

State of the Sub-surface Microstructure of Carbides strengthened cast Superalloys after High Temperature Oxidation

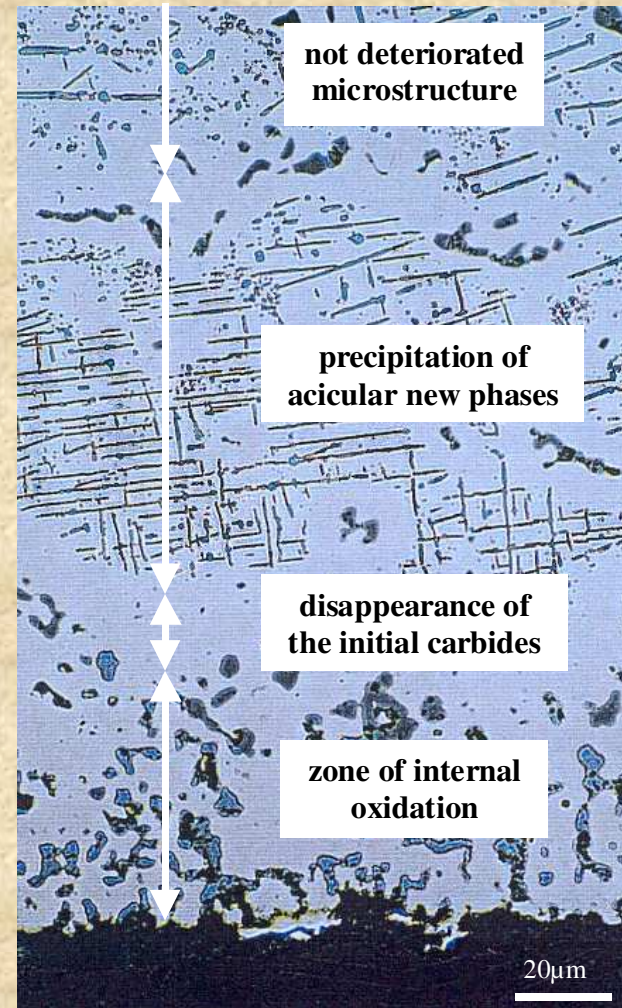
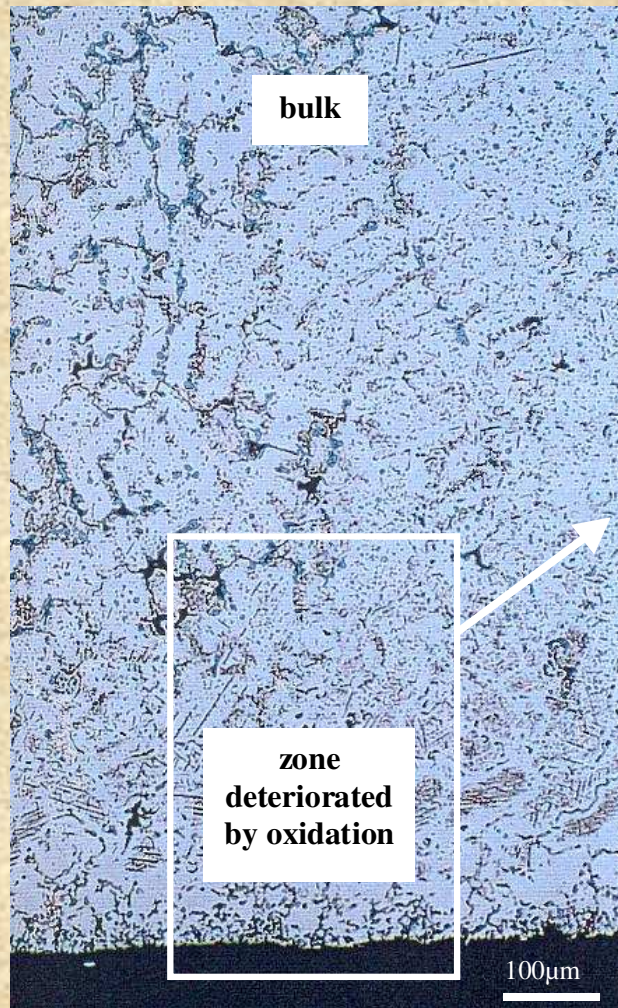
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Use of Thermodynamic Modelling for a better Understanding

