Ciência para o Desenvolvimento Sustentável

Composição da atmosfera (amostra isenta de água), por volume

ppmv: partes por milhão por volume (nota: a fração de volume é igual à fração molar para apenas em gases ideais)

Gás	Volume
Nitrogênio (N_2)	780.840 ppmv (78,084%)
Oxigênio (O_2)	209.460 ppmv (20,946%)
Argônio (Ar)	9.340 ppmv (0,9340%)
Dióxido de carbono (CO_2)	390 ppmv (0,0390%)[2]
Neônio (Ne)	18,18 ppmv (0,001818%)
Hélio (He)	5,24 ppmv (0,000524%)
Metano (CH_4)	1,79 ppmv (0,000179%)[3]
Criptônio (Kr)	1,14 ppmv (0,000114%)
Hidrogênio (H_2)	0,55 ppmv (0,000055%)
Óxido nitroso (N_2O)	0,3 ppmv (0,00003%)
Monóxido de carbono (CO)	0,1 ppmv (0,00001%)
Xenônio (Xe)	0,09 ppmv ($9x10^{-6}$%)
Ozônio (O_3)	0,0 a 0,07 ppmv (0% a $7x10^{-6}$%)
Dióxido de nitrogênio (NO_2)	0,02 ppmv ($2x10^{-6}$%)
Iodo (I)	0,01 ppmv (10^{-6}%)
Amônio (NH_3)	traços
Gases não incluídos na alta atmosfera (amostra isenta de água):	
Vapor de água (H_2O)	~0.40% em toda a atmosfera, normalmente entre 1%-4% na superfície

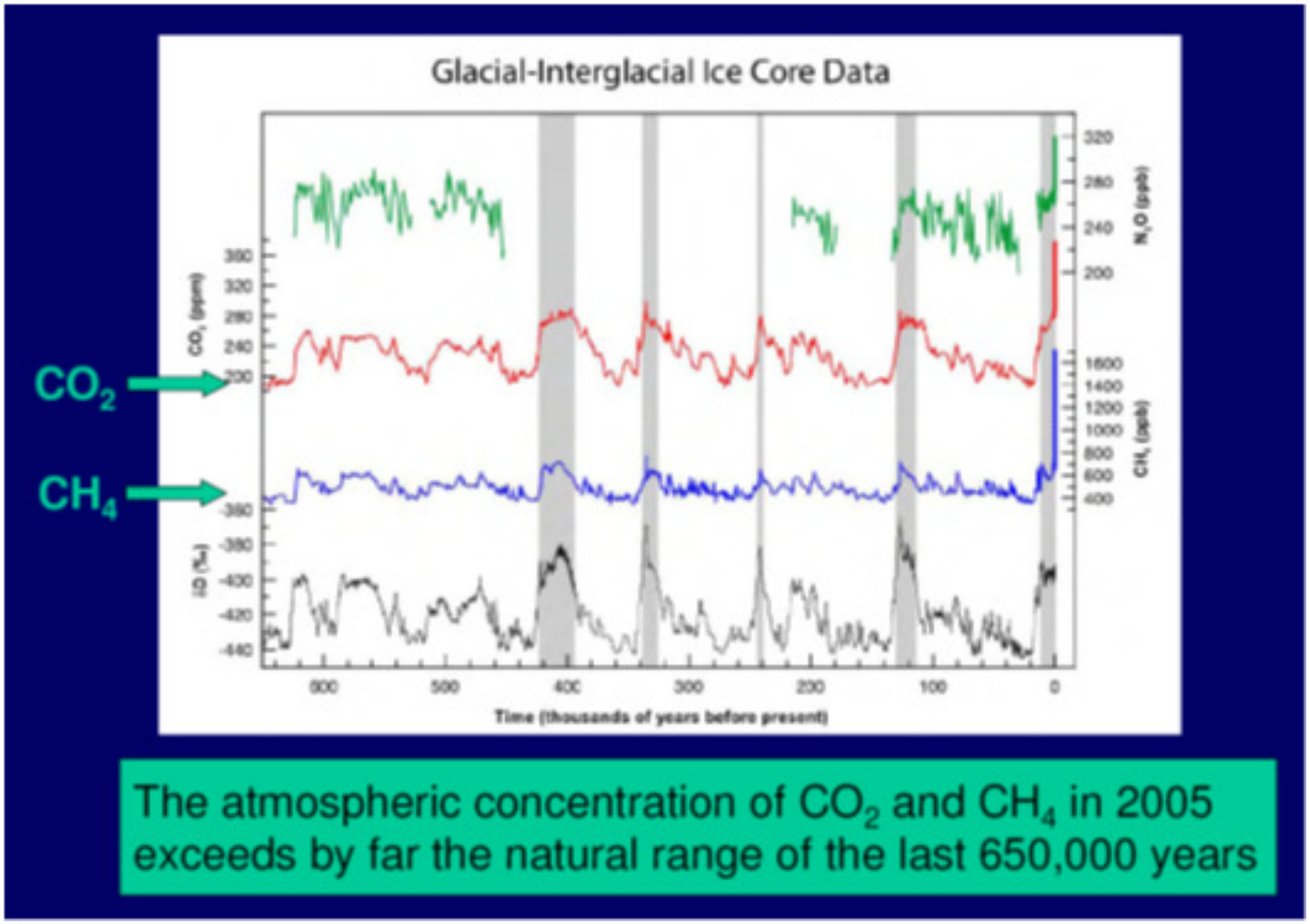
http://pt.wikipedia.org/wiki/Atmosfera_terrestre

The 21st Century changes

Four distinctive characteristics:

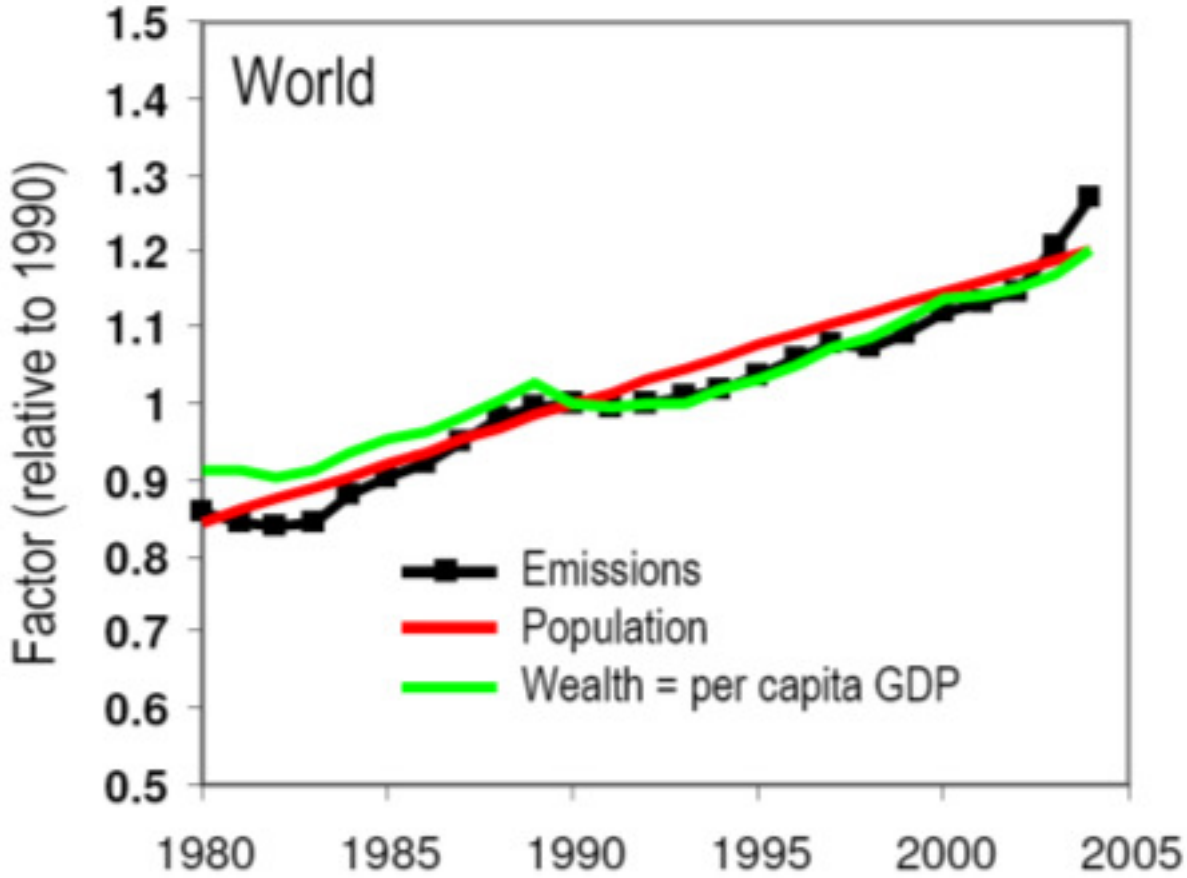
- **They are cumulative**
- **The effects are irreversible**
- **Large time lags – today's actions are tomorrow's problems**
- **They are global**

http://www.ipcc.ch/pdf/presentations/pre-cop-warsaw-2-10-2008/pres-warsaw-climate%20-botagaj-1.pdf



http://www.ipcc.ch/pdf/presentations/pre-cop-warsaw-2-10-2008/pres-warsaw-climate%20-botagaj-1.pdf

Drivers of Anthropogenic Emissions



http://www.ipcc.ch/pdf/presentations/pre-cop-warsaw-2-10-2008/pres-warsaw-climate%20-botagaj-1.pdf

Curiosidades

Variação populacional mundial por dia:
Morrem 150.000
Nascem 211.000
Saldo 61.000 (uma cidade de quase 2 milhões de habitantes por mês)
Fonte: diversas (http://www.un.org/), (http://wikipedia.org/), etc.

Disponibilidade de água:
Somente 0,007% da água doce disponível é própria para o consumo humano e encontra-se em rios, lagos e pântanos. Estes 0,007% estão ainda divididos da seguinte forma: Agricultura 70%, Indústria 22%, Individual 8% (clubes; hospitais; residências; etc)
Fonte: http://www.altoqi.com.br/suporte/hydros/duvidas_usuais/Utilizacao/Consumo_agua_uso_racional.htm

Crescimento econômico: ...

Consumo de energia: ...

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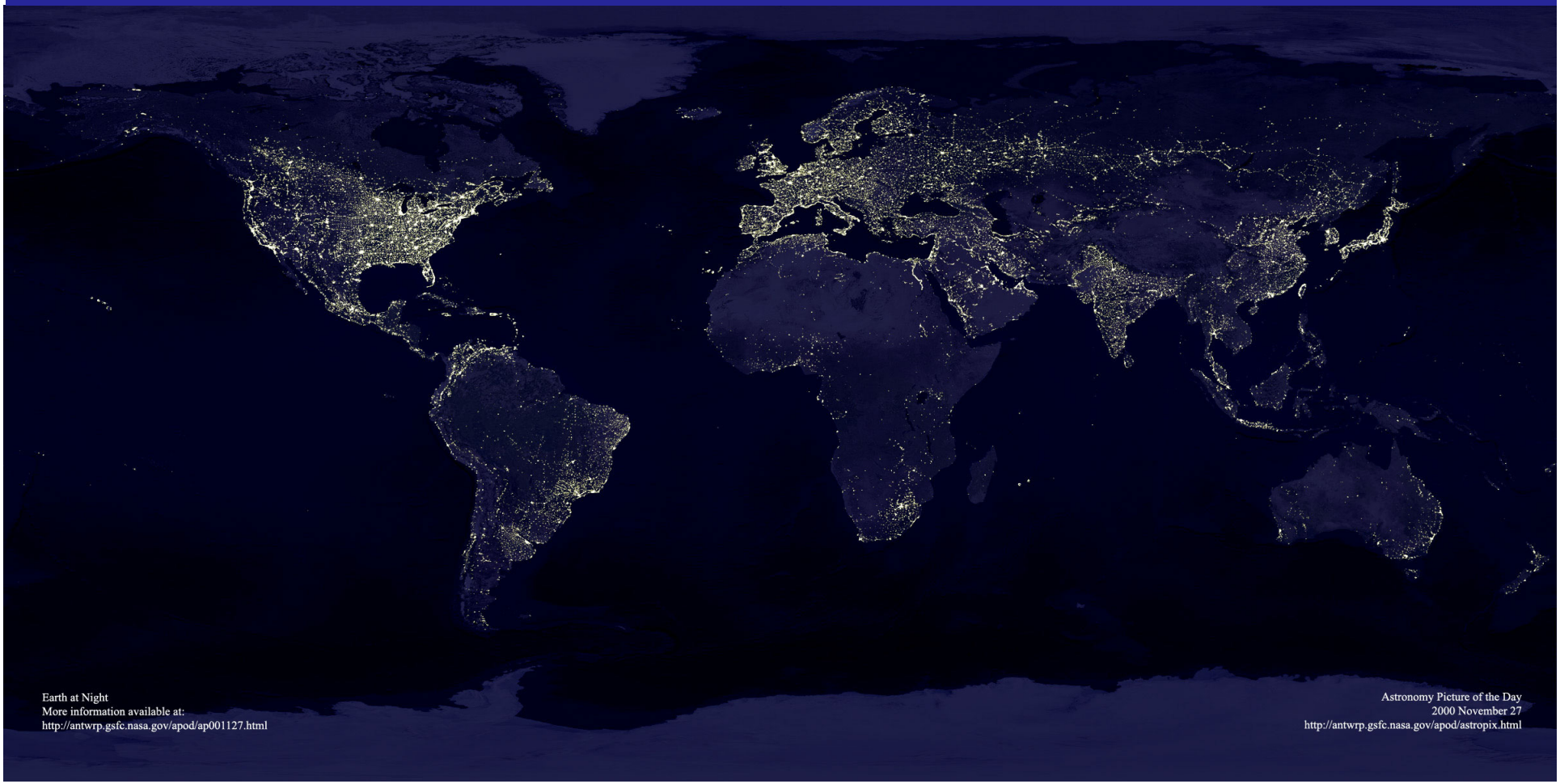
Imagem de satélite da terra à noite



http://apod.nasa.gov/apod/image/0011/earthlights2_dmsp_big.jpg

Scenario characteristics

(34 scenarios, IPCC/WEC)

	1800	2000	Δf	2050	Δf
Population (billion)	1	6	x6	10	x1.6
GDP (trillion 1990 $)	0.3	30	x100	85-110	<x3-x4
Primary energy (EJ)	13	420	x30	600-1,040	x1.5-x2.5
CO_2 emissions (GtC)	0.3	6.4	x20	5-15	<x1-x3
Mobility (km/person/day)	0.04	40	x1,000	120-160	x3-x4

http://www.ipcc.ch/pdf/presentations/pre-cop-warsaw-2-10-2008/pres-warsaw-climate%20-botagaj-1.pdf

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http://www.ipcc.ch/pdf/presentations/pre-cop-warsaw-2-10-2008/pres-warsaw-climate%20-botagaj-1.pdf

Ciência para o Desenvolvimento Sustentável

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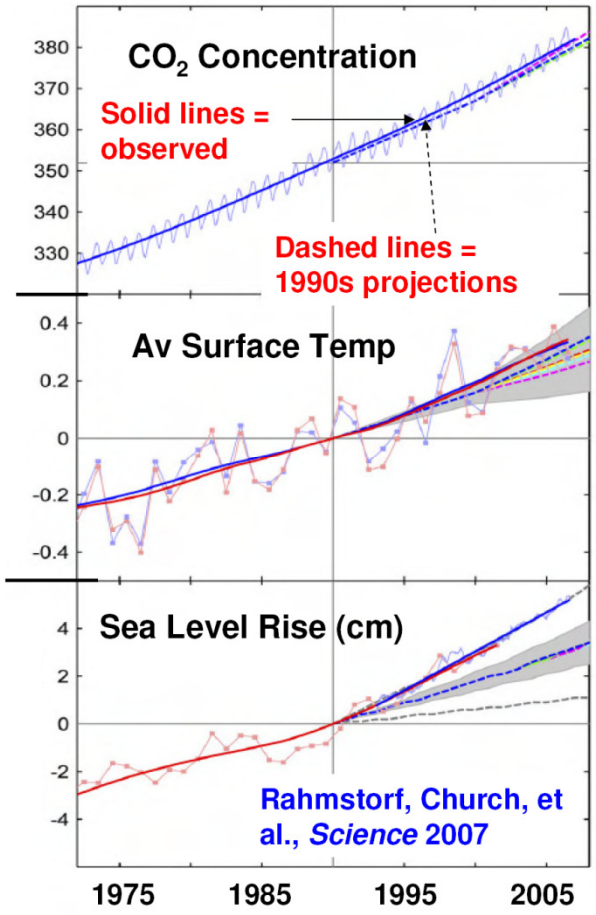


Climate Change: Faster than expected in 1990s

IPCC 4 (2007) was limited to science published by early 2006

Subsequent research shows increasing rates of:

