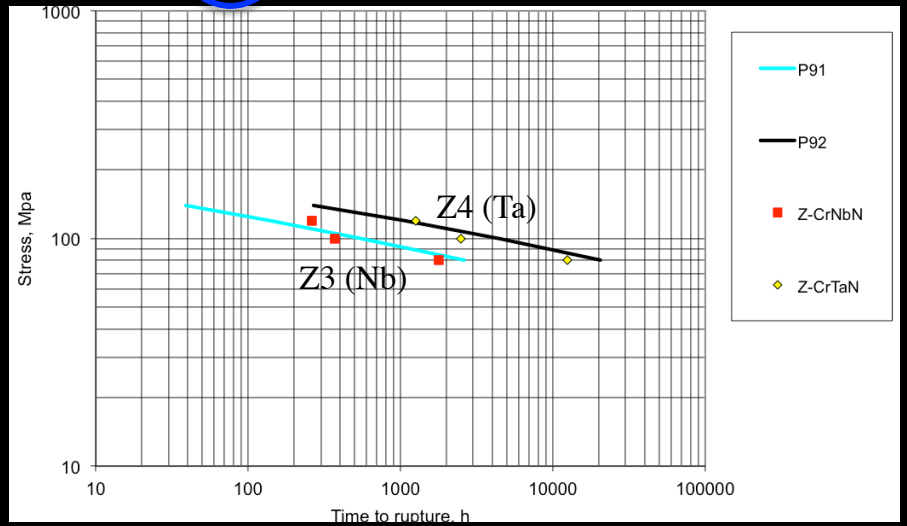


Atom Probe Tomography



- Proof of concept

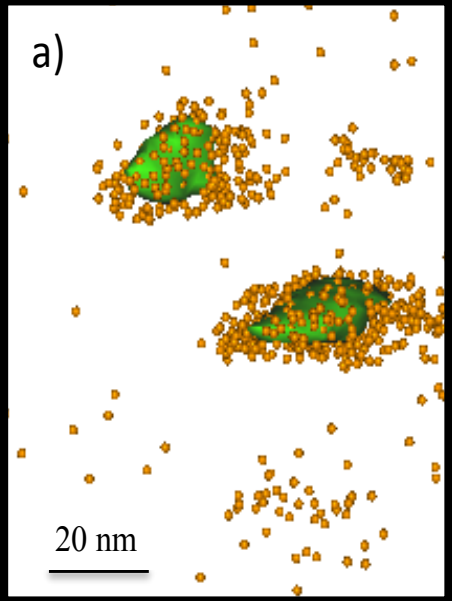
Steel wt.%	C	Mn	Si	Cr	Ni	W	Co	B	N	Nb	Ta
Z3	0.005	0.50	0.30	11.64	1.47	2.82	5.4	0.004	0.036	0.26	-
Z4	0.005	0.48	0.30	11.79	0.50	2.90	7.3	0.004	0.033	-	0.39

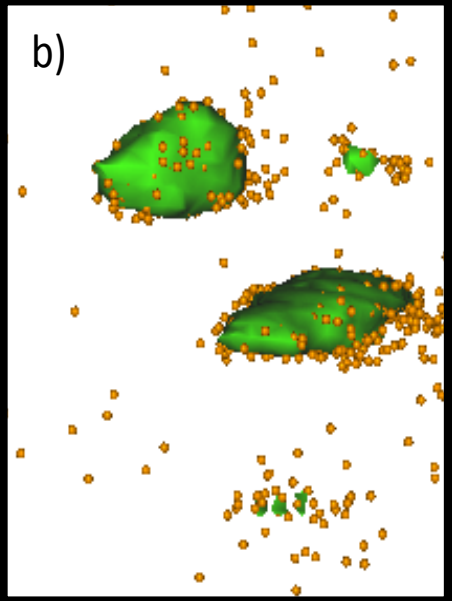


M.Rashidi, et al." Microstructure characterization of two Z-phase strengthened 12% chromium steels" Proc. 10th Liège Conference: Materials for Advanced Power Engineering 2014