P. Berthod, S. Michon, S. Mathieu, R. Podor, C. Rapin, P. Steinmetz

Laboratoire de Chimie du Solide Minéral (UMR 7555)
Université Henri Poincaré Nancy 1
BP 239 – 54506 Vandoeuvre-les-Nancy Cedex - FRANCE

Sub-surface microstructure due to HT oxidation in an industrial superalloy



Consequences for the alloys ?

mechanical properties

refractoriness (T_{sol}) of



of the sub-surface layer

Why these carbides modifications ?

disappearance

growth and/or new natures

new acicular carbides

THE STUDIED ALLOYS

T4

Four nickel-base alloys and two cobalt-base alloys
strengthened by chromium carbides and/or tantalum carbides
synthesised by a foundry way

%wt	Co	Ni	Cr	C	Ta
Alloy 1	/	bal	30	0.2	/
Alloy 2	/	bal	30	0.2	2
Alloy 3	/	bal	30	0.4	3
Alloy 4	/	bal	30	0.4	6
Alloy 5	bal	8.5	30	0.4	6
Alloy 6	bal	8.5	30	1.0	6

Tests : 1200°C
1100°C
1000°C } in air for 100 hours

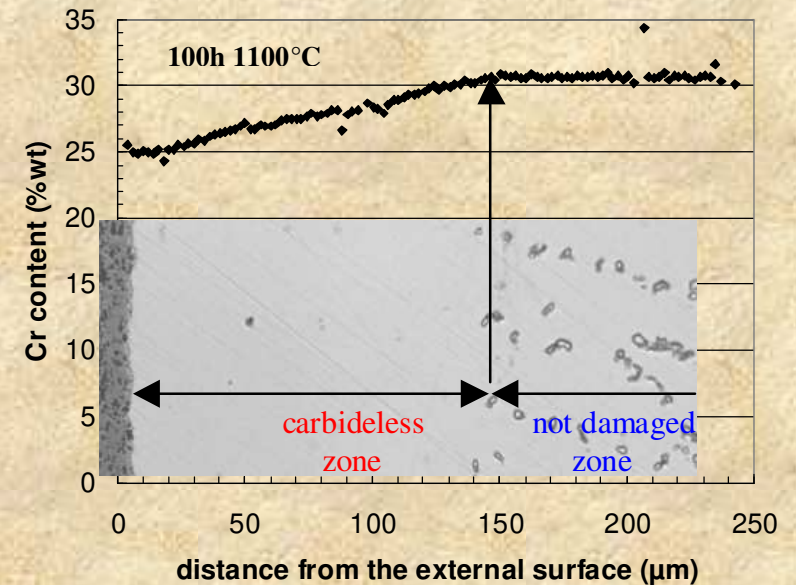
MICROSTRUCTURAL RESULTS

T5

Alloy 1

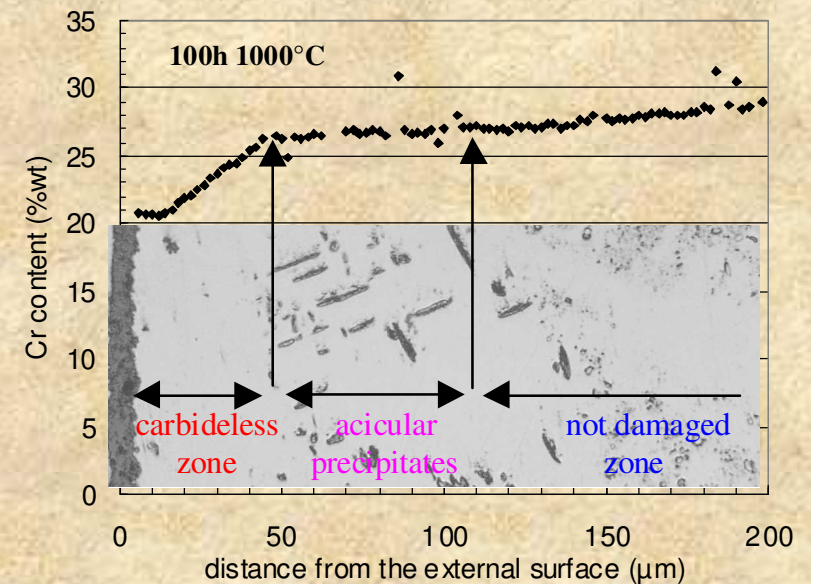
After 100h at 1100°C :