Global GHG emissions

3.3% p.a. in 2000s, vs 1.3% p.a. in 1990s

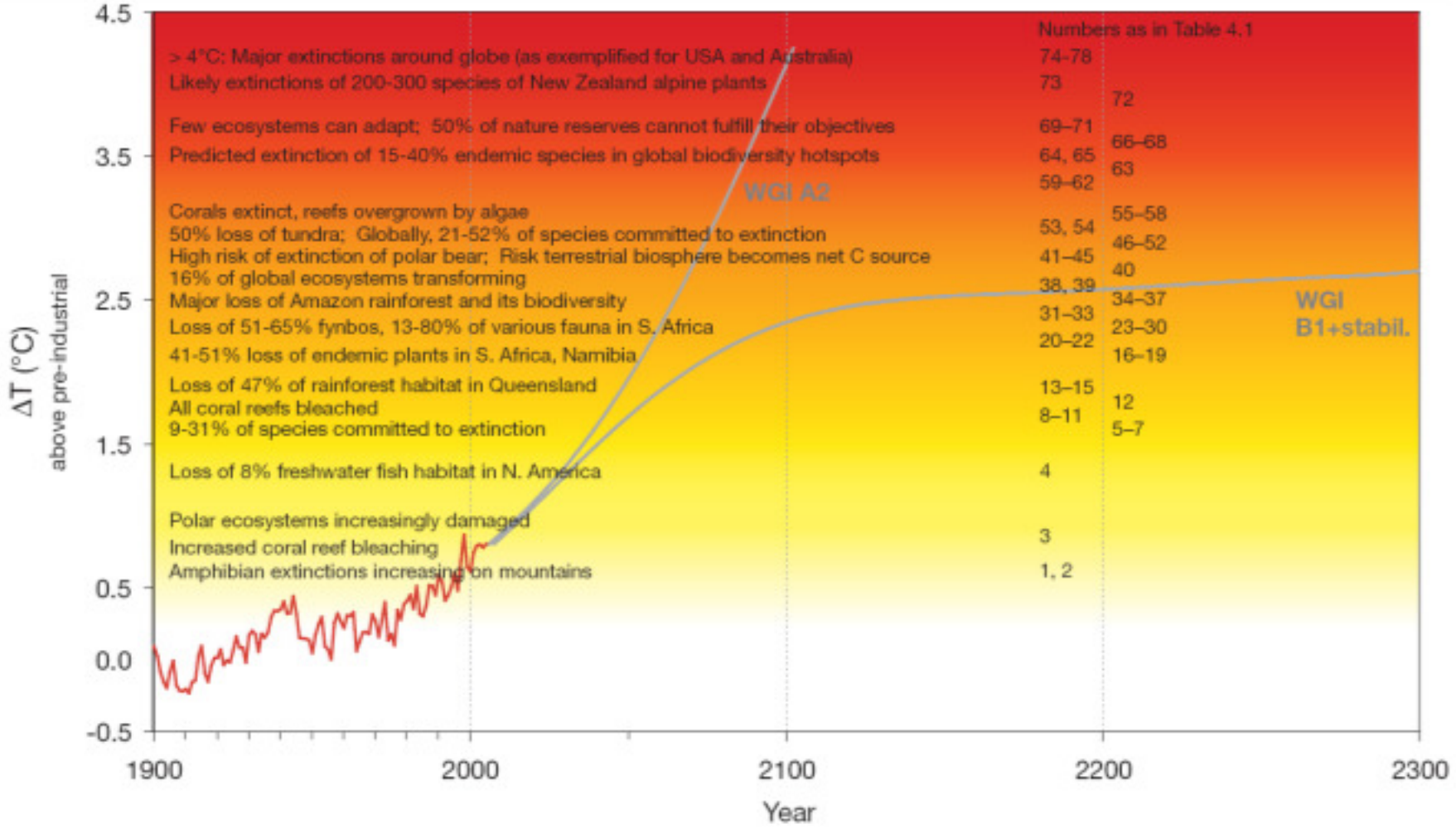
Temperature rise

especially in polar regions

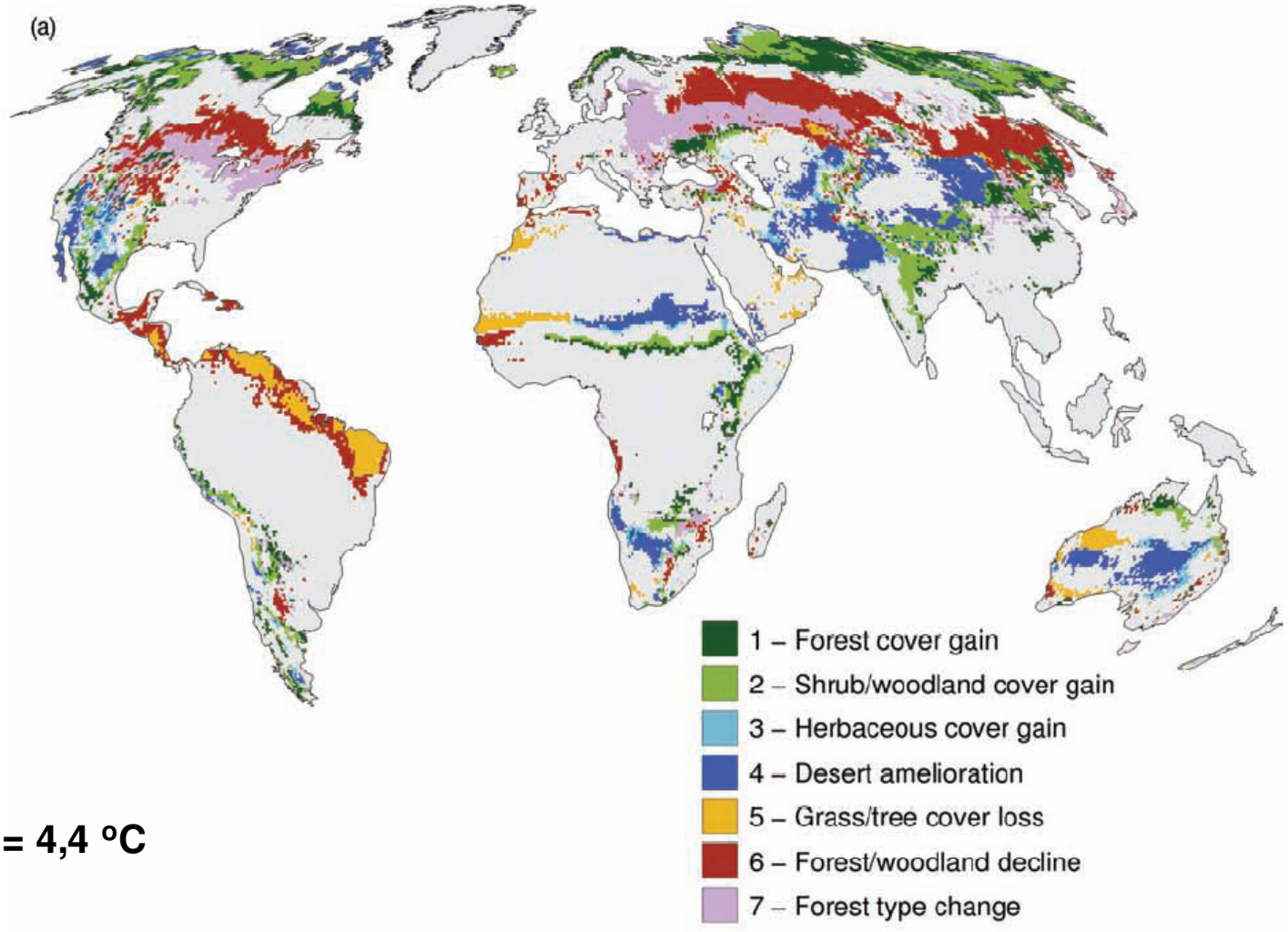
Ice melt (Arctic: 40% loss since 1980, accelerating 2006-07)

http://www.ipcc.ch/pdf/presentations/pre-cop-warsaw-2-10-2008/pres-warsaw-climate%20-botagaj-1.pdf

Ciência para o Desenvolvimento Sustentável

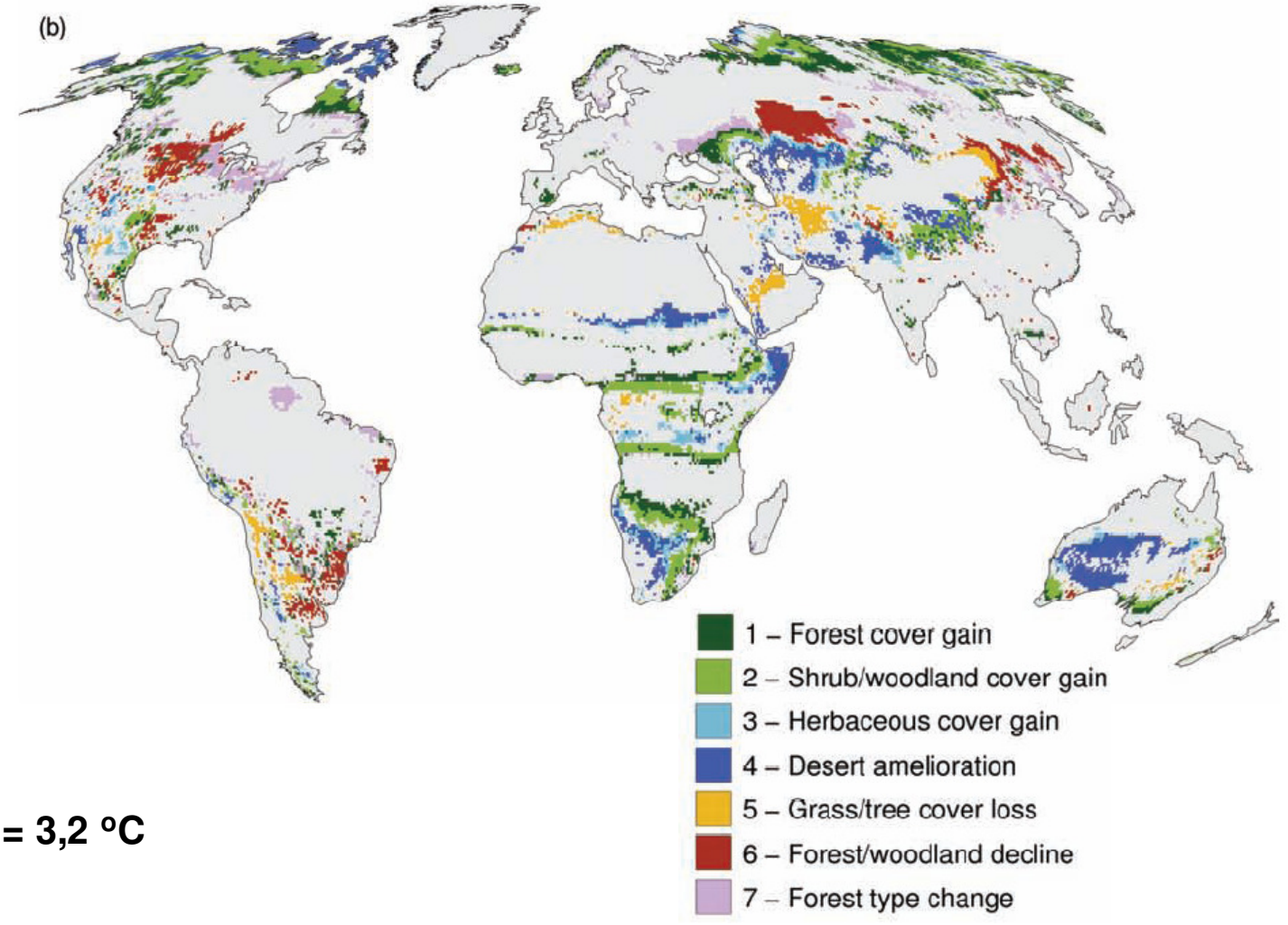


http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-chapter4.pdf



ΔT 2100 = 4,4 ºC

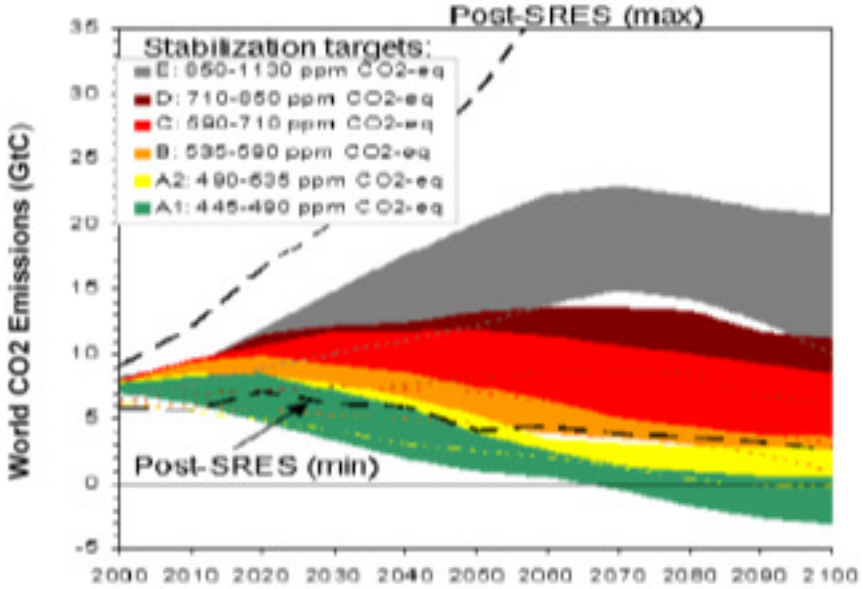
http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-chapter4.pdf

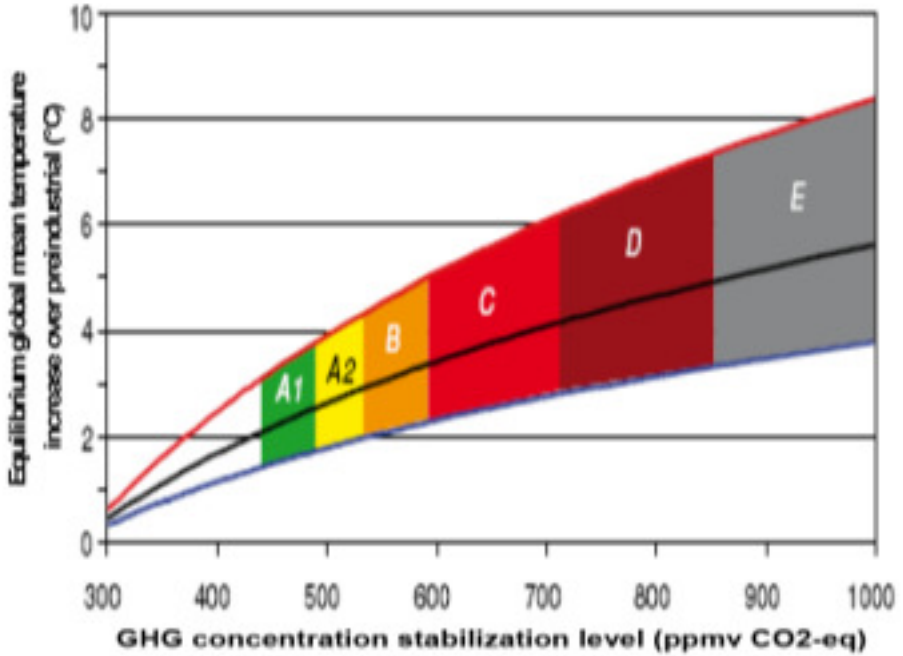


ΔT 2100 = 3,2 °C

http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-chapter4.pdf

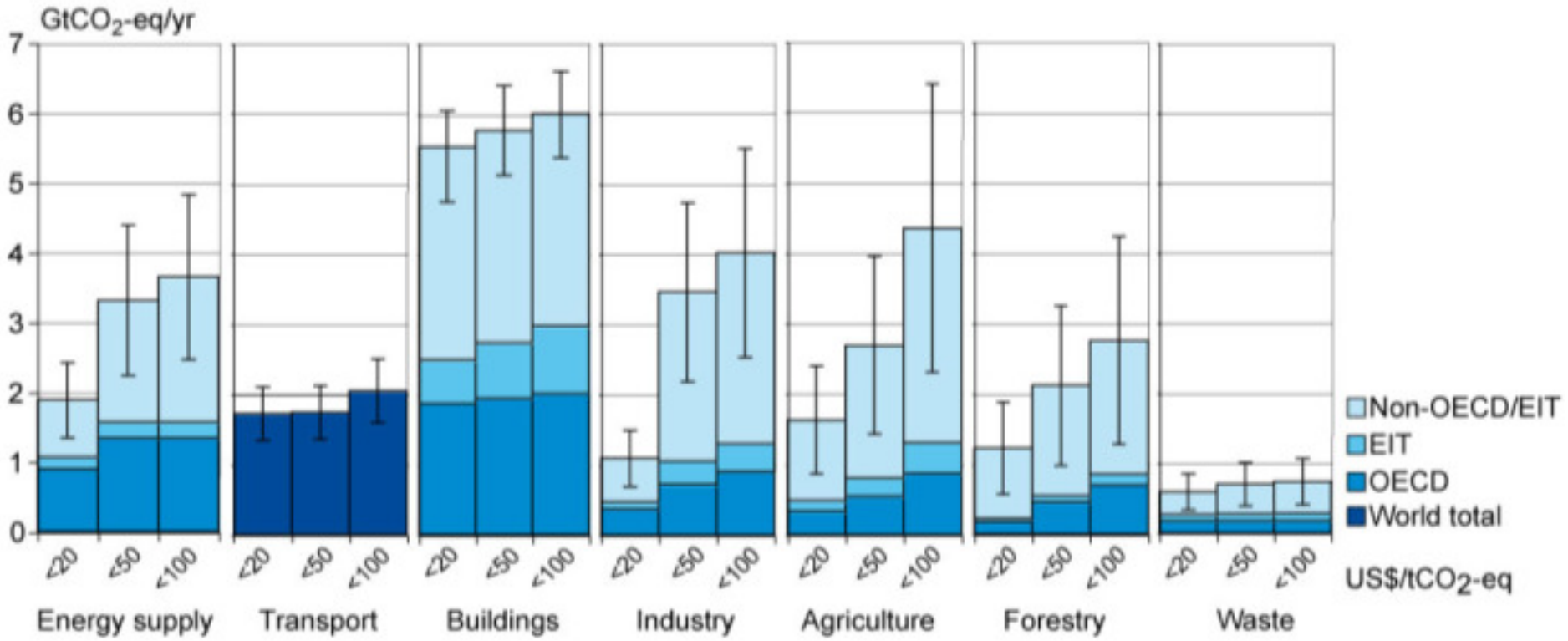
- Equilibrium temperatures reached after 2100
- Uncertainty of climate sensitivity important





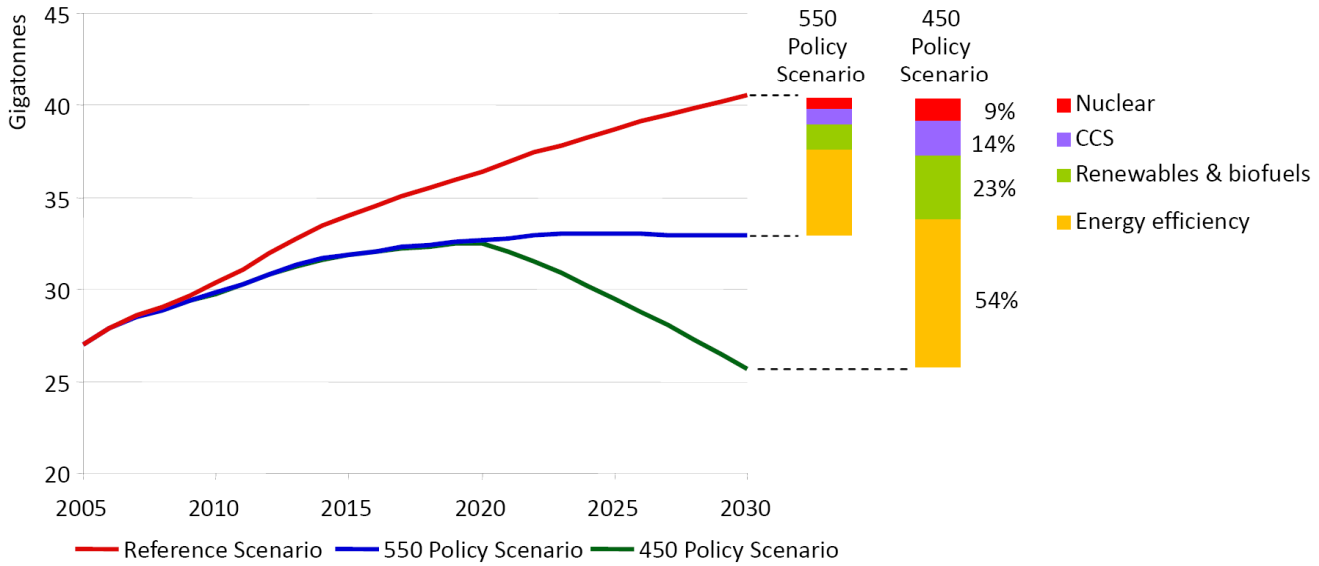
http://www.ipcc.ch/pdf/presentations/poznan-COP-14/ottmar-edenhofer.pdf

todos os setores e regiões têm potencial para contribuir



http://www.ipcc.ch/pdf/presentations/poznan-COP-14/ottmar-edenhofer.pdf

Reductions in energy-related CO_2 emissions in the climate-policy scenarios

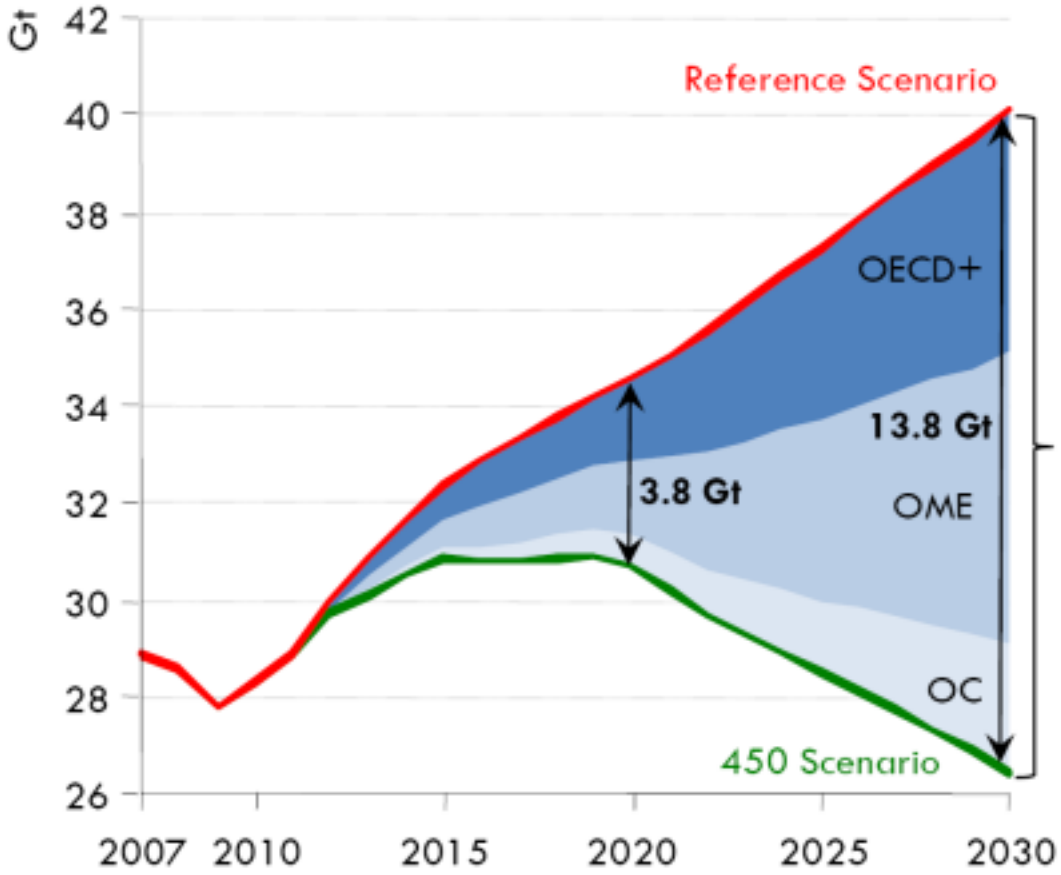


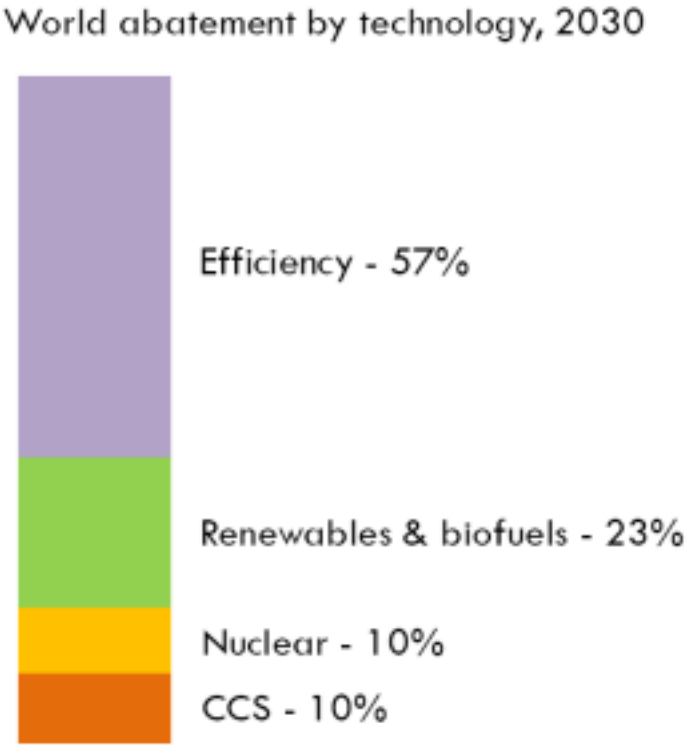
While technological progress is needed to achieve some emissions reductions, efficiency gains and deployment of existing low-carbon energy accounts for most of the savings