Z-Phase Formation

Cr Ta N

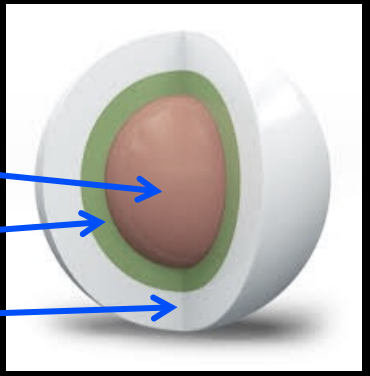




Core

Shell 1

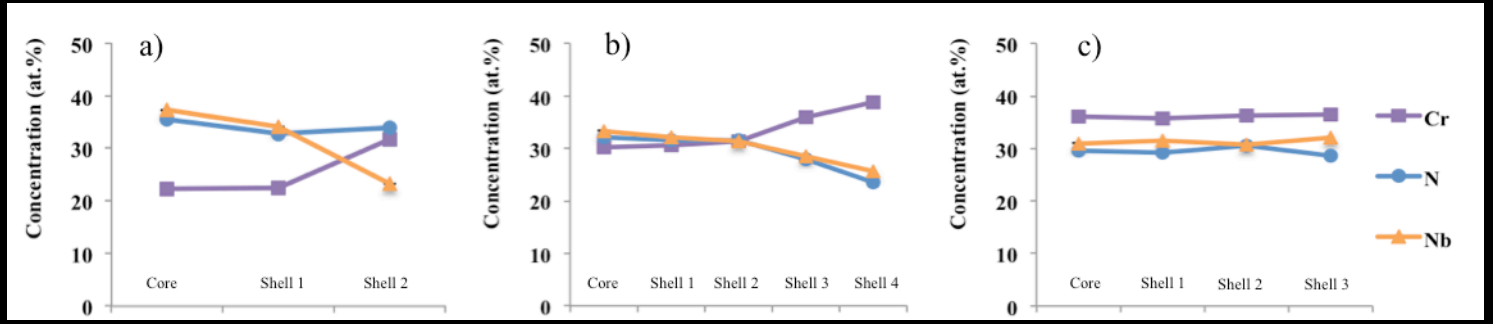
Shell 2



M.Rashidi, et al. “Core-shell structure of intermediate precipitates in Z-phase strengthened 12% Cr steel” Microscopy and Microanalysis 2017, in press

Core-shell structure of intermediate precipitates

As-tempered | 1005 h aged | 3000 h aged



Particle Size: 5nm | Size: 10 nm | Size: 20 nm

MN →→→→→ $Cr_{1+x}M_{1-x}N$

Modell alloy → → → → Real alloys

Steel wt.%	Ni	Co	Cr	W	Ta	C	B	N	Si	Mn	Cu	Other
S1	0.19	3.5	12.1	2.47	0.36	0.06	0.0063	0.049	0.31	0.21	1.95	–
S2–1	0.18	2.7	11.2	2.0	0.35	0.028	0.0042	0.045	0.34	0.12	2.00	–
S2–2	0.17	3.1	11.2	2.1	0.19	0.03	0.0054	0.042	0.32	0.13	2.10	Nb 0.16
S2–3	0.20	3.1	11.1	1.8	0.43	0.05	0.0042	0.036	0.23	0.12	–	Mo 0.5
S3–1	0.11	3.93	11.45	2.02	0.38	0.013	0.0026	0.046	0.29	0.08	2.01	–
S3–2	0.11	5.65	11.46	2.47	0.40	0.012	0.0026	0.042	0.28	0.09	1.02	–
S3–3	0.08	5.11	11.33	2.32	0.41	0.011	0.0042	0.043	0.30	0.10	2.01	–
S3–4	0.11	5.60	11.30	2.68	0.43	0.009	0.0025	0.041	0.30	0.93	1.54	–