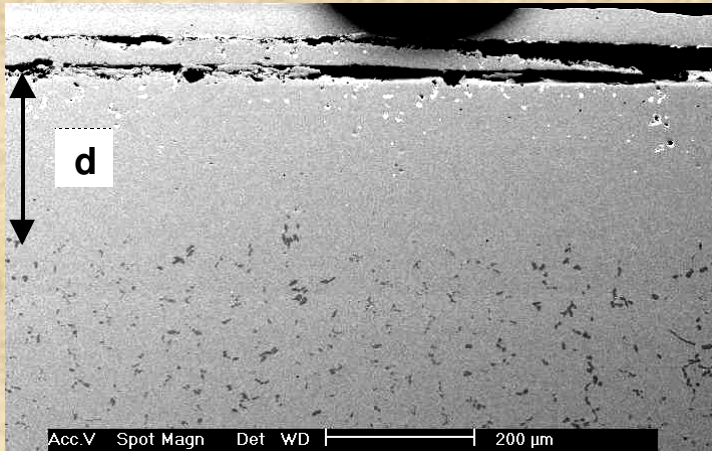
- * a deep zone without carbides



After 100h at 1000°C :

- * a thinner carbideless zone
- * new precipitates



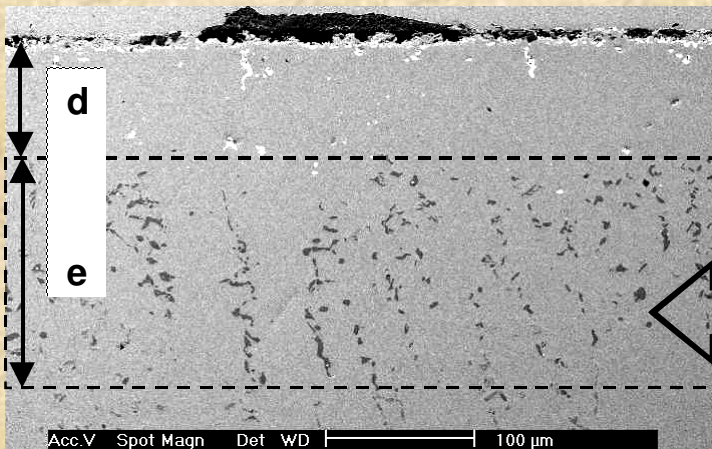


Alloy 2

1200°C

d=230μm

no new carbides

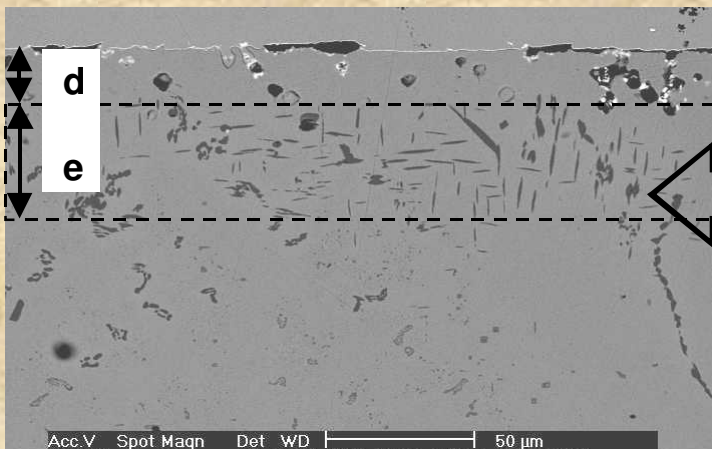
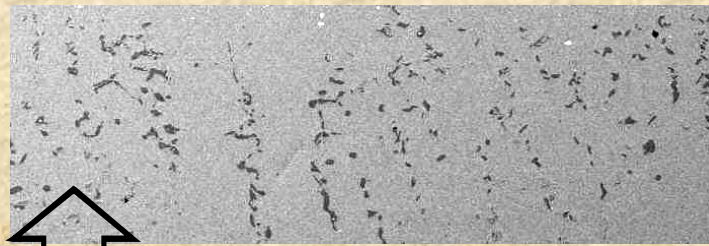