Slide 4

INTERNATIONAL ENERGY AGENCY | AGENCE INTERNATIONALE DE L'ENERGIE

http://www.iea.org/speech/2009/Tanaka/Tanaka_MEET.pdf





http://www.iea.org/speech/2009/Birol_WEO2009_Rome.pdf

Materiais para aplicação em altas temperaturas: Turbinas aeronáuticas e para geração de energia

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GRUPO PHASE – Grupo de Diagrama de Fases e Termodinâmica Computacional

- **Membros do grupo:**

  Prof. Gilberto Carvalho Coelho

  Prof. Carlos Angelo Nunes

  Prof. Paulo Atsushi Suzuki

- **Temas de pesquisa:**

  Termodinâmica experimental (diagramas de fases)

  Termodinâmica computacional (bases de dados)

  Materiais para aplicação em altas temperaturas

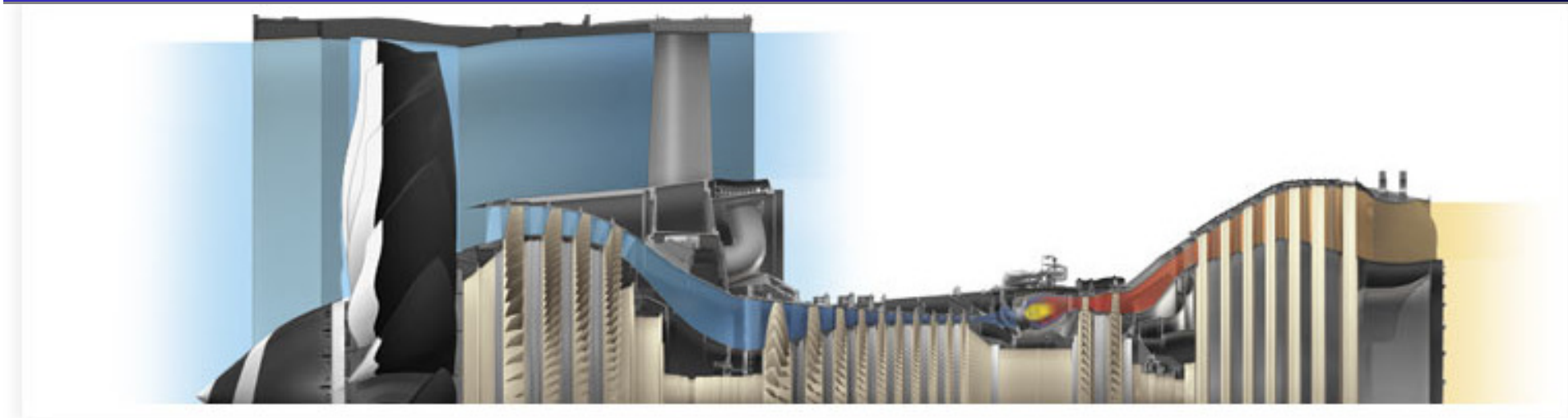
ROTEIRO

- Introdução
- Tipos de turbinas
- Superligas de níquel
- Novos materiais
- Conclusão

Tipos de Turbinas

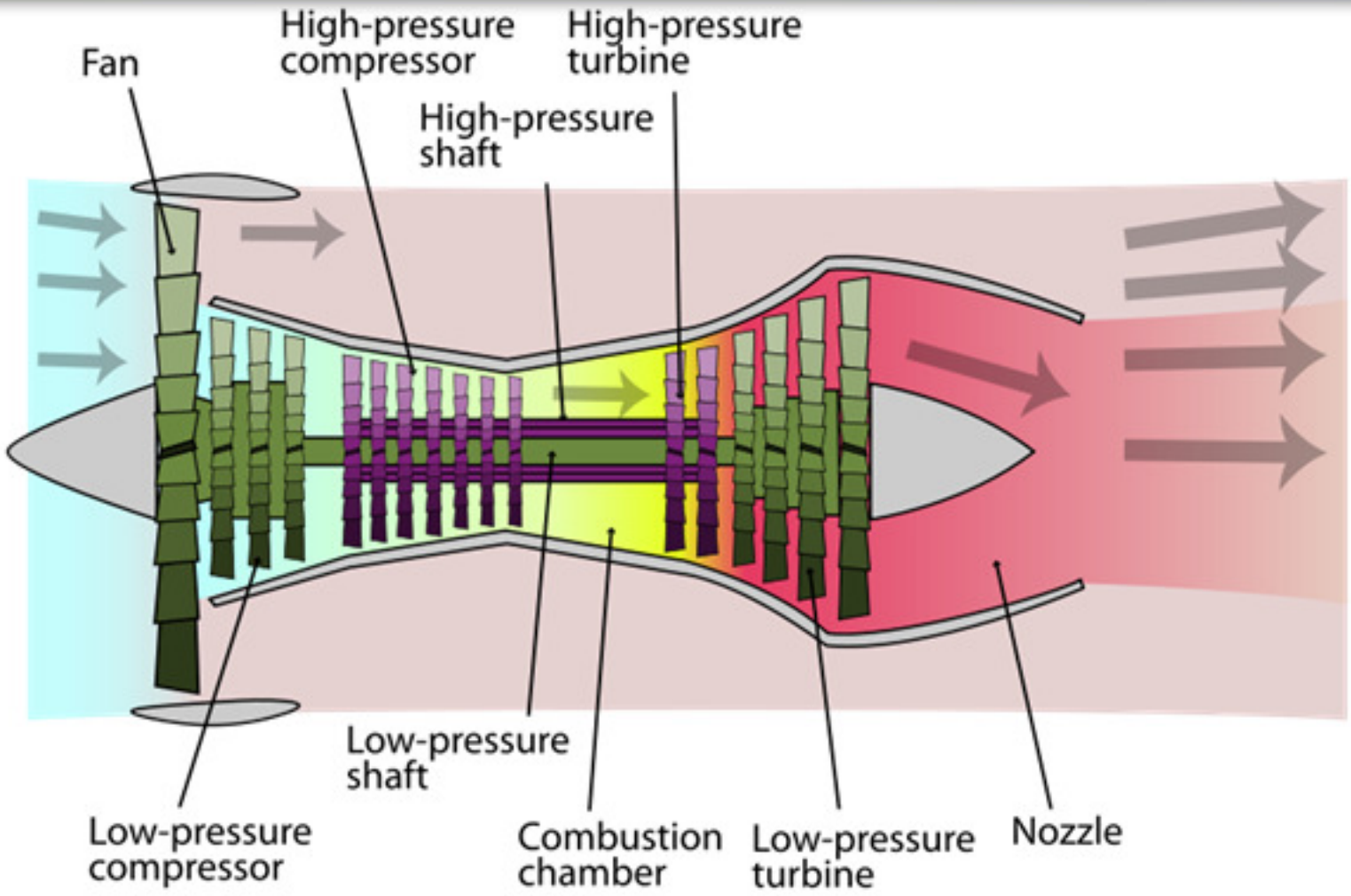
http://www.geae.com/engines/commercial/genx/index.html

Tipos de Turbinas



http://www.geae.com/engines/commercial/genx/index.html

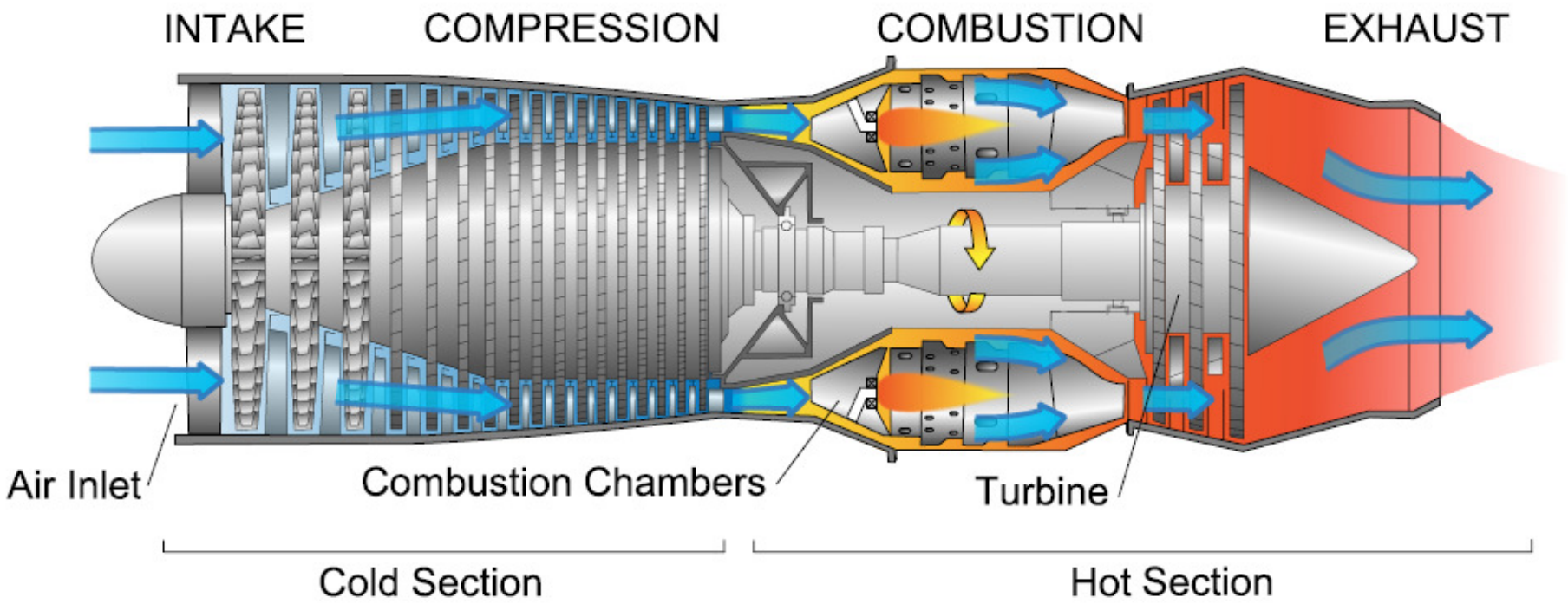
Tipos de Turbinas



http://en.wikipedia.org/wiki/Turbofan

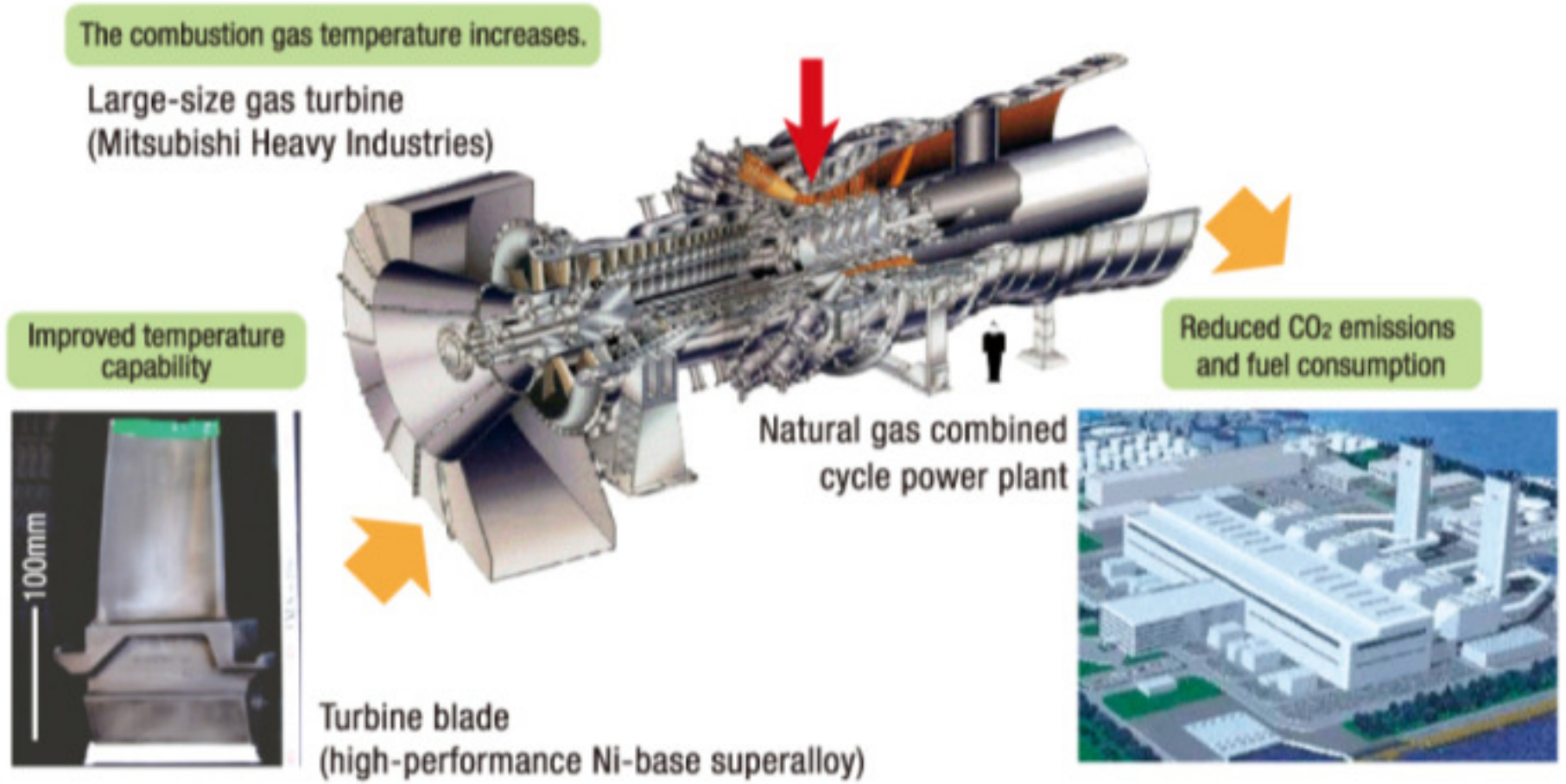
Tipos de Turbinas

Tipos de Turbinas



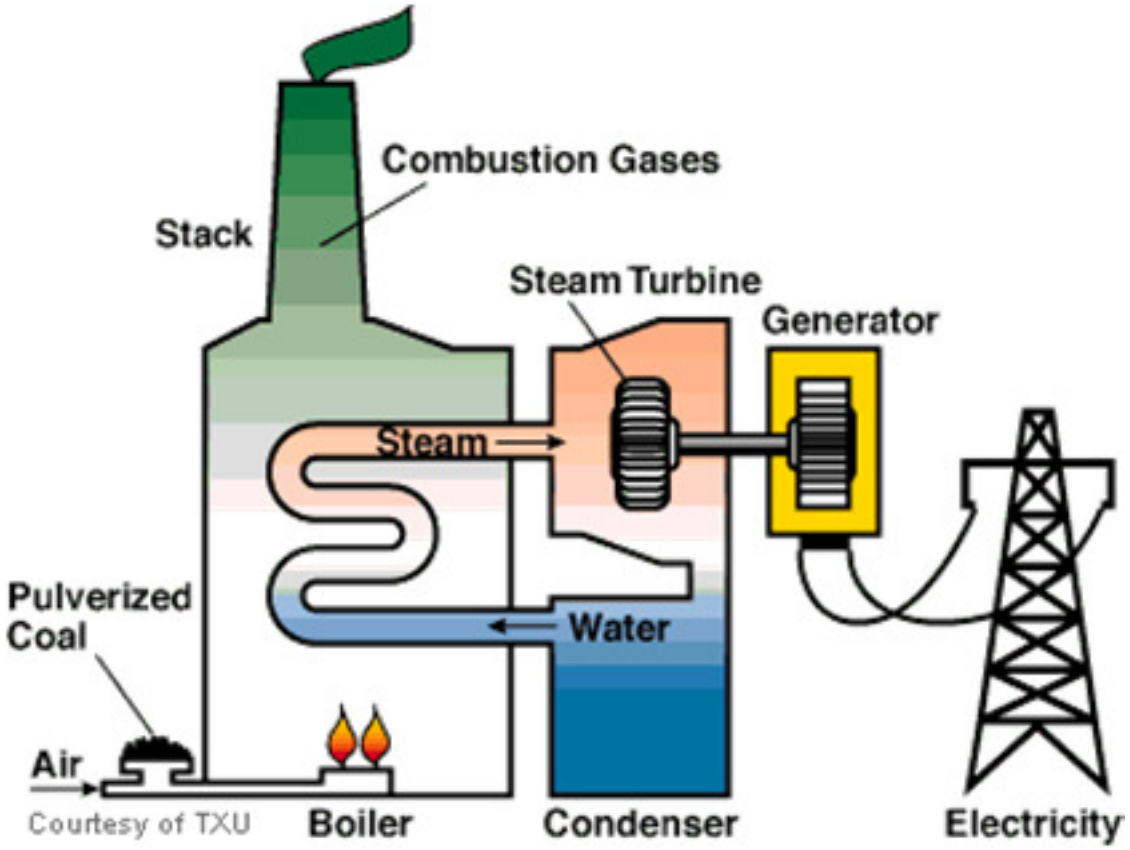
http://en.wikipedia.org/wiki/Gas_turbine

Tipos de Turbinas



H. Harada, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 604-614, 2010

Tipos de Turbinas



Cerca de 80% da energia elétrica no mundo é gerada usando turbinas a vapor

Propriedades dos materiais – aplicações em altas temperaturas

Requirement in design and service	Material property
Static strength	Tensile strength (UTS) 0.2 Yield Strength (0.2YS)
Long-term strength	Creep Rupture Strength (CRS) Creep elongation limits (CEL)
Toughness - short-term - long-term	 Fracture toughness (K_{IC}) Creep rupture elongation Toughness values after long-term aging
Fatigue strength	Low Cycle Fatigue (LCF) High Cycle Fatigue (HCF) Creep Fatigue Interaction (CFI)
Crack tolerance	Static: Creep Crack Growth behaviour (CCG) Alternating: Fatigue Crack Growth (FCG)
Oxidation resistance	Steam oxidation behaviour
Erosion resistance	Erosion behaviour