Effect of C on Z-phase formation

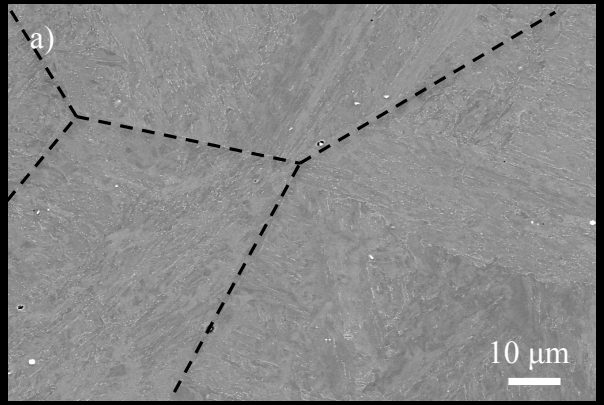
Material

Steel		C	Mn	Si	Cr	Ni	W	Co	Cu	N	B	Ta
Z-steel	wt%	0.005	0.48	0.30	11.79	0.50	2.90	7.30	-	0.033	0.004	0.39
ZC-steel	wt%	0.06	0.21	0.31	12.10	0.19	2.47	3.50	1.95	0.049	0.006	0.36

Effect of C addition

Low Carbon

0.005 Wt. %

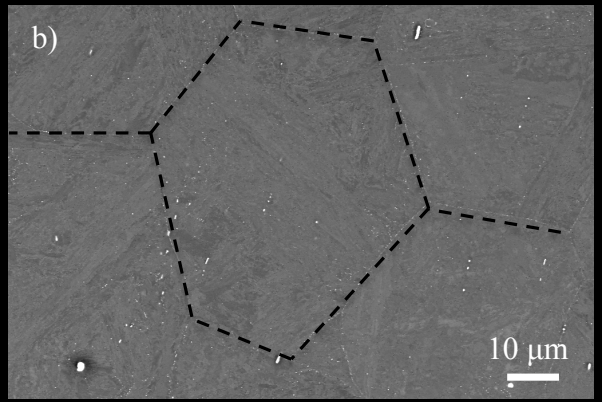


Grain size

100µm

High Carbon

0.06 Wt. %



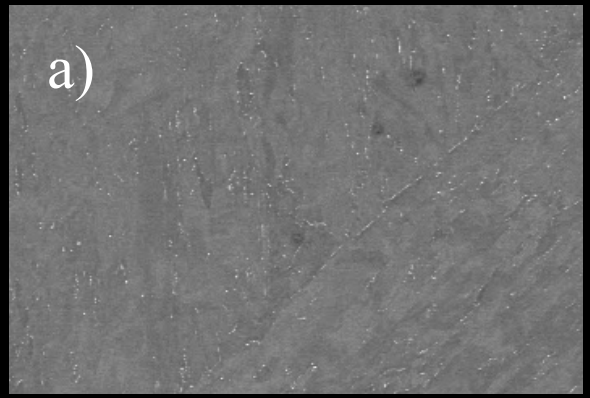
50µm

Cr Ta N

Low Carbon

0.005 Wt. %

Effect of C addition

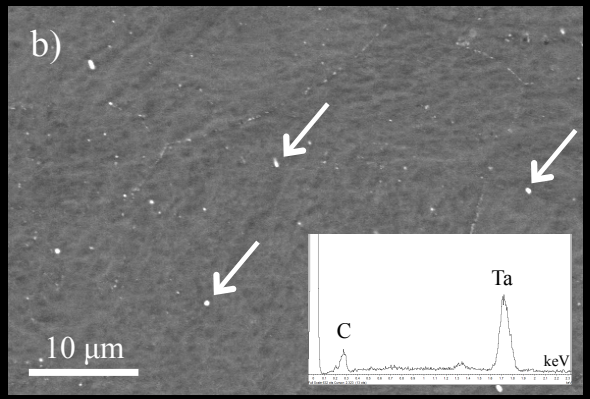


No Carbide

Cr Ta N

High Carbon

0.06 Wt. %



TaC

$Cr_{23}C_6$

Cr Ta N

Low Carbon

0.005 Wt. %