Alloy 2

1100°C

d=79μm e=158μm

3.39% M₇C₃



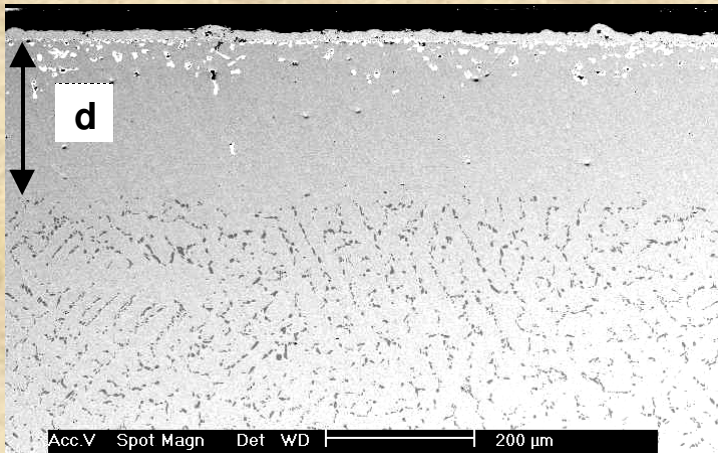
Alloy 2

1000°C

d=18μm e=39μm

6.20% M₂₃C₆



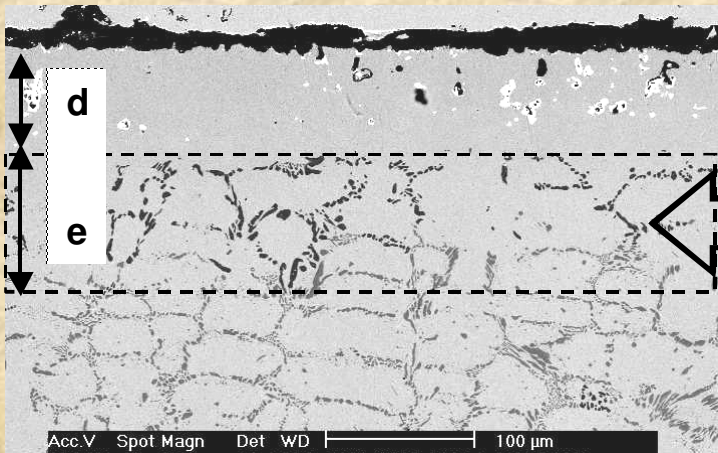


Alloy 3

1200°C

d=200μm

no new carbides

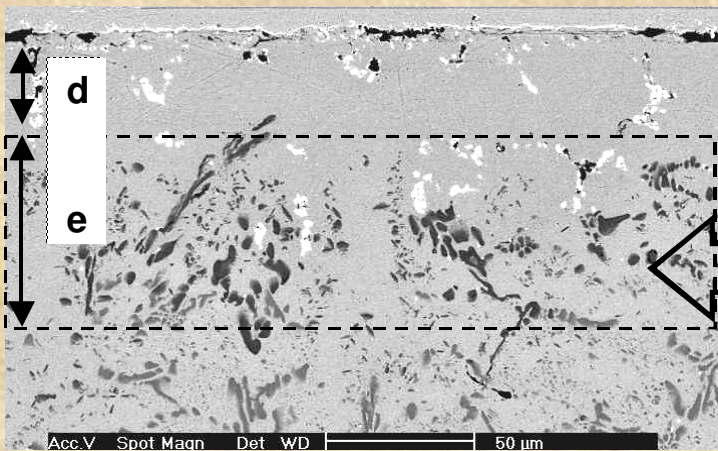


Alloy 3

1100°C

d=73μm e=97μm

6.3% M₇C₃ and 2.5% M₂₃C₆

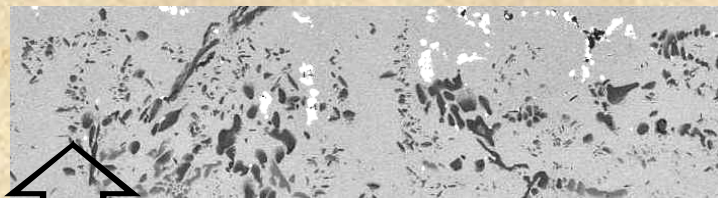


Alloy 3

1000°C

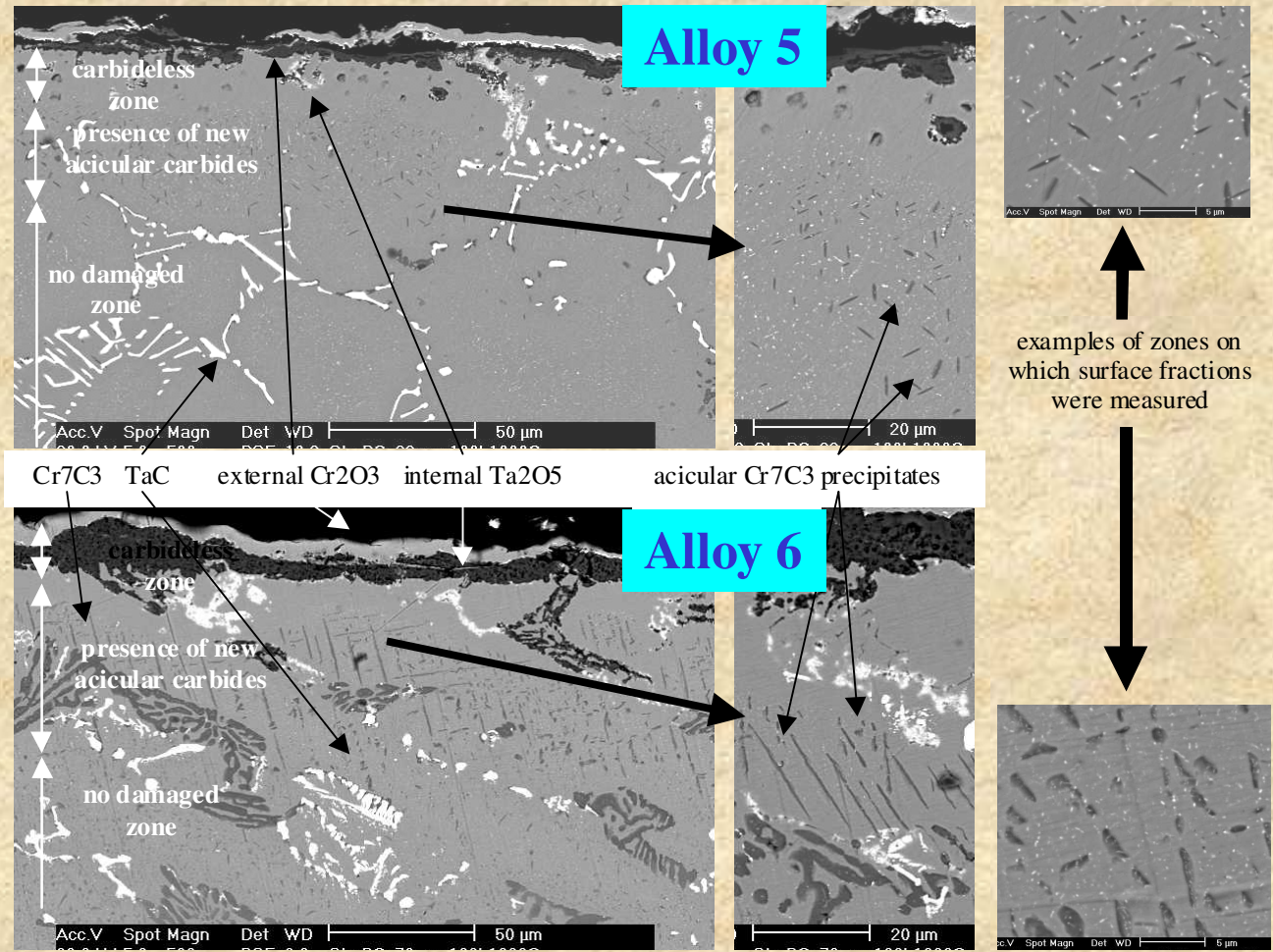
d=40μm e=64μm

6.0% M₇C₃ and 4.5% M₂₃C₆



Cobalt Base Alloys

1000°C



Summary of the observations

Alloy	Temp. (°C)	thickness (µm)		surface or volume fraction of carbides in the intermediate zone	