H. Tschaffon, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 20-28, 2010

Turbinas a vapor – tendências das condições de operação

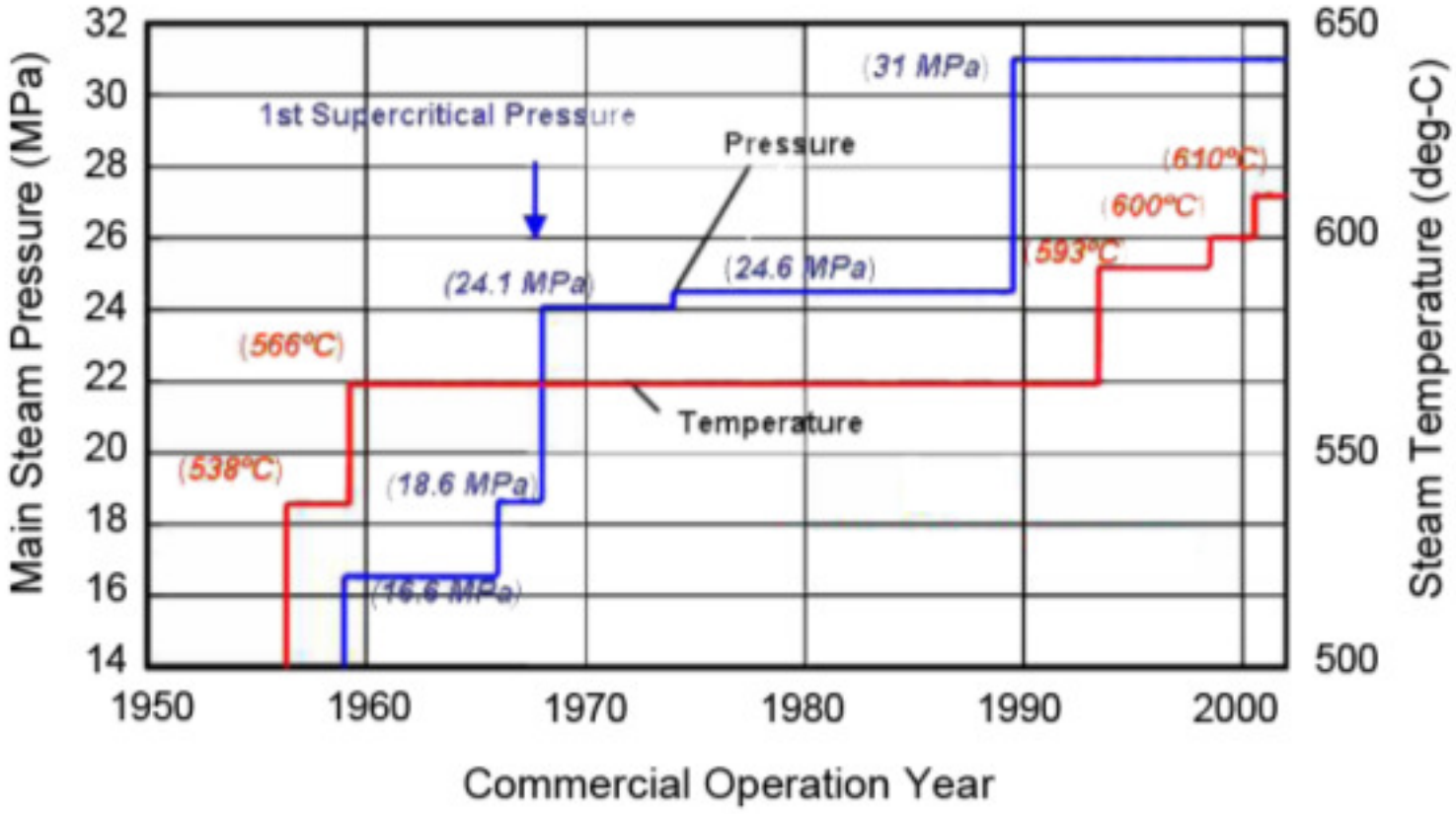


Figure 1 Trend of steam conditions in Japan

M. Fukuda, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 5-19, 2010

Turbinas a vapor – tendências das condições de operação

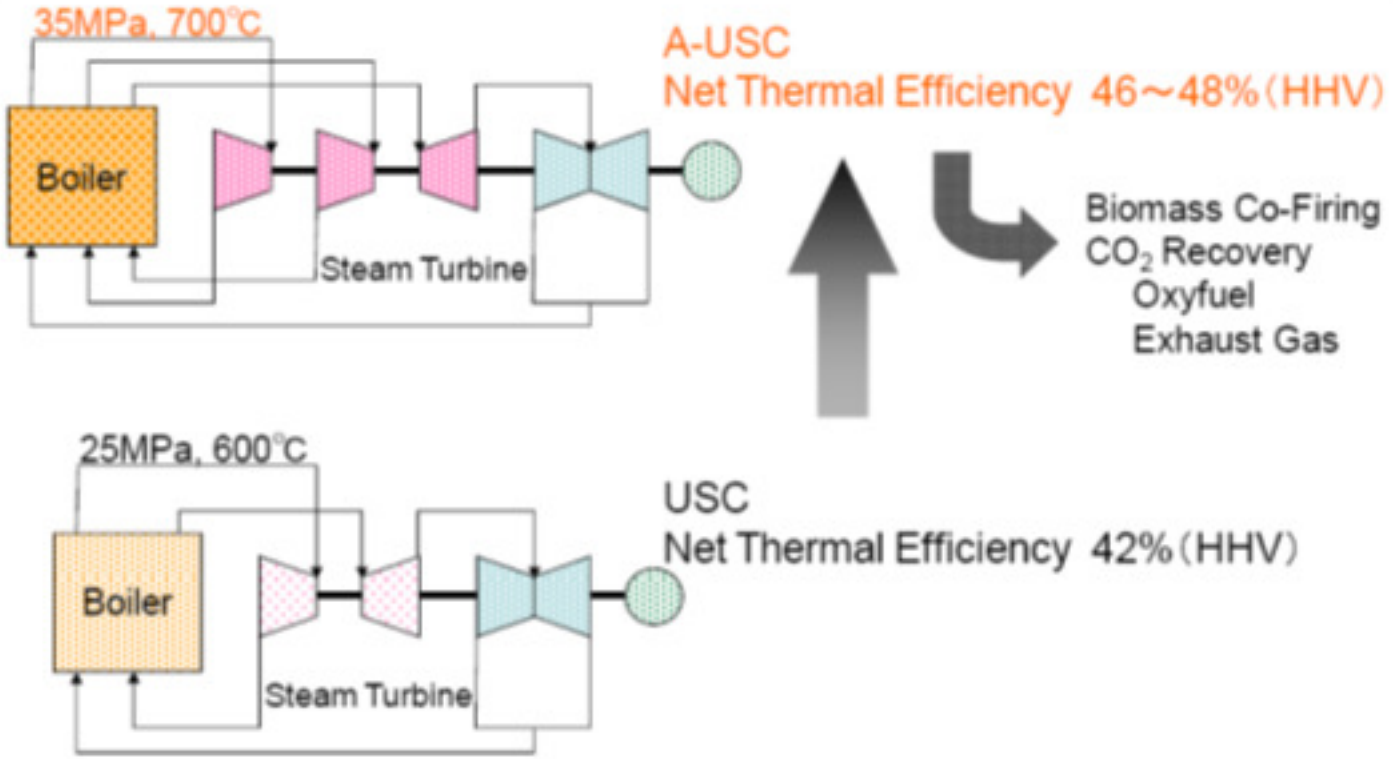
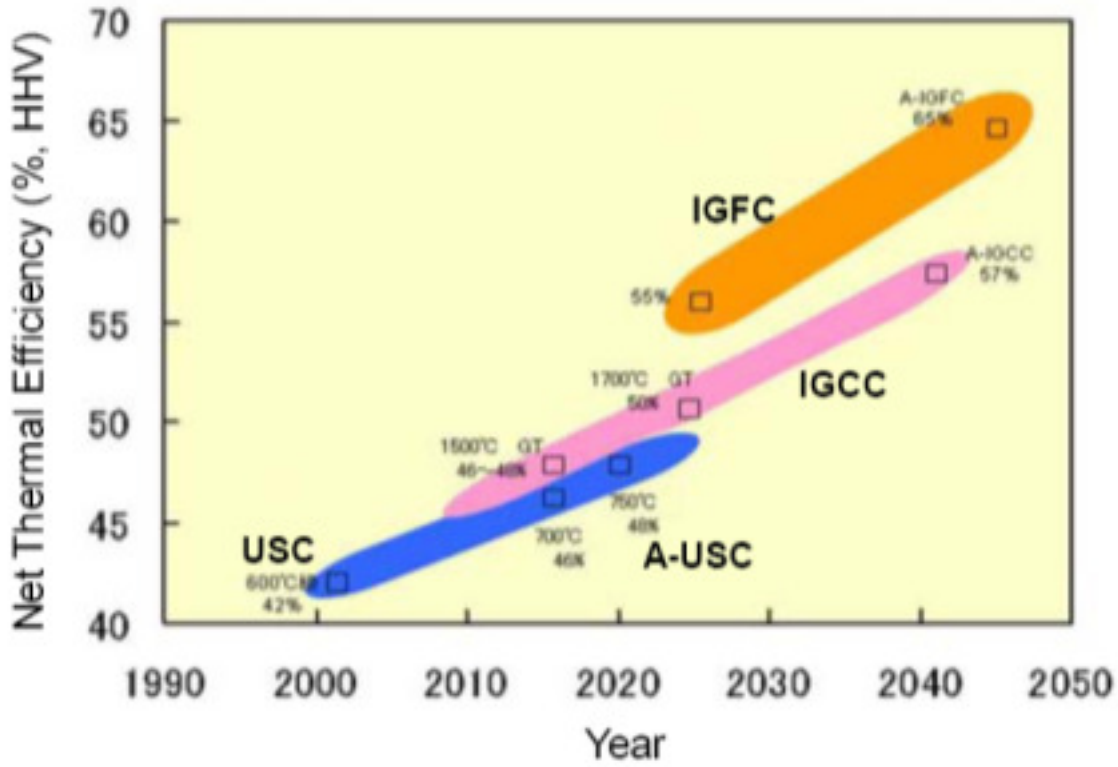


Figure 5 700deg-C class advanced USC (A-USC)

USC (Ultra Super-Critical steam condition)
A-USC (Advanced Ultra Super-Critical steam condition)
HHV (Higher Heating Value – poder calorífico superior)

M. Fukuda, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 5-19, 2010

Turbinas a vapor – tendências das condições de operação



USC **(Ultra Super-Critical steam condition)**
A-USC **(Advanced Ultra Super-Critical steam condition)**
IGCC **(Integrated coal Gaseification Combined Cicle)**
IGFC **(Integrated coal Gaseification Fuel Cell Combined Cicle)**

M. Fukuda, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 5-19, 2010

Turbinas a vapor – tendências das condições de operação

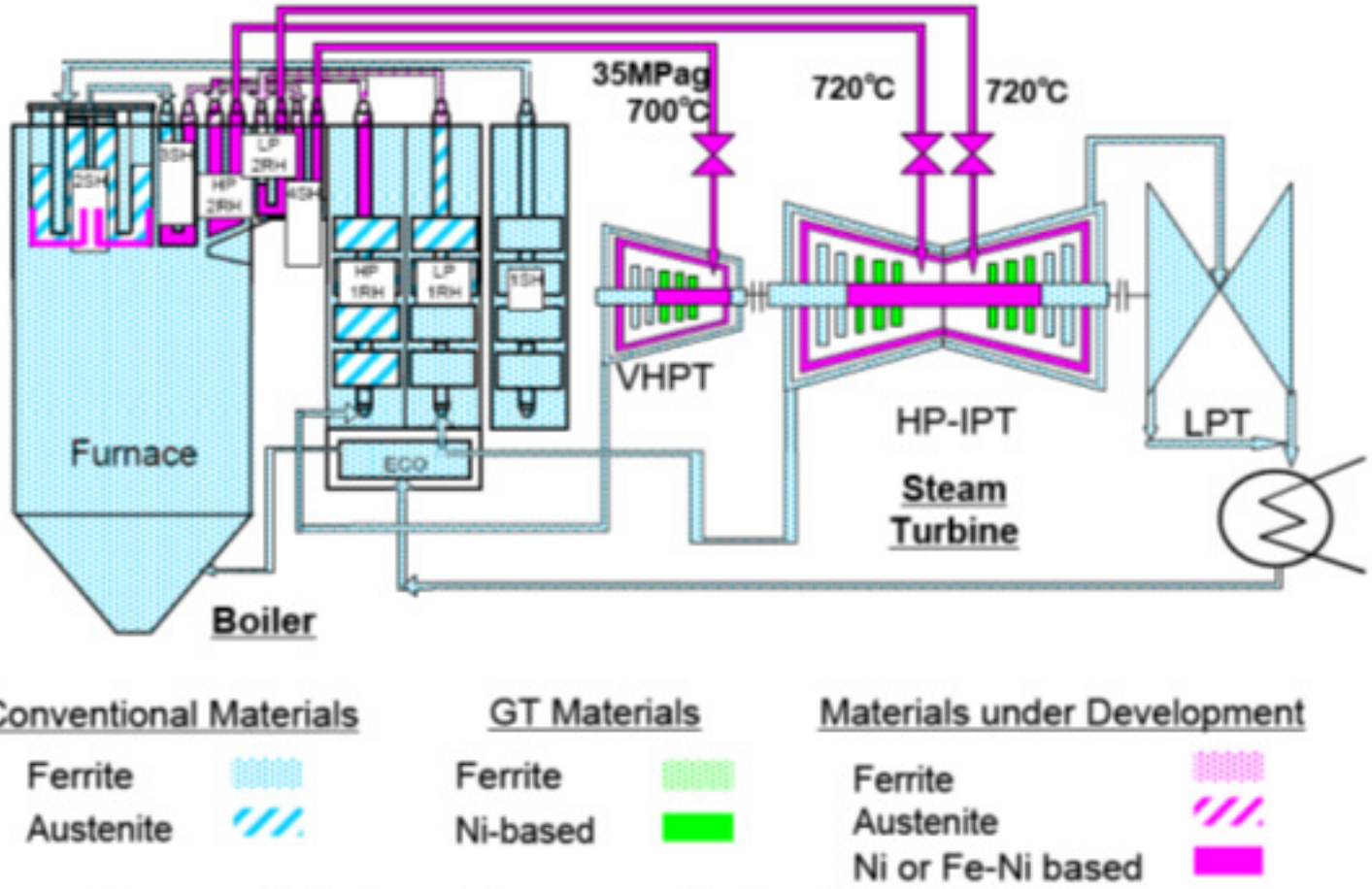


Figure 8 Selected materials for double reheat system

M. Fukuda, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 5-19, 2010

Turbinas a vapor – tendências das condições de operação

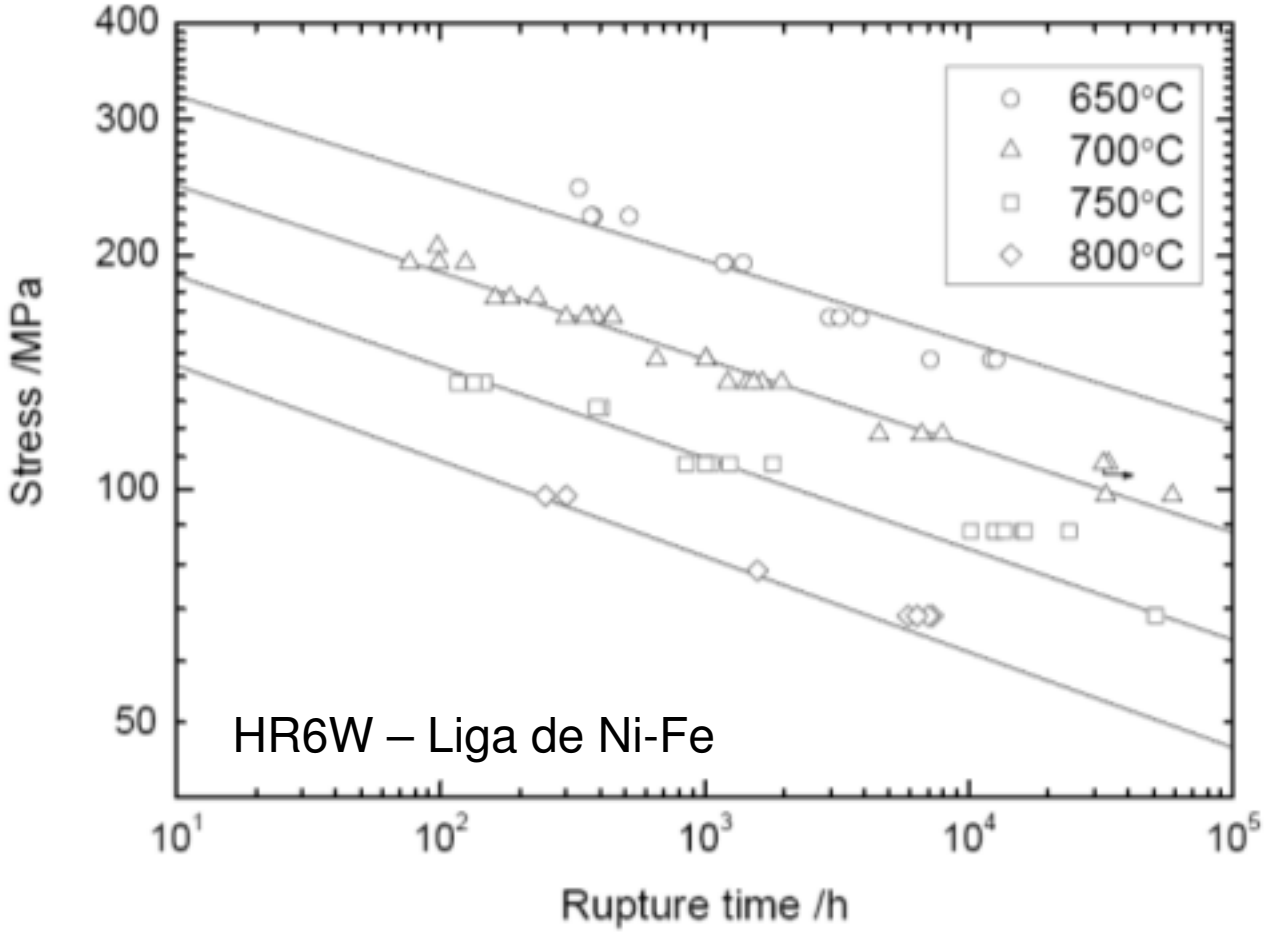


Figure 14 HR6W creep rupture strength (Courtesy of Sumitomo Metal Industries)

M. Fukuda, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 5-19, 2010

Turbinas a vapor – tendências das condições de operação

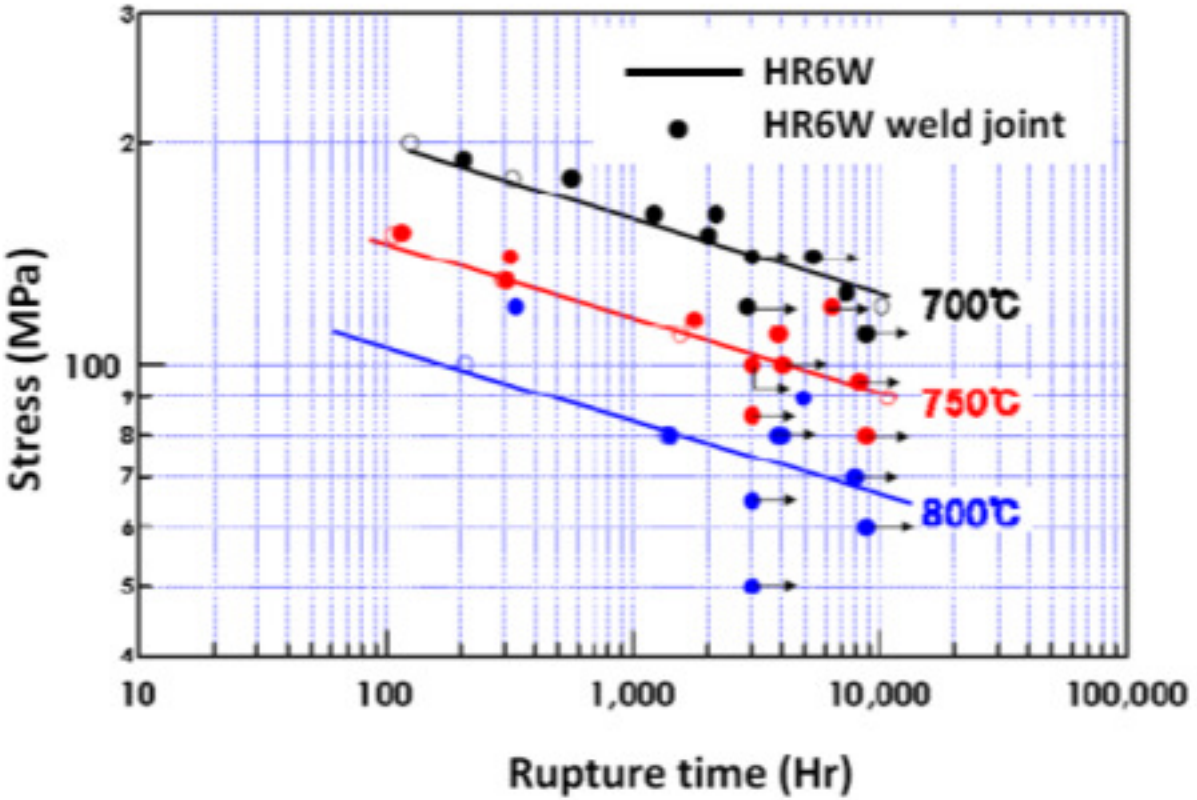


Figure 15 Creep rupture strength of HR6W weld
(Courtesy of Babcock-Hitachi, IHI, Mitsubishi Heavy Industries)