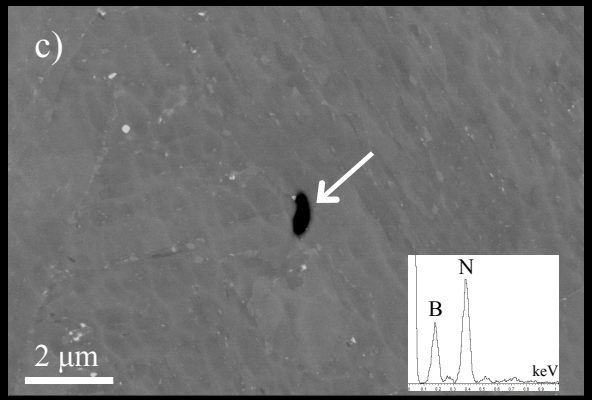
No BN

Effect of C addition

Cr Ta N

High Carbon

0.06 Wt. %

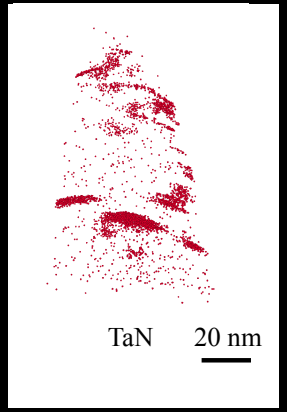


BN

Effect of C addition

Low Carbon

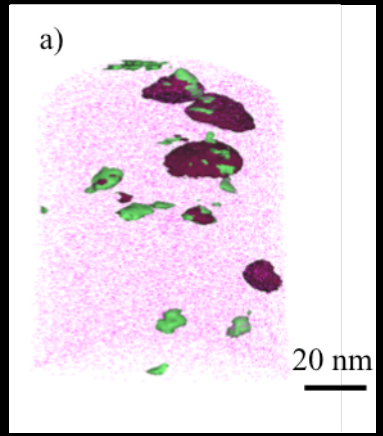
0.005 Wt. %



TaN → CrTaN

High Carbon

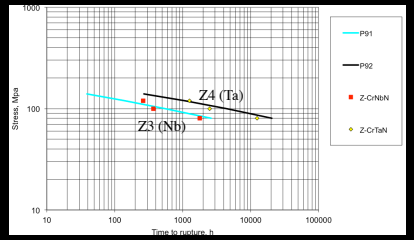
0.06 Wt. %



TaN → CrTaN

TaCN →→→→→ CrTaN

Summary



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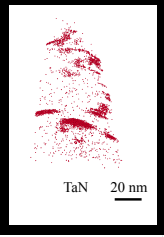
Cr Ta N

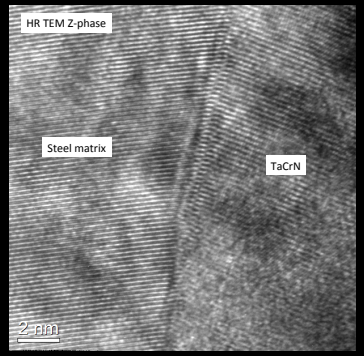
Cr Ta N

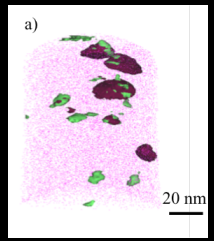
Cr Ta N

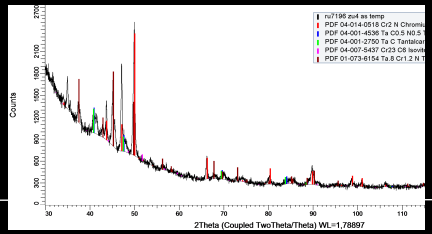
Cr Ta N

Cr Ta N









Thank you for your attention