		carbideless zone	intermediate zone	M7C3	M23C6
Alloy 1	not studied	/	/	/	/
	1100	100	/	/	/
	1000	50	50	5.8	/
				bulk : 2.7% M7C3	
Alloy 2	1200	230	/	/	/
	1100	79	158	bulk : 2.4% M7C3	
				3.4	/
				bulk : 2.7% M7C3 and M23C6	
1000	18	39	/	6.2	
				bulk : 3.7% M23C6	
Alloy 3	1200	200	/	/	/
	1100	73	97	bulk : 6.2% M7C3	
				6.3	2.5
				bulk : 7.0% M7C3 and M23C6	
1000	40	64	6.0	4.5	
				bulk : 7.1% M23C6	
Alloy 4	1200	170	/	/	/
	1100	85	85	bulk : 3.7% M7C3 and 2.9% TaC	
				10.0	/
				bulk : 7.0% M23C6 and 3.5% TaC	
1000	24	48	/	12.8	
				bulk : 7.7% M23C6 and 2.1% TaC	

Why a carbideless zone ?

diffusion of Cr towards the oxidation front

-> Cr (and Ta) in solid solution : through the matrix


-> dissociation of Cr (and Ta) carbides : along G.B.

Why an intermediate zone with new carbides ?

Nature modification of the carbides ($M_{23}C_6 \rightarrow M_7C_3$)

Growth of the interdendritic carbides

Precipitation of new carbides in matrix



Local carbon enrichment ?

What happened to carbon ?

Study of the carbideless zone

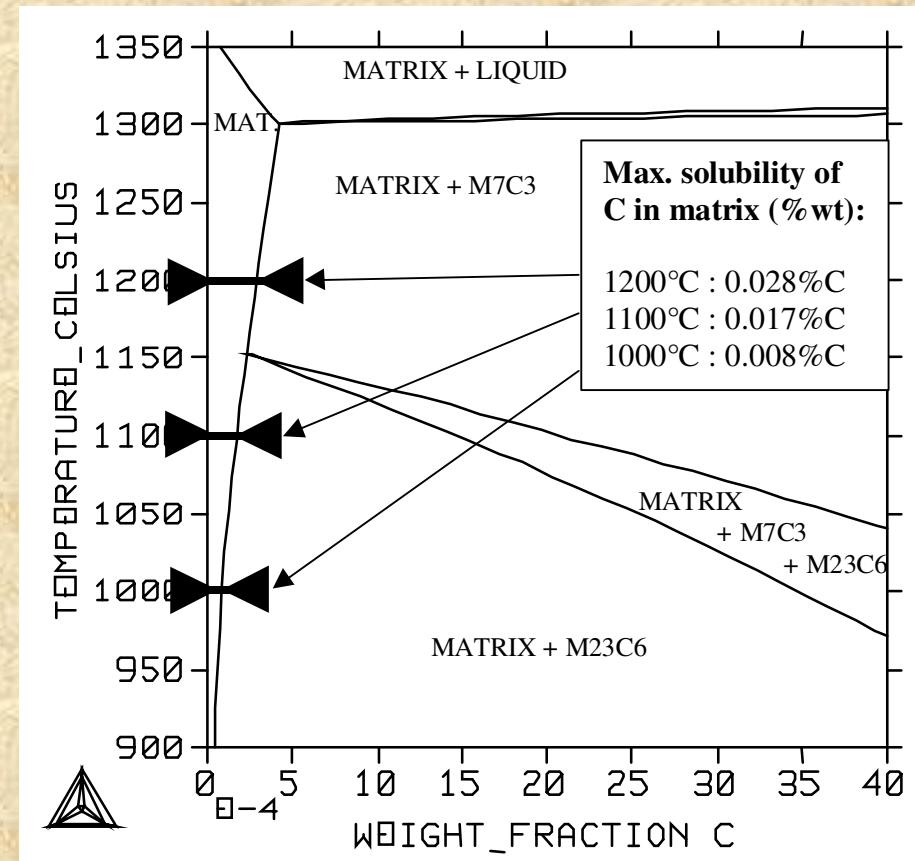
Example of Alloy 2

How the carbideless zone did appear ?