M. Fukuda, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 5-19, 2010

Turbinas a vapor – ensaio de corrosão

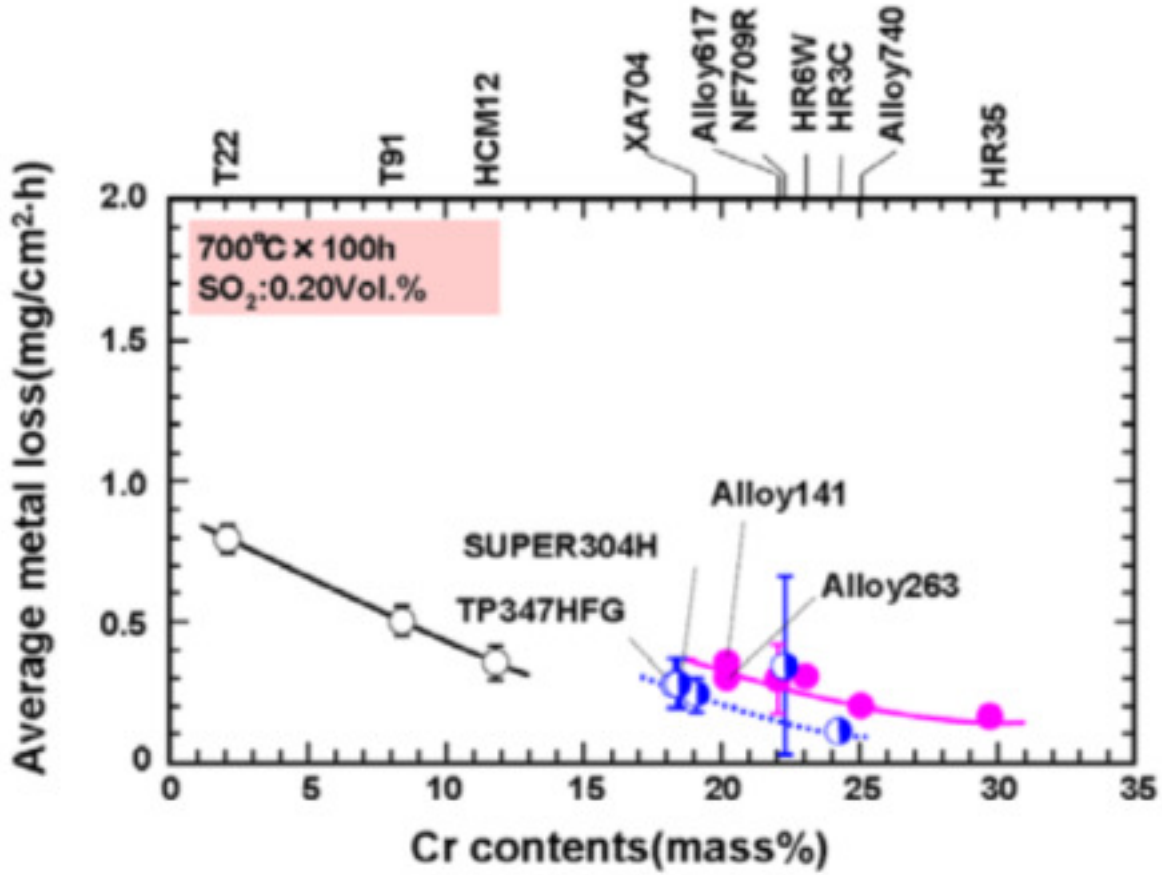


Figure 16 Hot corrosion test (Courtesy of Mitsubishi Heavy Industries)

M. Fukuda, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 5-19, 2010

Turbinas a vapor – ensaio de oxidação

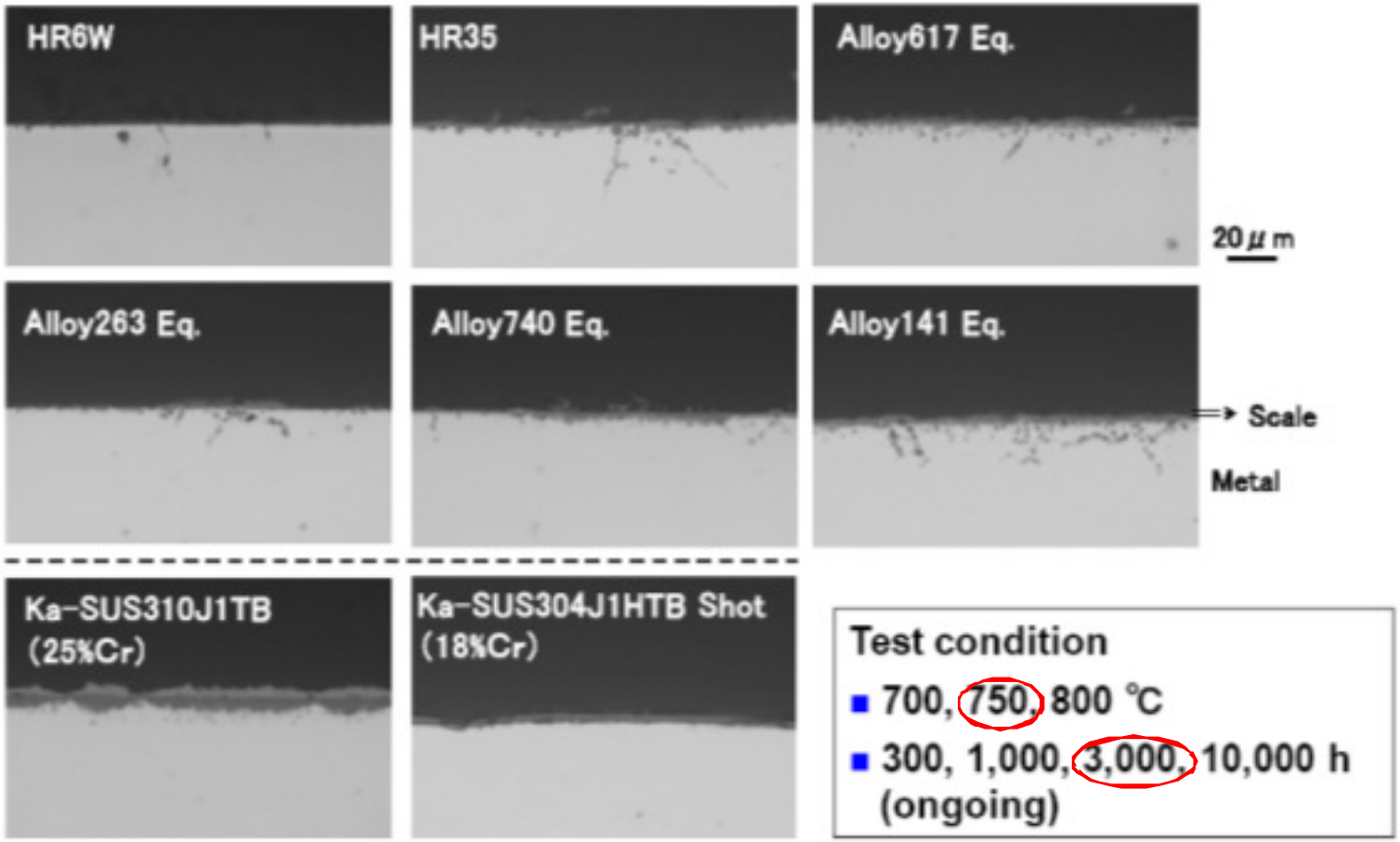


Figure 17 Steam oxidation test (Courtesy of Babcock-Hitachi)

M. Fukuda, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 5-19, 2010

Turbinas a vapor – desenvolvimento de processos (extrusão)

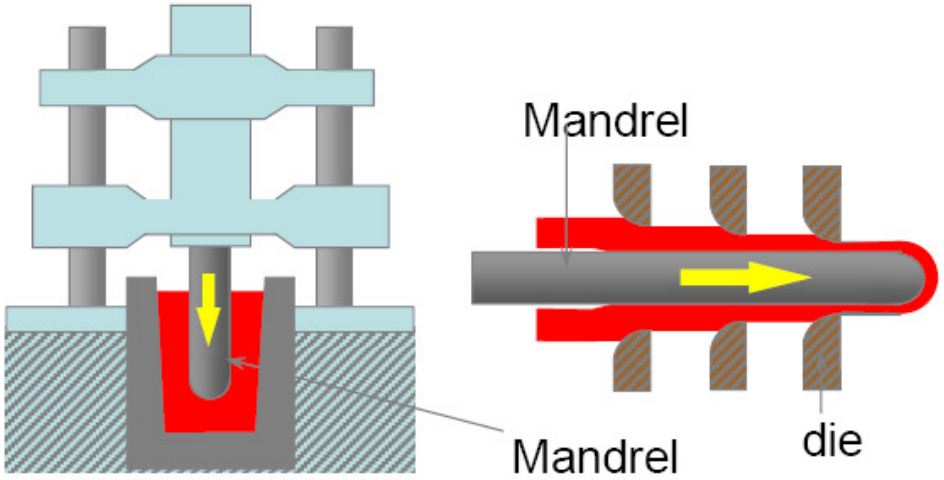
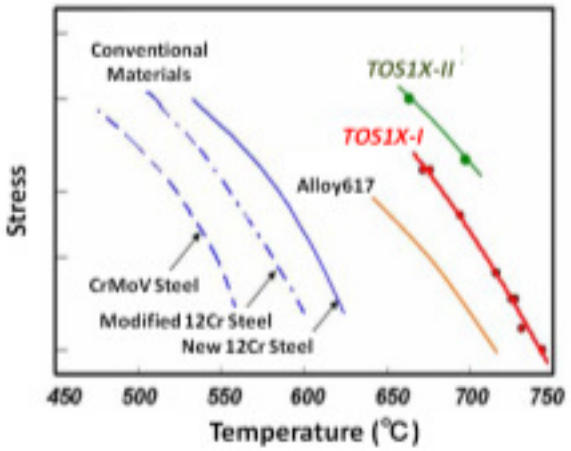


Figure 18 Pipes prepared for material test (Courtesy of Sumitomo Metal Industries)

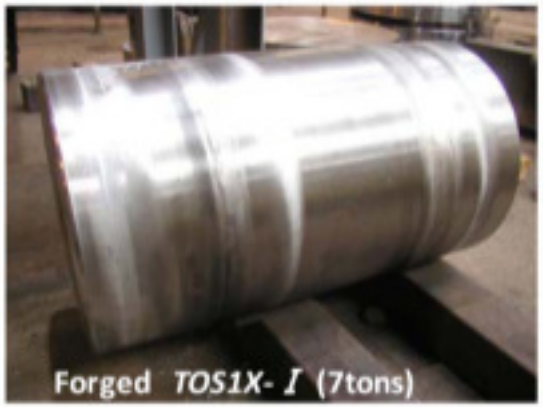
M. Fukuda, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 5-19, 2010

Turbinas a vapor – desenvolvimento de ligas para forjamento

Figure 24 12Cr steel disc for welding test with LTES700R (Courtesy of Mitsubishi Heavy Industries)



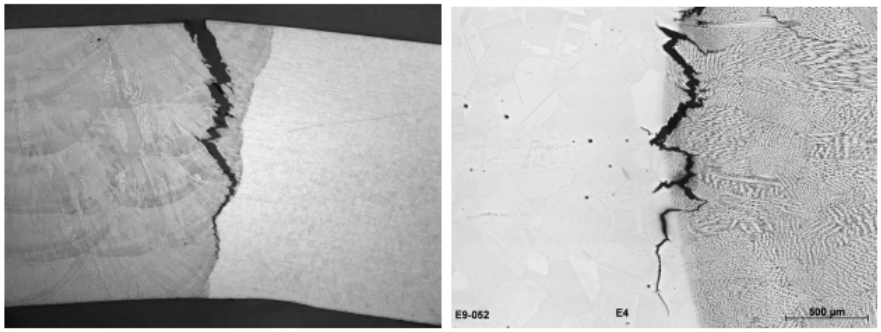
100,000 hr Creep Rupture Strength



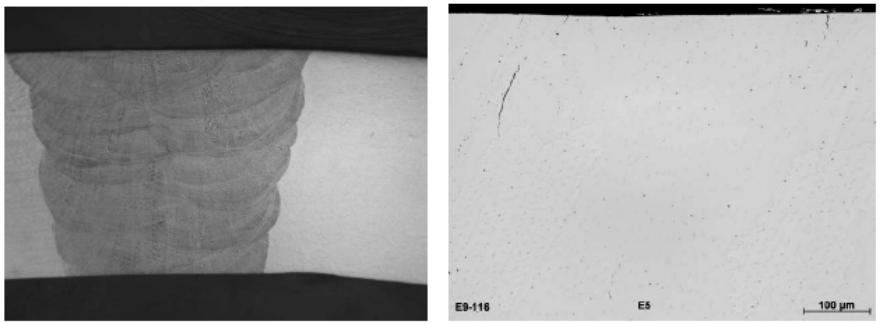
M. Fukuda, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 5-19, 2010

Turbinas a vapor – desenv. de processos (soldagem + T.T.)

Figure 6: TNO-test: Crack behaviour with and without heat treatment with 980°C, 3h



Without heat treatment: Interdendritic macro crack in the weld metal next to the fusion line propagating towards the HAZ



Nearly no cracks with heat treatment (high ductility of the material)

H. Tschaffon, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 20-28, 2010

Turbinas a vapor – tendências das condições de operação

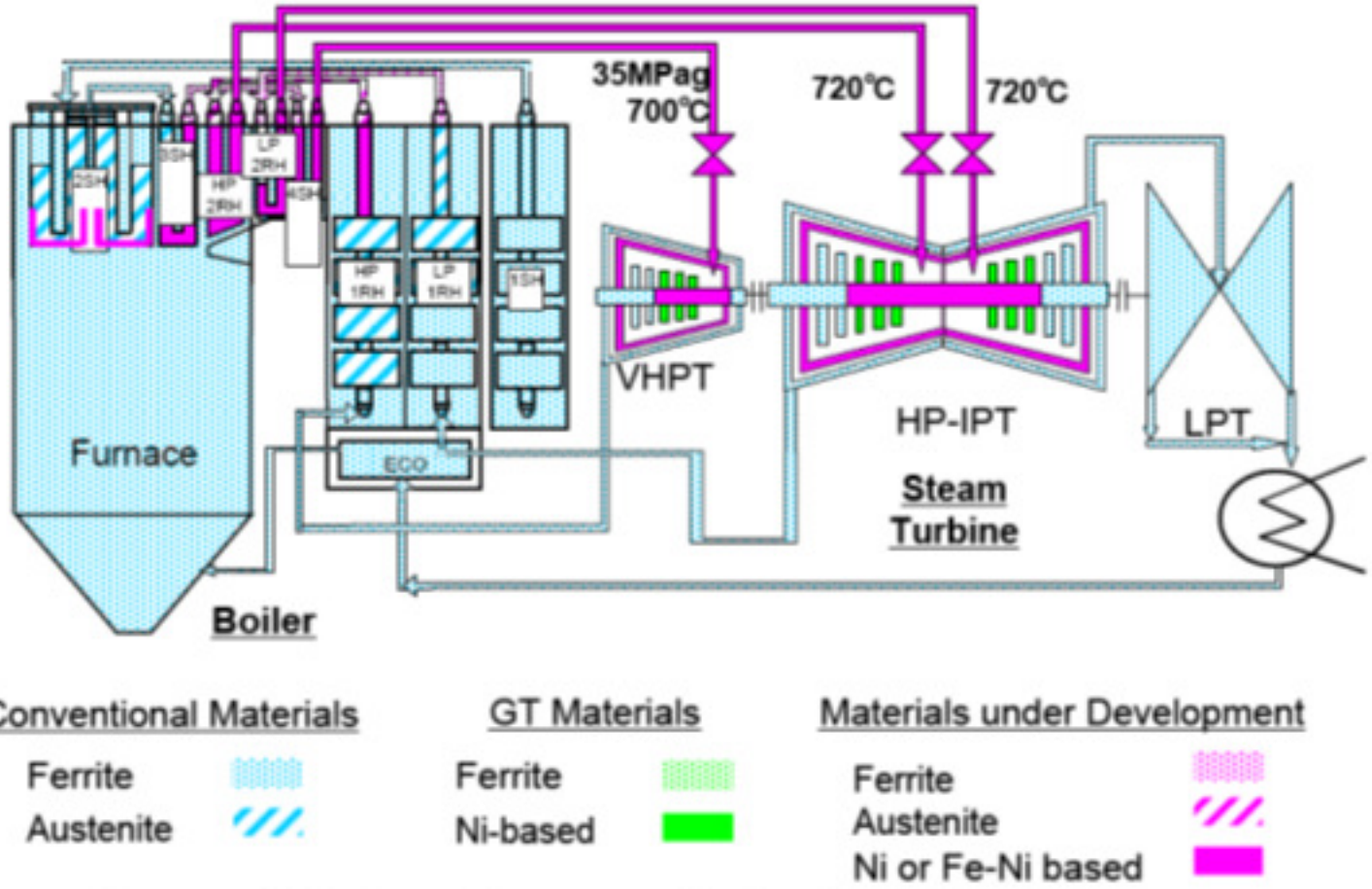
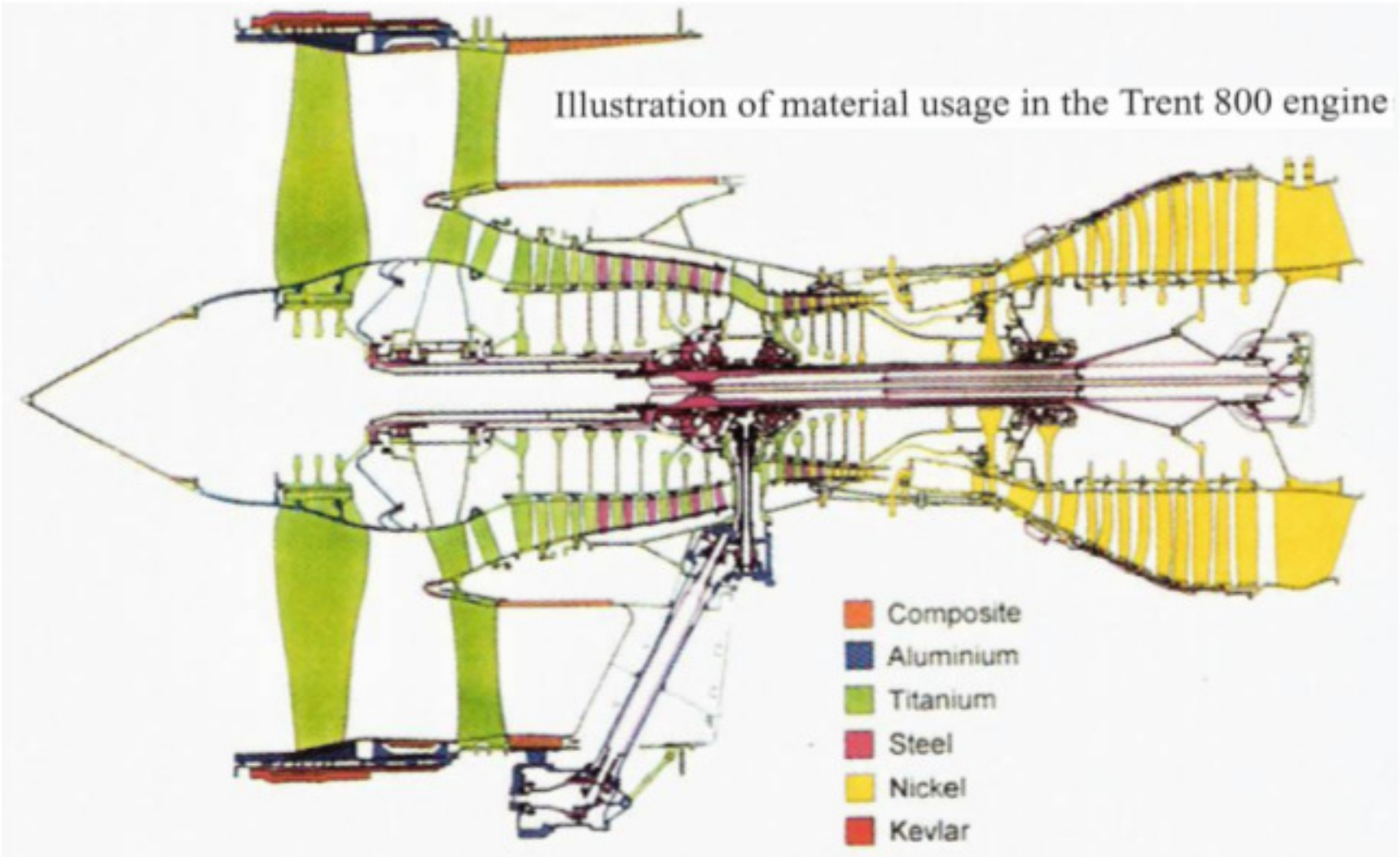


Figure 8 Selected materials for double reheat system

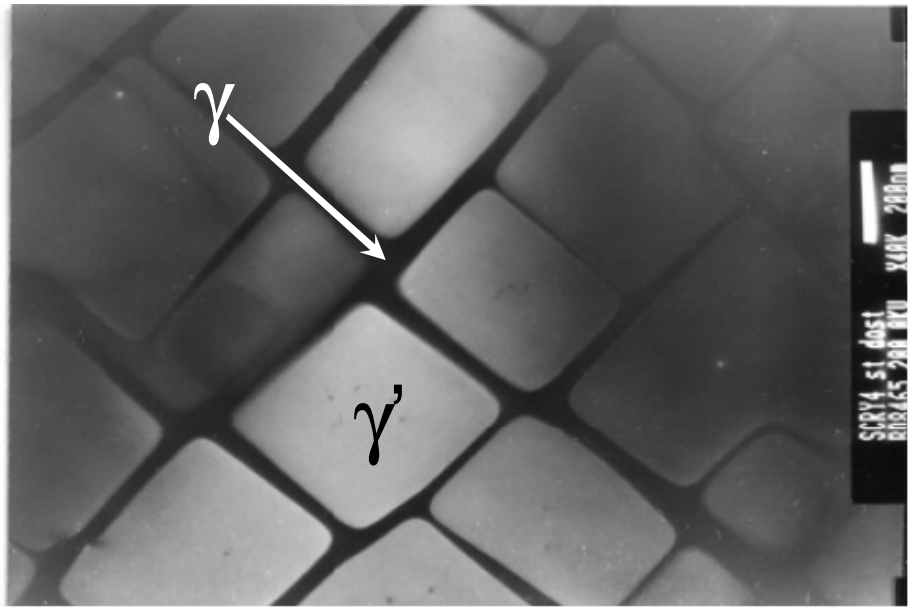
M. Fukuda, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 5-19, 2010

Superligas de níquel



R.C. Reed, The Superalloys – Fundamentals and Applications, Cambridge University Press, Cambridge, 2006

Superligas de níquel – Microestrutura



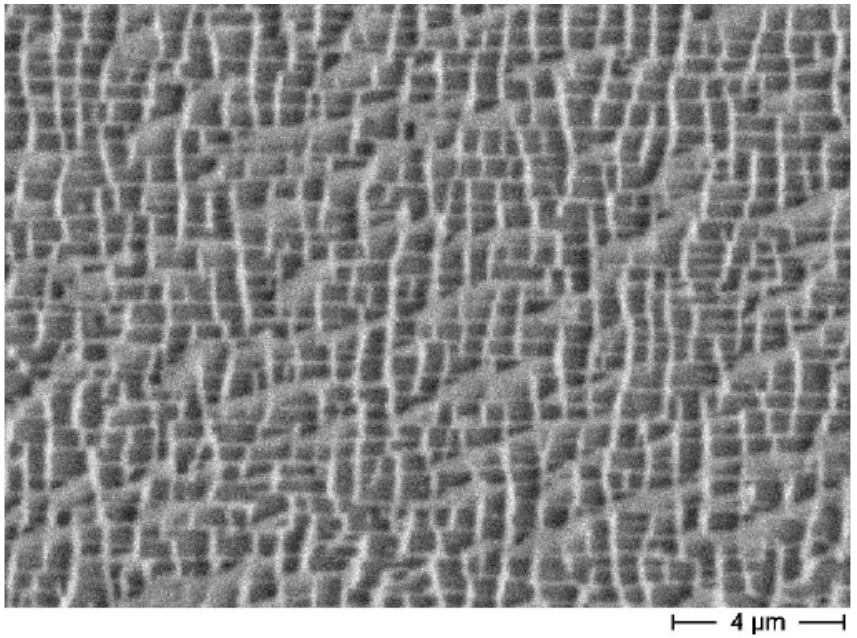
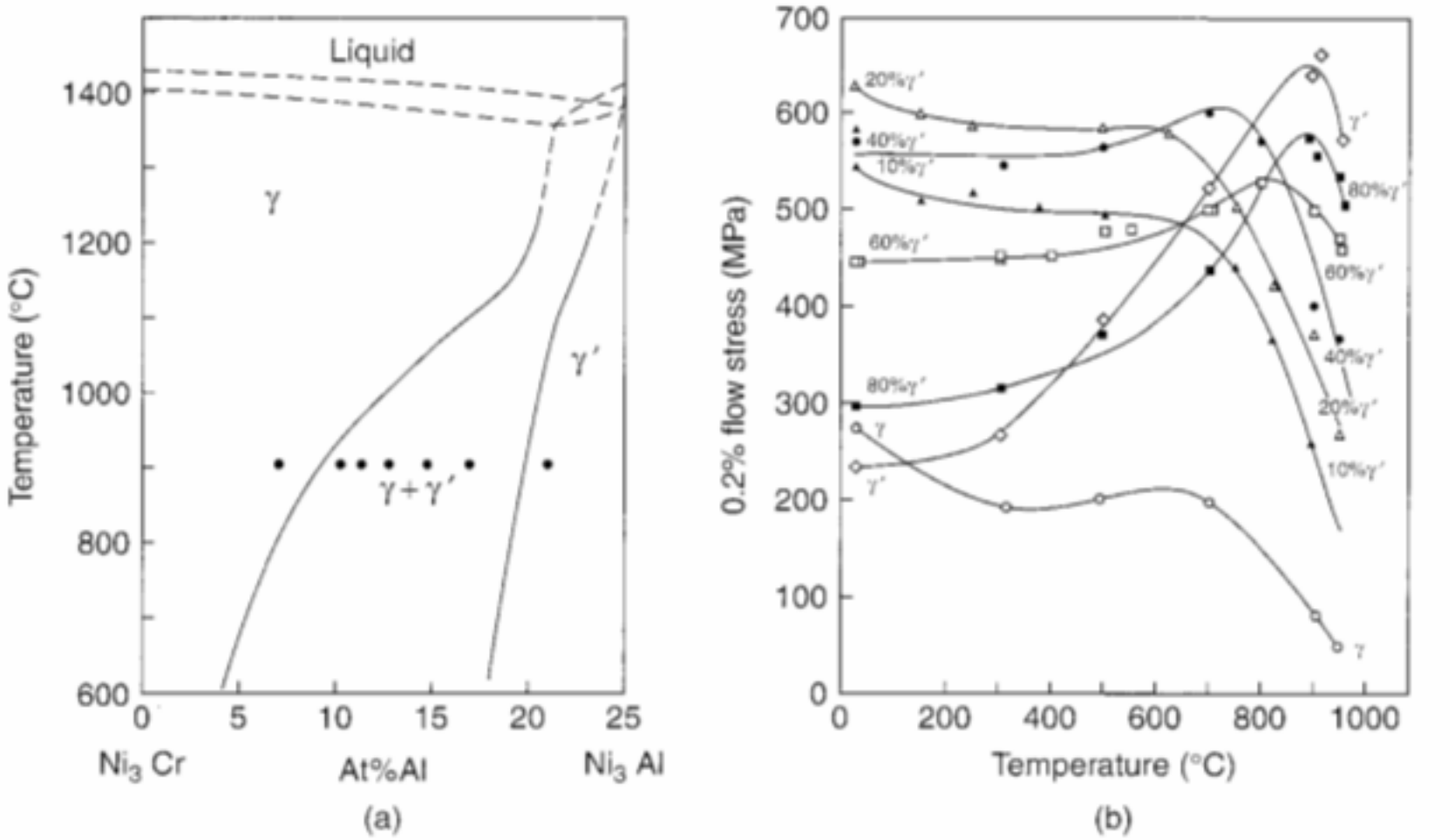


Figure 2: SEM dark field image of CMSX-4 microstructure (taken from γ' reflection), (left) & SEM image (right)

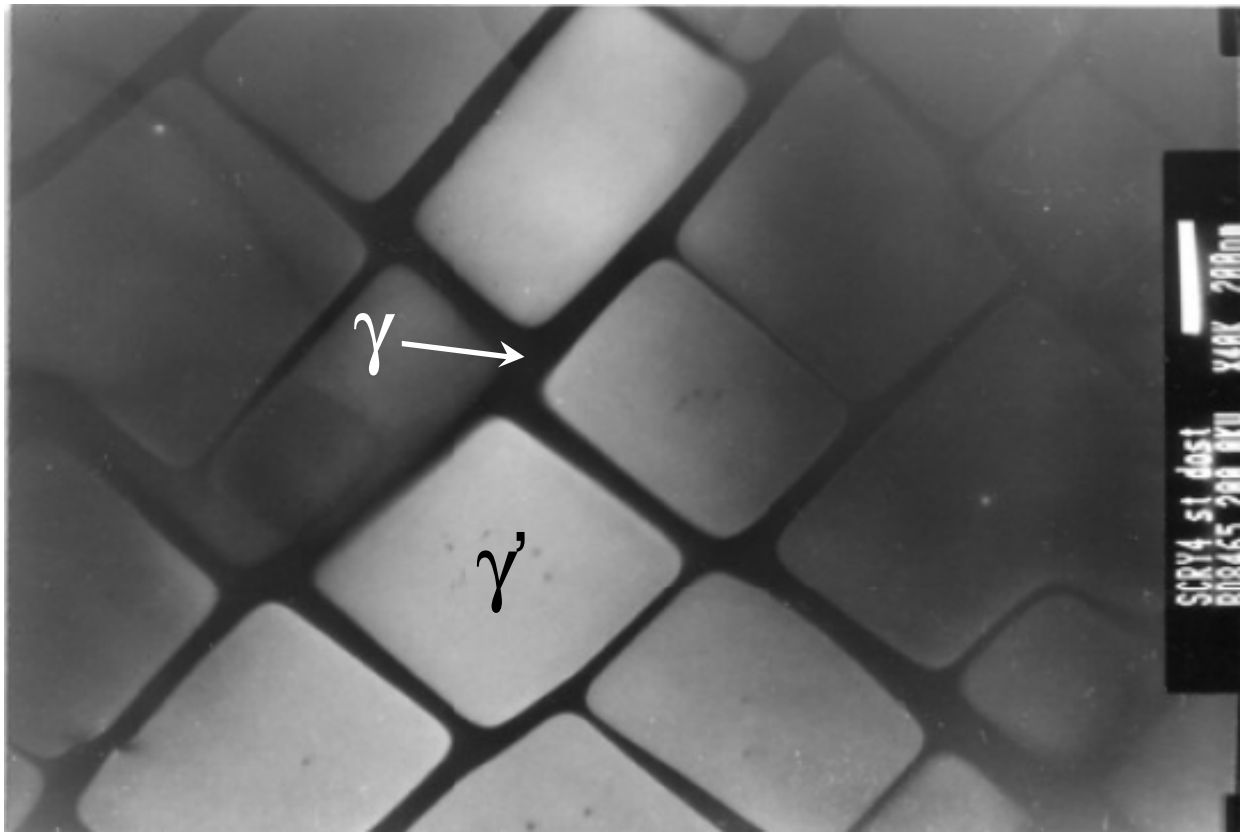
A. Scholz *et al.*, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 567-587, 2010

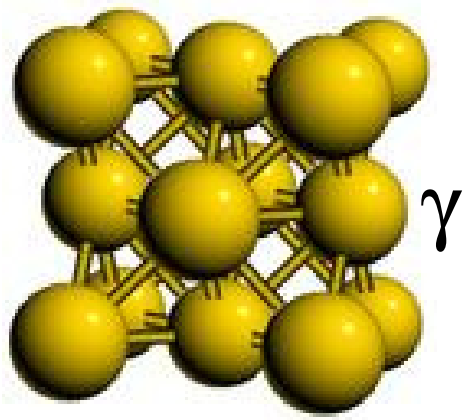
Superligas de níquel – Anomalia na tensão de escoamento

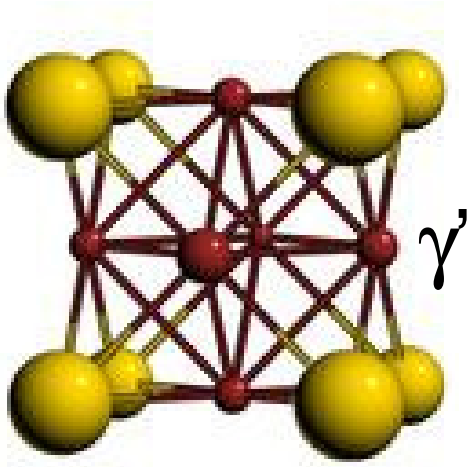


R.C. Reed, The Superalloys – Fundamentals and Applications, Cambridge University Press, Cambridge, 2006

Superligas de níquel – Microestrutura







A. Scholz *et al.*, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 567-587, 2010

Superligas de níquel – Estabilidade Microestrutural

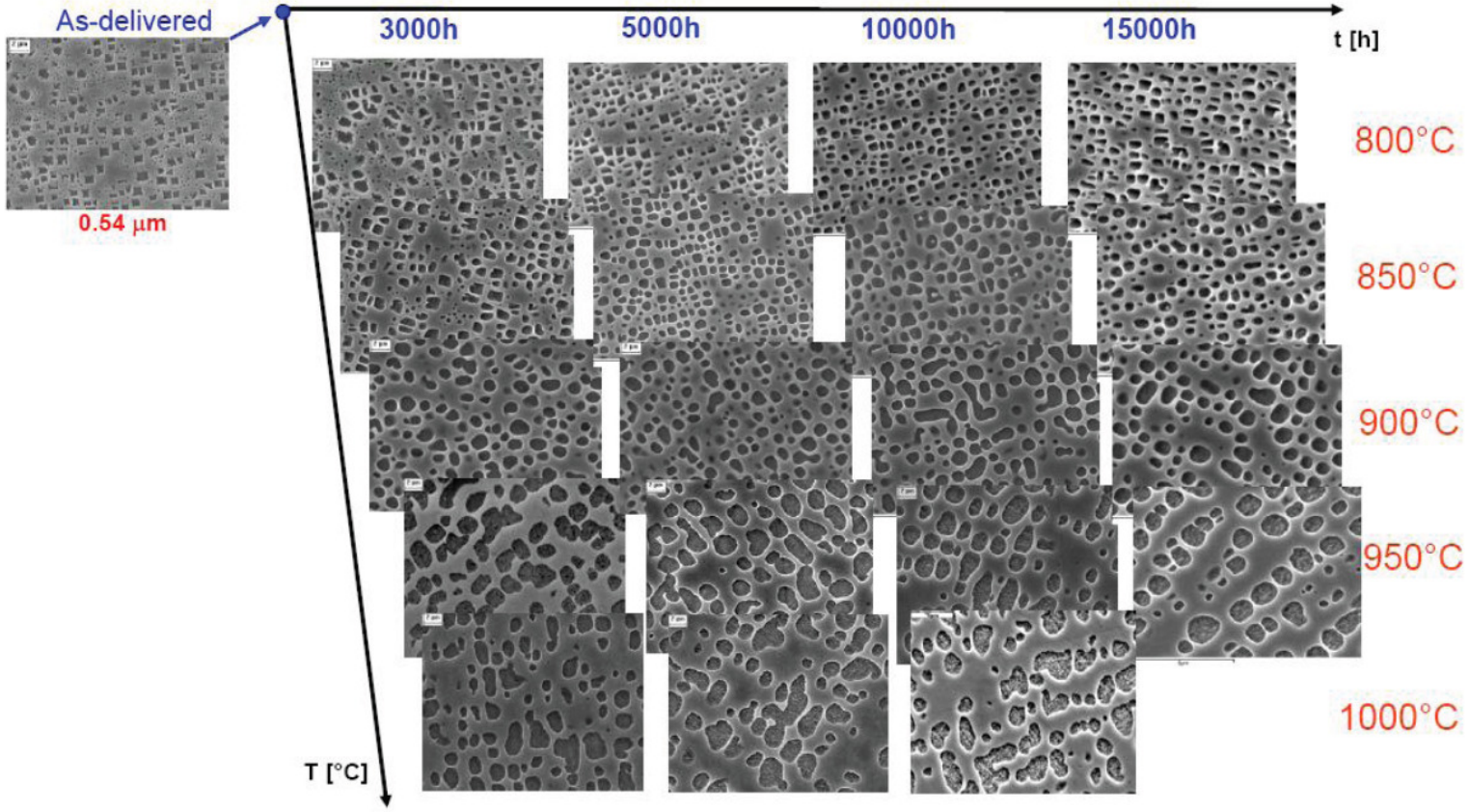


Figure 1: Microstructure evolution of primary γ' phase in IN738LC superalloys after isothermal exposure.