Matrix alone



Very low values of % wt C



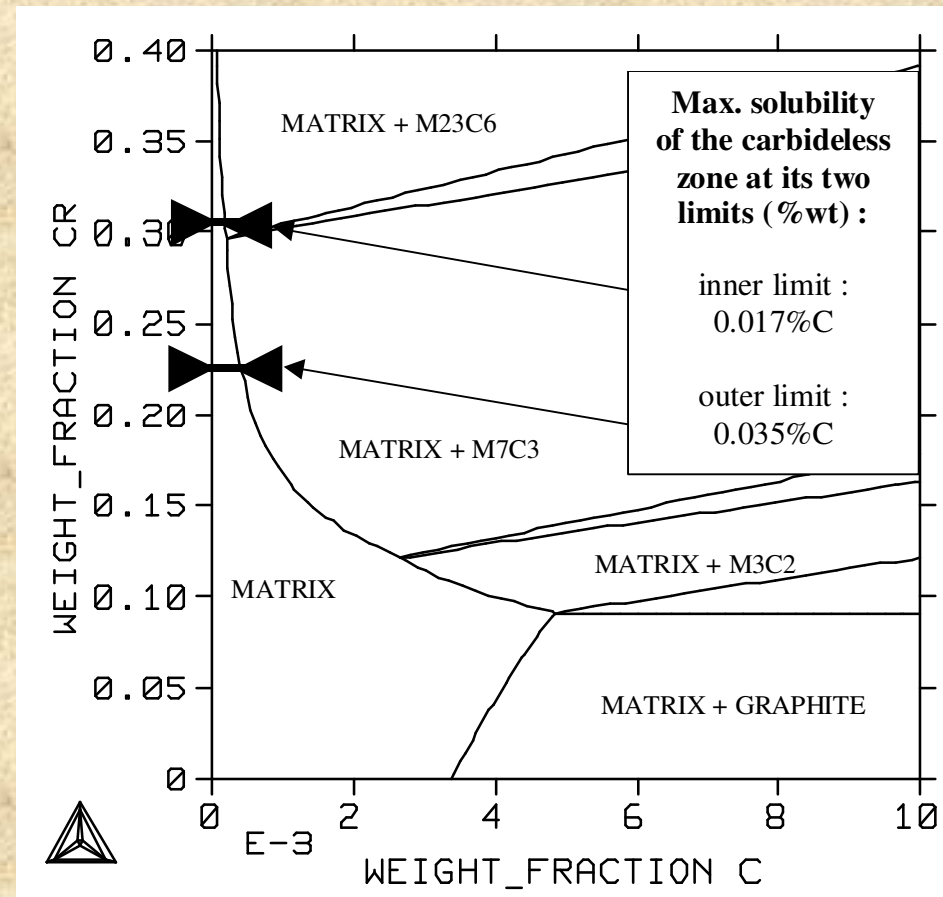
Study of the carbideless zone

Example of Alloy 2

Taking into account the chromium gradient :



Same conclusions about C



Study of the new carbides zone

chemical composition
 Ni (Co)
 Cr Ta

quantified microstructure
 $\%_{\text{surf or vol}} M_x C_y$
 (-> $\%_{\text{wt}} M_x C_y$)