M. Mandeli *et al.*, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 707-716, 2010

Superligas de níquel – Estabilidade Microestrutural

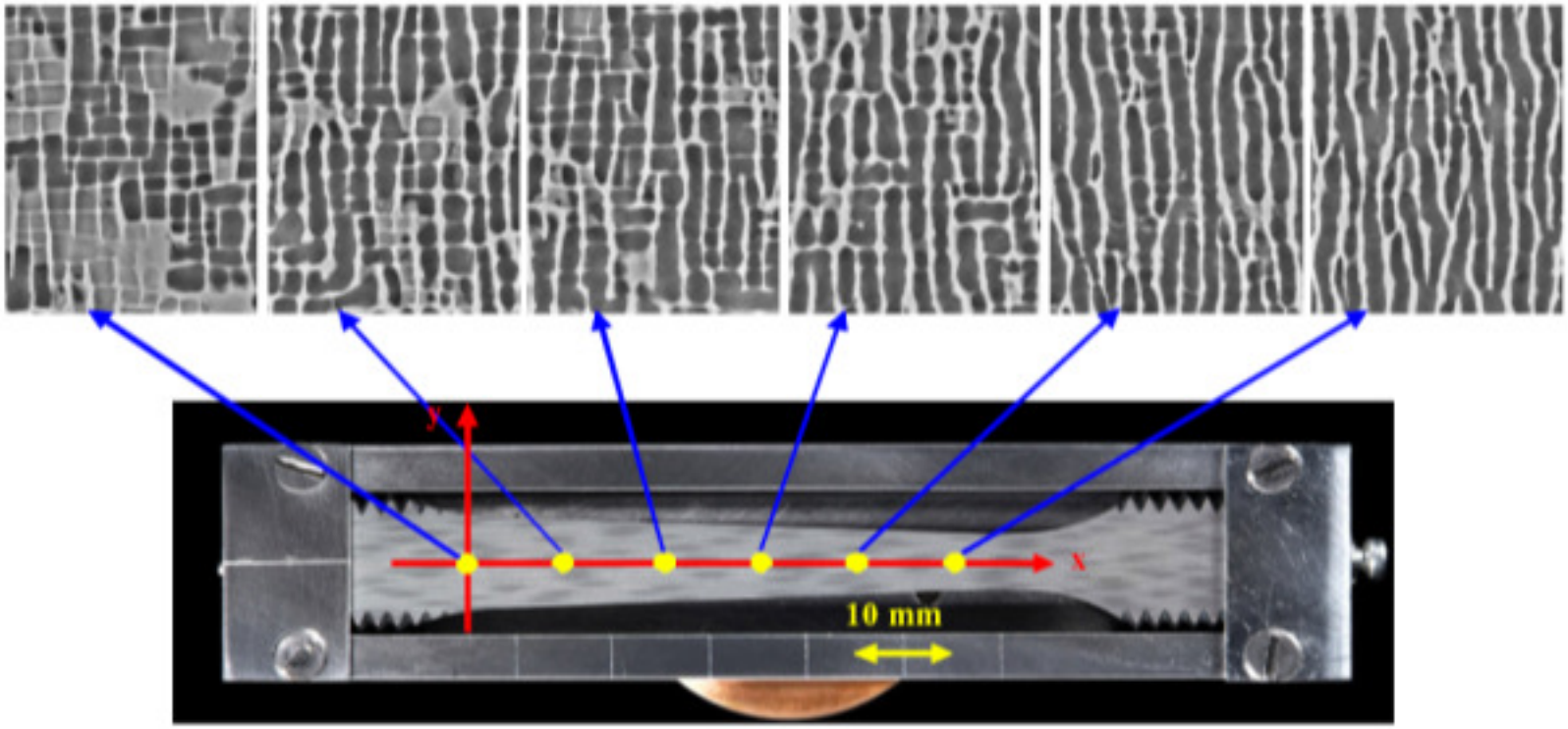
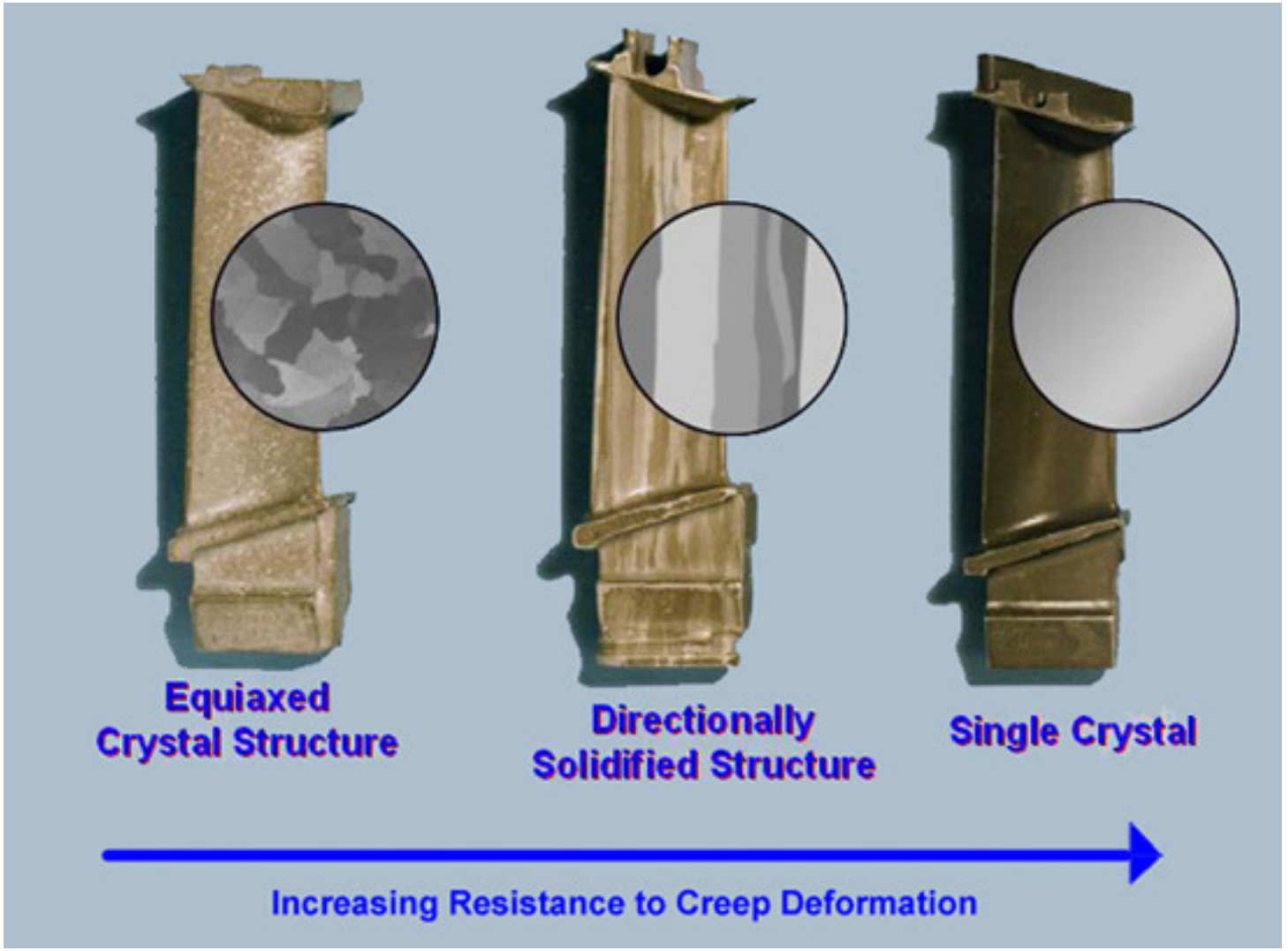


Figure 8: SEM holder with conical specimen degraded at 1050°C/175 h. Areas of analysis and SEM images correspond to the stress range 59 to 94 MPa [6]

A. Scholz *et al.*, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 567-587, 2010

Superligas de níquel – Microestrutura



Superligas de níquel – Propr. Mecânicas em Altas Temperaturas

Table 1. Chemical composition single crystal superalloy, wt.%

Al	Cr	Mo	W	Ta	Co	Re	Ru	Ni
6.0	3.3	4.0	4.0	5.0	7.0	6.5	4.0	basic

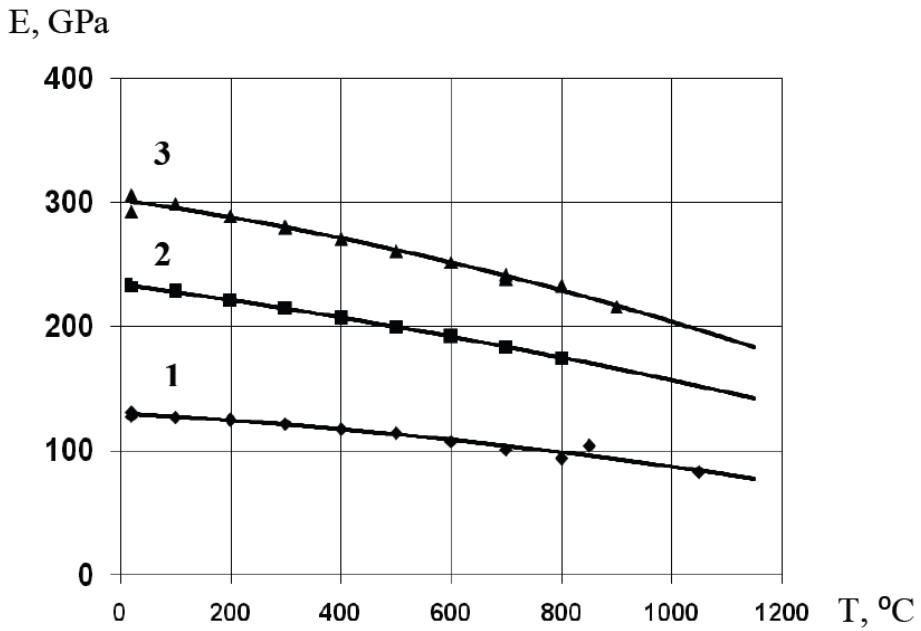


Fig. 1 Temperature dependence of Young modulus in single crystals of 1 - <001>, 2 - <011>, 3 - <111> orientations

I.L. Svetlov *et al.*, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 652-659, 2010

Superligas de níquel – Propr. Mecânicas em Altas Temperaturas

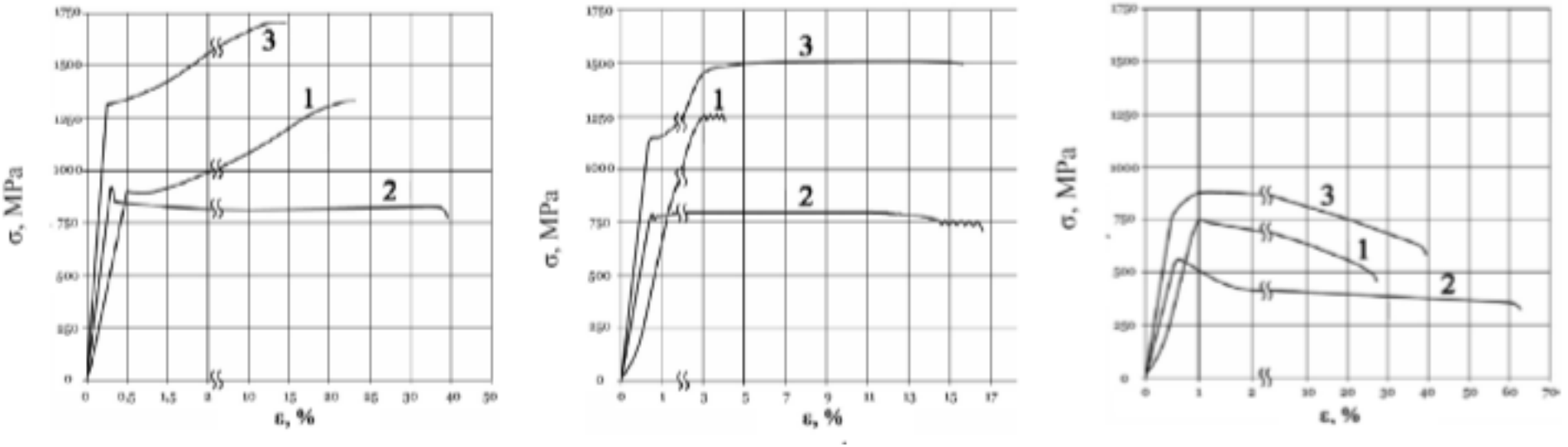


Fig. 2 Deformation diagrams of the investigated alloy with crystallographic orientations, close to <001>,<011> and <111> at temperatures: 20 °C (a), 700 °C(b) and 1000 °C (c)

I.L. Svetlov *et al.*, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 652-659, 2010

Superligas de níquel – Propr. Mecânicas em Altas Temperaturas

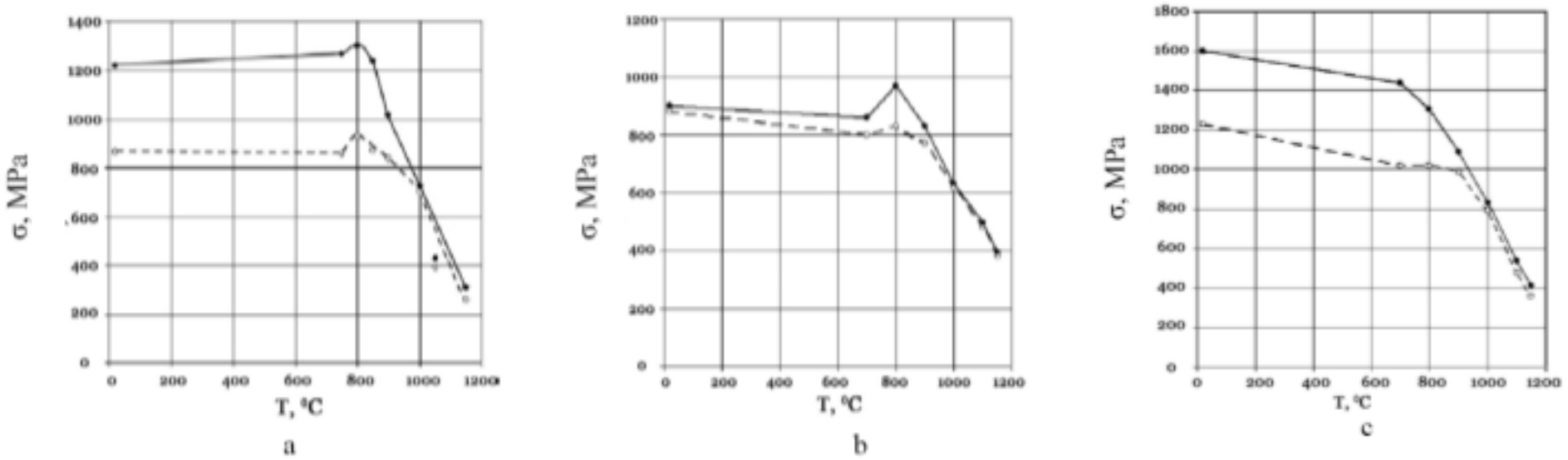
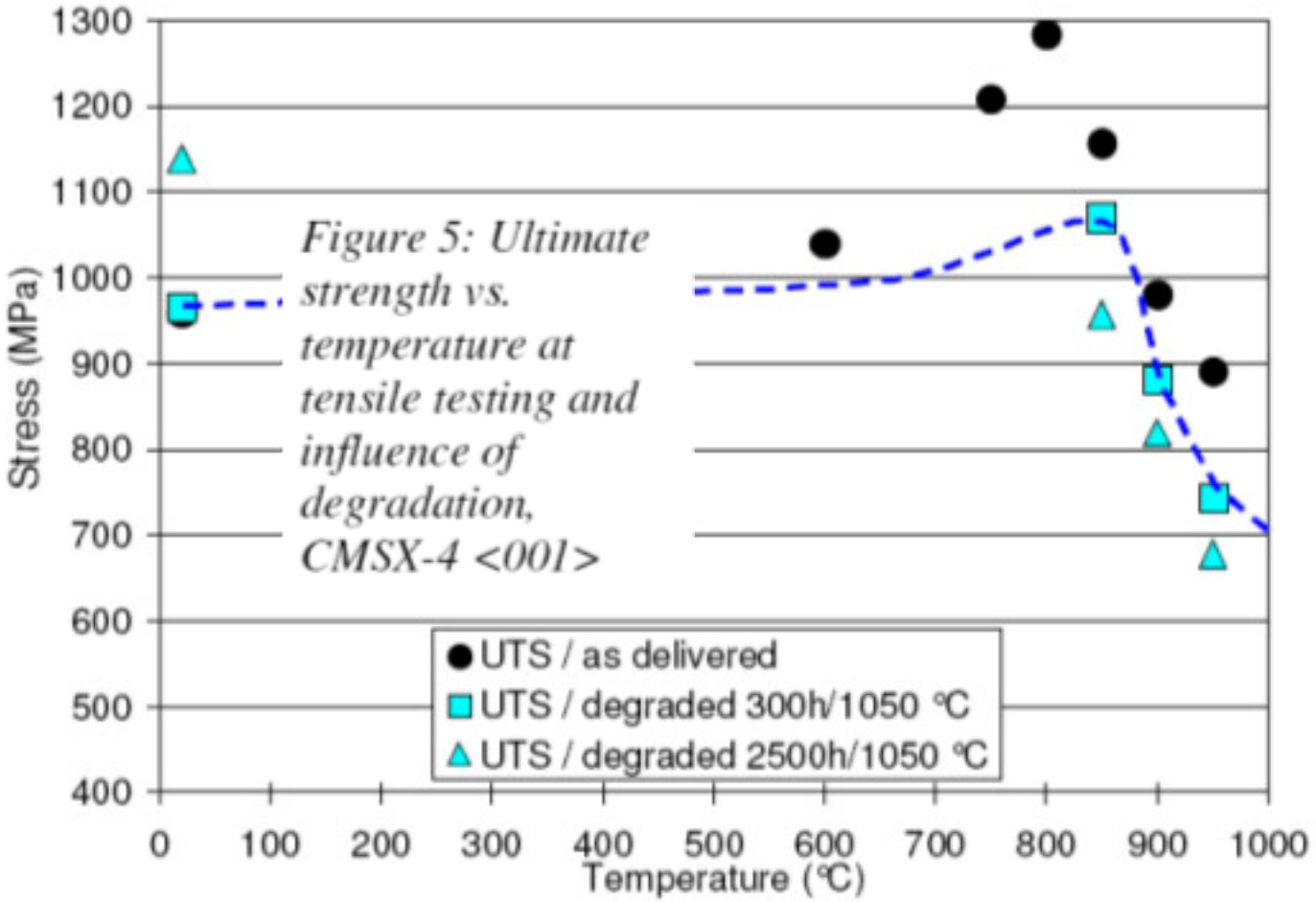


Fig. 3. Temperature and orientation dependence of yield and tensile strengths in the single crystals of investigated alloy. a - <001> orientation, b - <011> orientation, c - <111> orientation

I.L. Svetlov *et al.*, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 652-659, 2010

Superligas de níquel – Propr. Mecânicas em Altas Temperaturas



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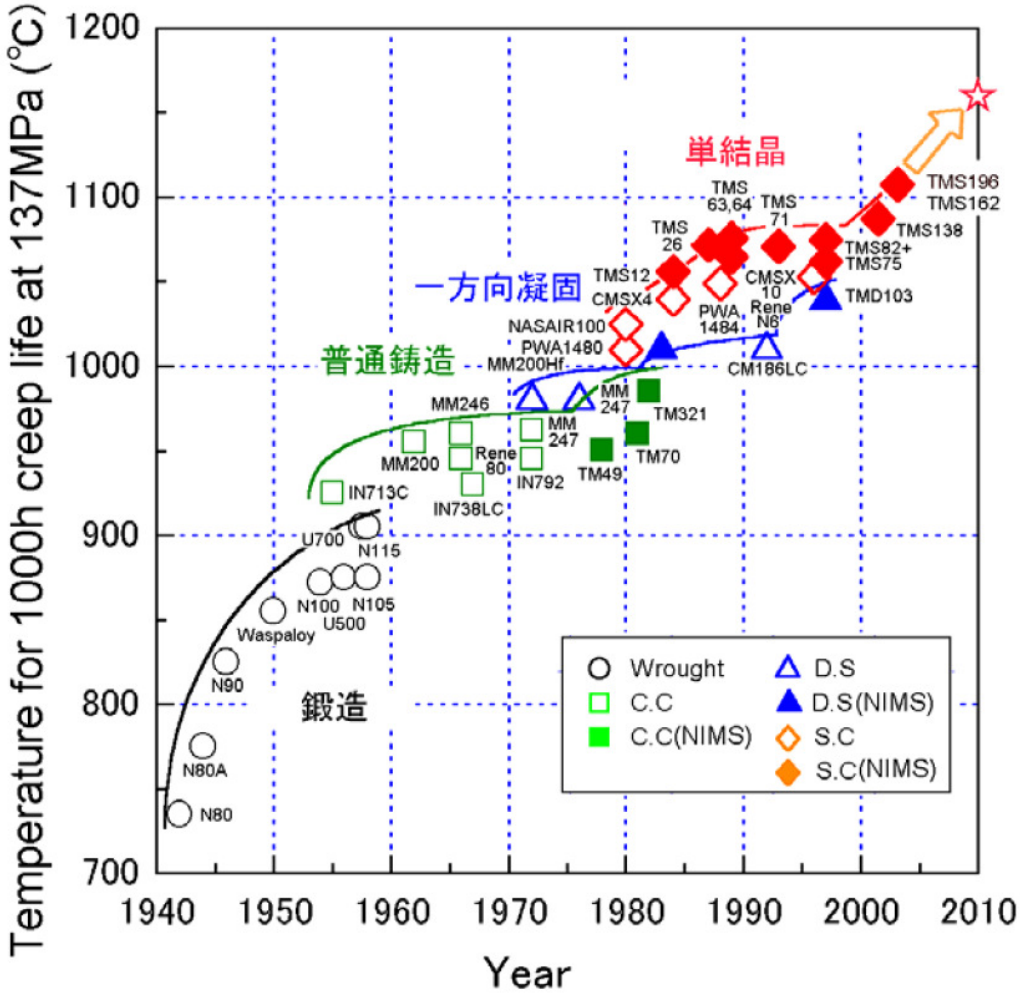
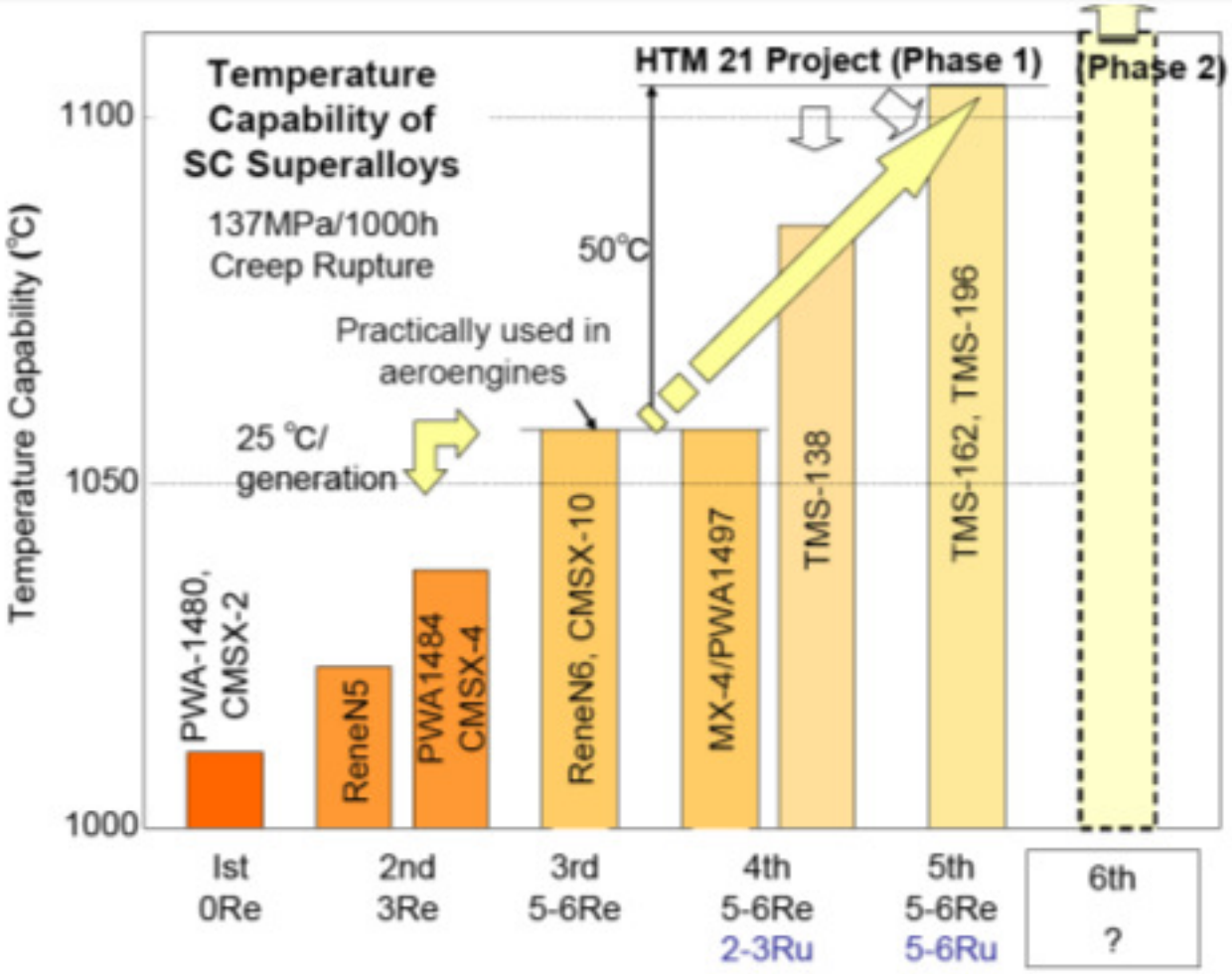
Superligas de níquel – Evolução Temperaturas de Aplicação