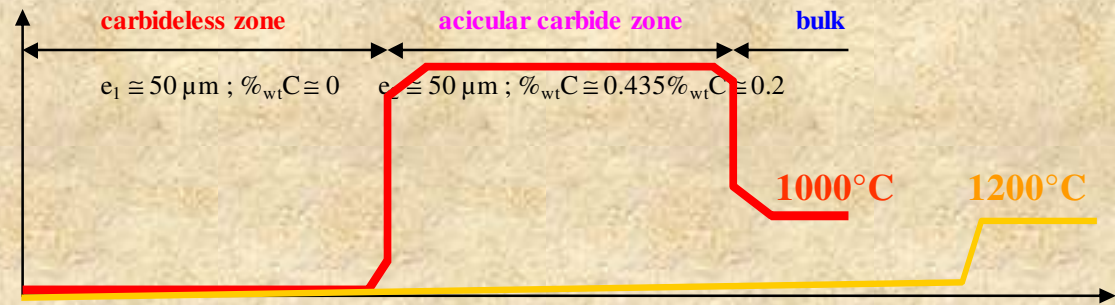
thermodynamic calculations

$\%_{\text{wt}} C$

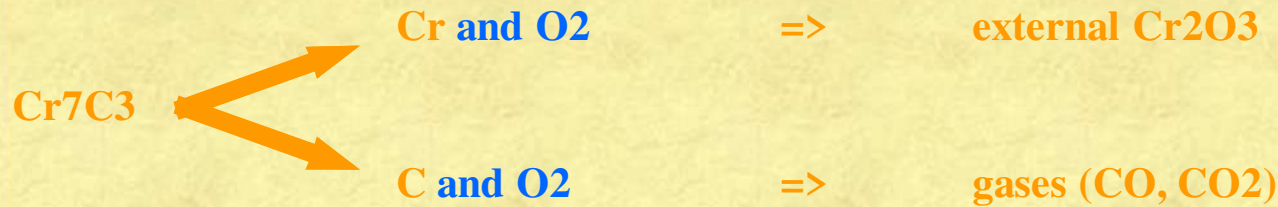
Alloy (initial $\%_{\text{wt}} C$)	Temp. ($^{\circ}C$)	$\%_{\text{wt}} C$ in the C-enriched zone	max C lost by the carbideless zone (mg / cm^2)	part kept by the C-enriched zone ($\%$)
Alloy 1 (0.2%)	/	/	/	/
	1100	/	0.18	0
	1000	0.43	0.09	100
Alloy 2 (0.2%)	1200	/	0.41	0
	1100	0.26	0.14	60
	1000	0.29	0.03	96
Alloy 3 (0.4%)	1200	/	0.71	0
	1100	0.47	0.26	24
	1000	0.65	0.14	98
Alloy 4 (0.4%)	1200	/	0.61	0
	1100	0.74	0.30	84
	1000	0.59	0.09	96
Alloy 5	1000	0.27	(<= only in the intergranular zone)	
			...	
Alloy 6	1000	0.55	(<= containing the acicular carbides)	

DISCUSSION - CONCLUSION

Two different behaviours for carbon



1200°C

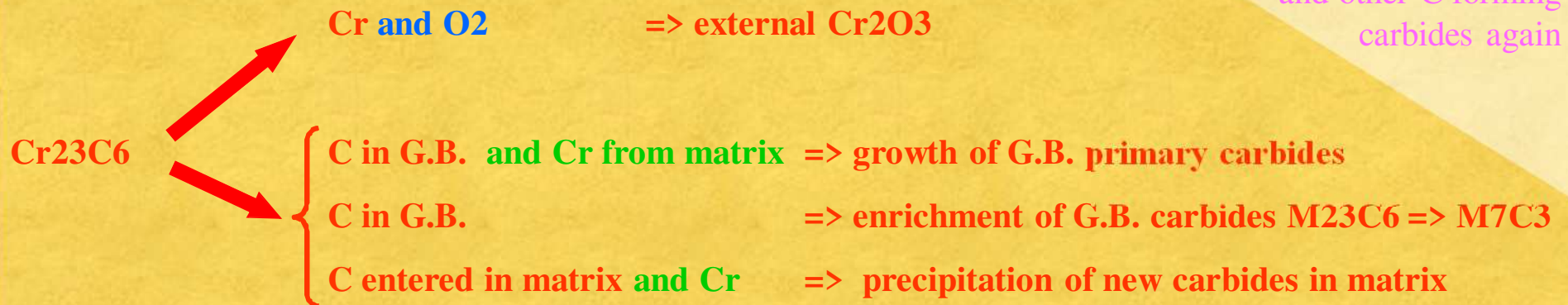


1100°C

a mix of the 2 phenomena :

1000°C

C oxidised into gases and other C forming carbides again



DISCUSSION - CONCLUSION

Metallographic study combined with thermodynamic calculations



What happened for carbon and new distribution in the zone affected by oxidation

PROSPECTS

Progress of the new carbides zone growth with time

Diffusion of C in two opposite directions (depending on T)

Thermodynamics reasons (forming either gases or carbides)

Effect of another element (here Ta)

Consequences on local properties