H. Harada, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 604-614, 2010

Superligas de níquel – Evolução Temperaturas de Aplicação



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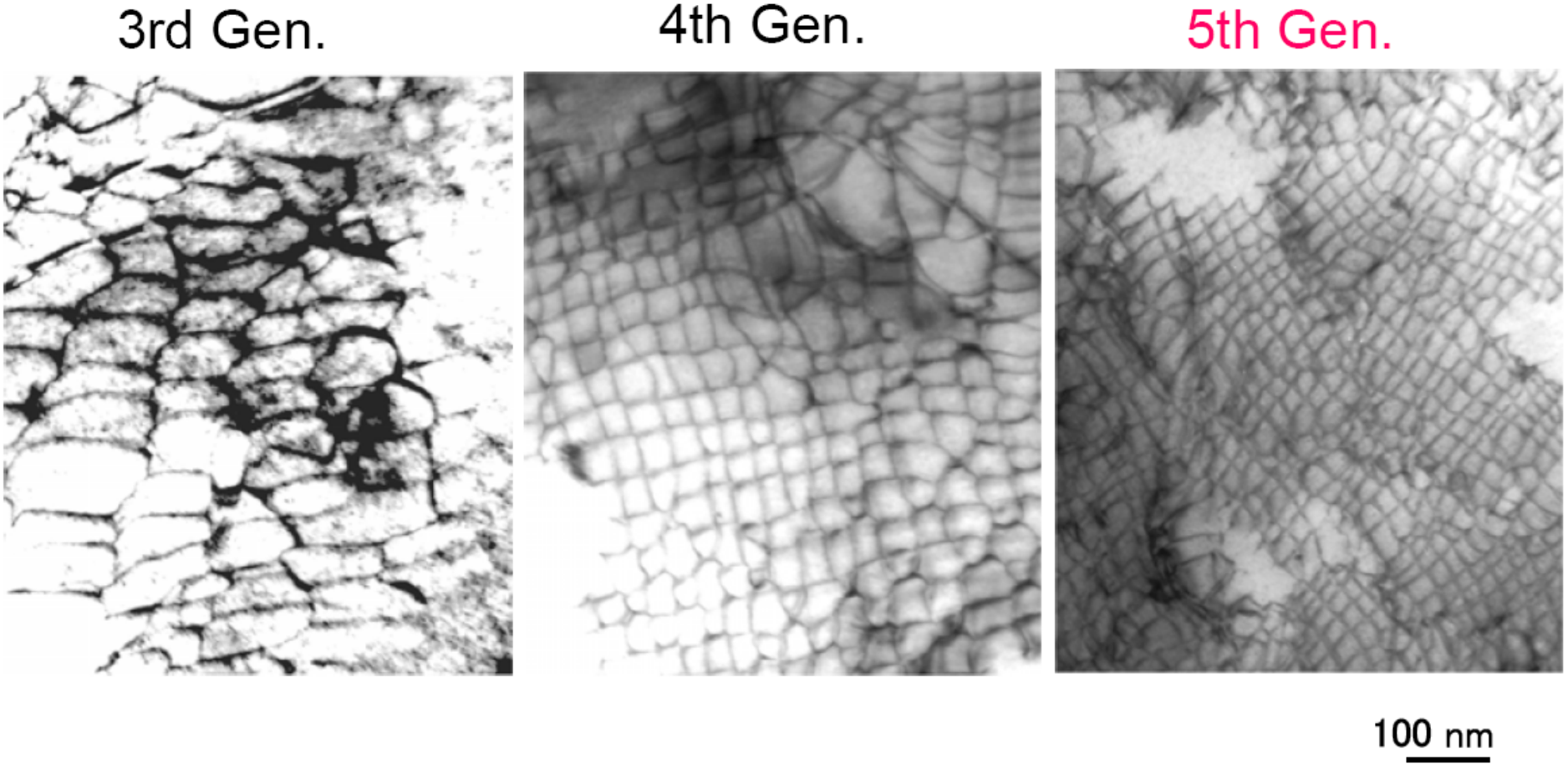

H. Harada, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 604-614, 2010

Superligas de níquel – Evolução Temperaturas de Aplicação

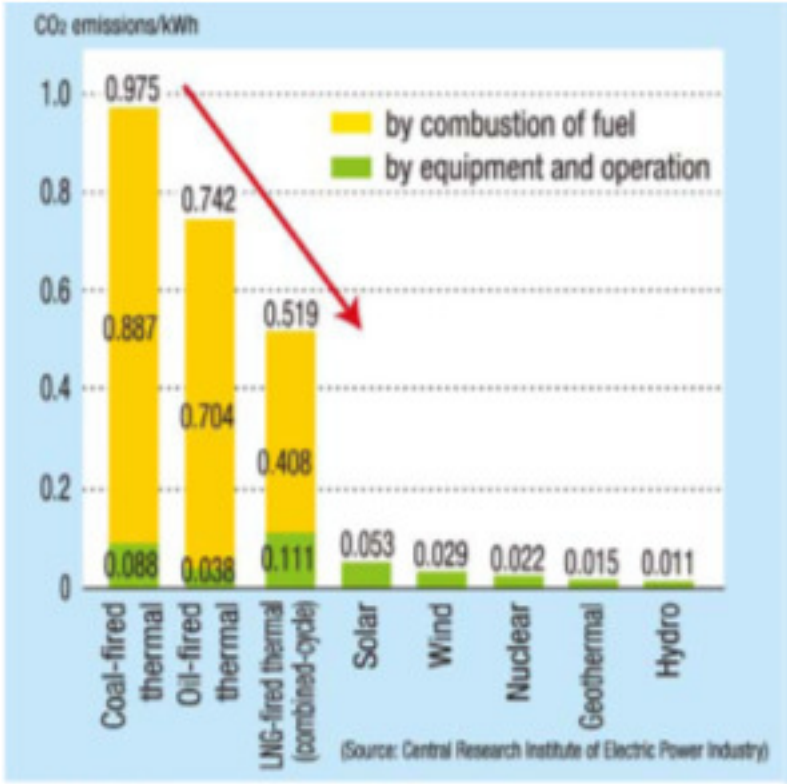

Fig. 1 CO_2 emissions by electric power source.

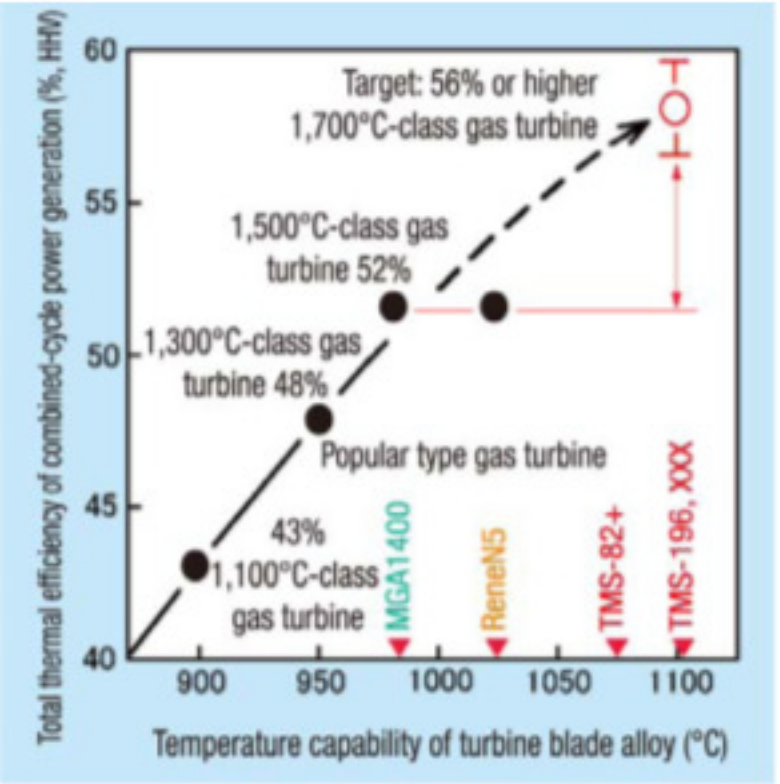

Fig. 2 Relationship between the temperature capability of turbine blade superalloys and power generation efficiency.

H. Harada, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 604-614, 2010

Superligas de níquel – Tecnologia de Revestimentos

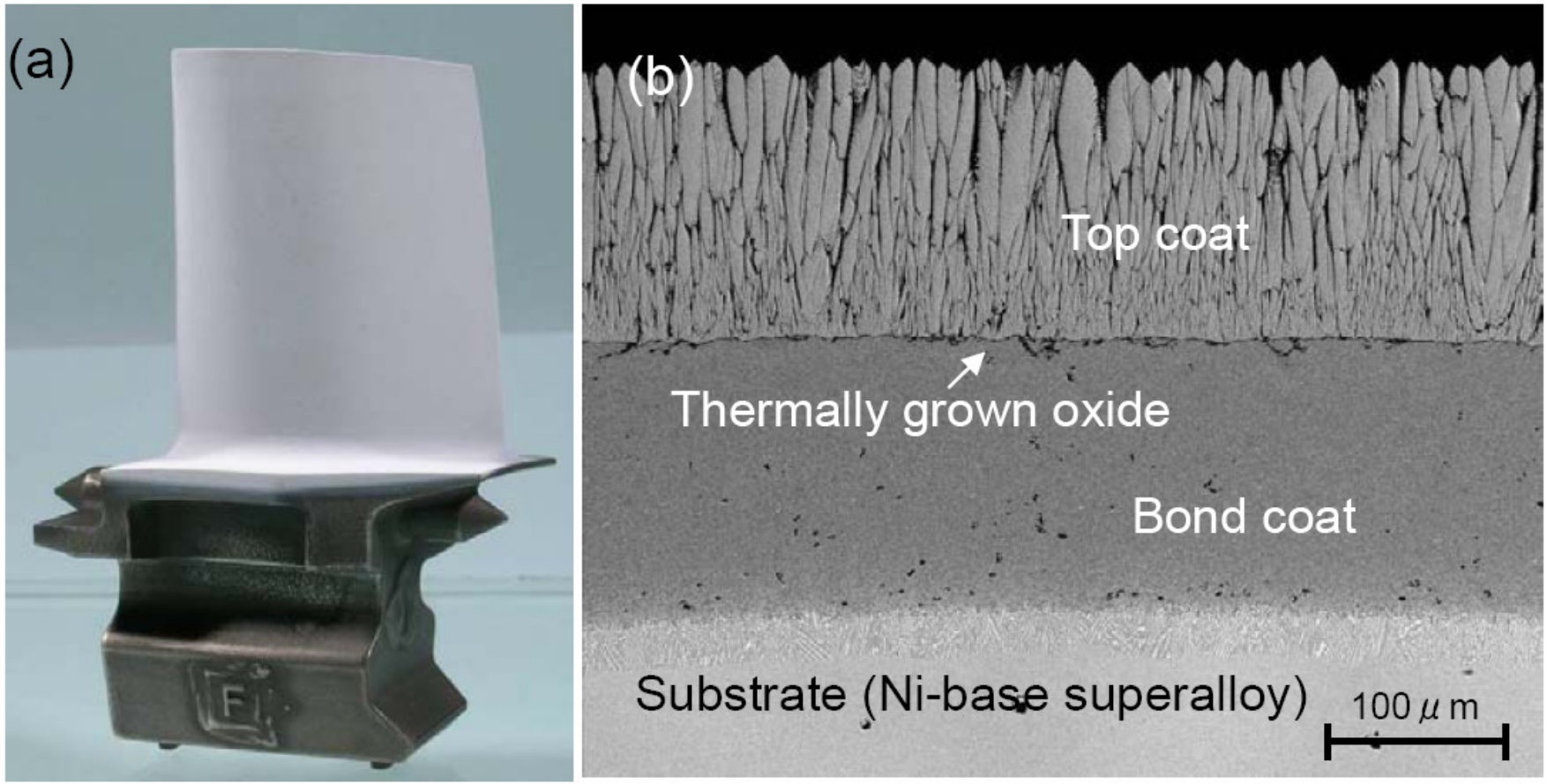

Fig.6 (a) Turbine blade with thermal barrier coating, (b) cross section of coating layer.

H. Harada, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 604-614, 2010

Superligas de níquel – Tecnologia de Revestimentos

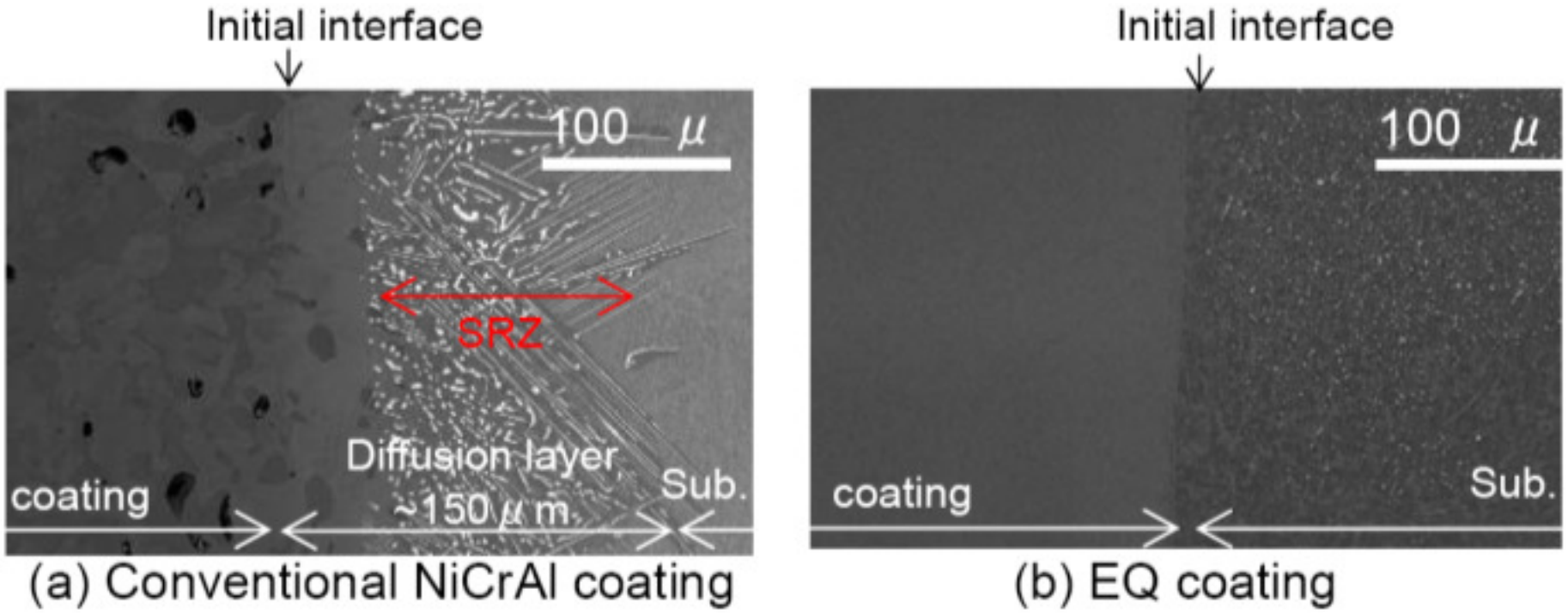

Fig. 7 Cross section of bond coat/substrate interface after 1,100°C for 300hours exposure [8].

H. Harada, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 604-614, 2010

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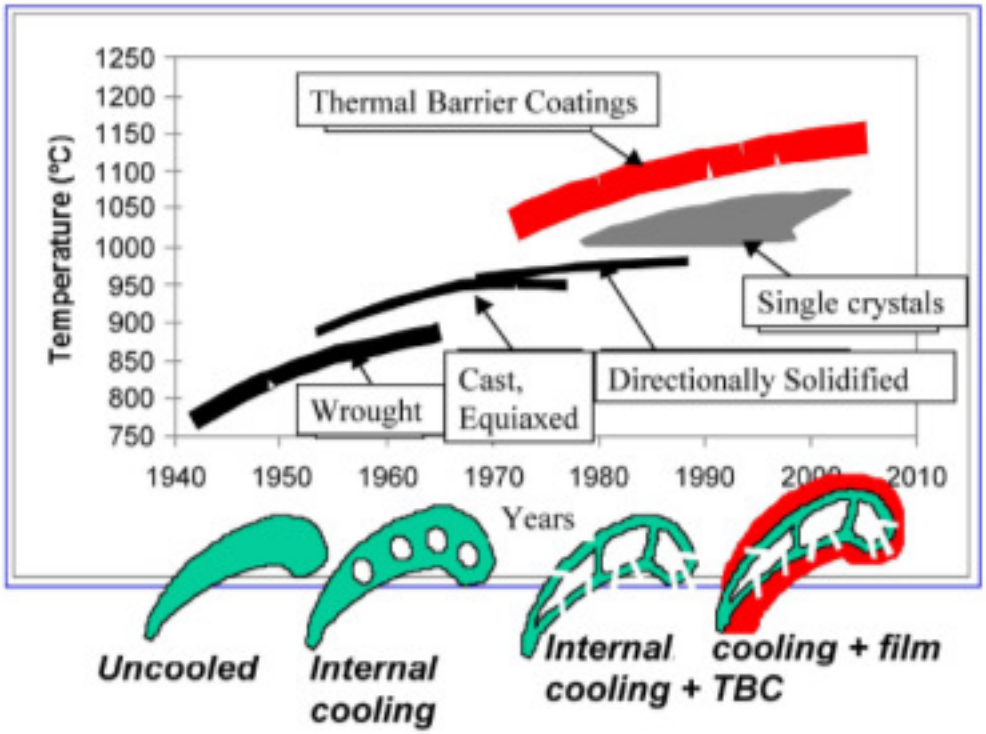

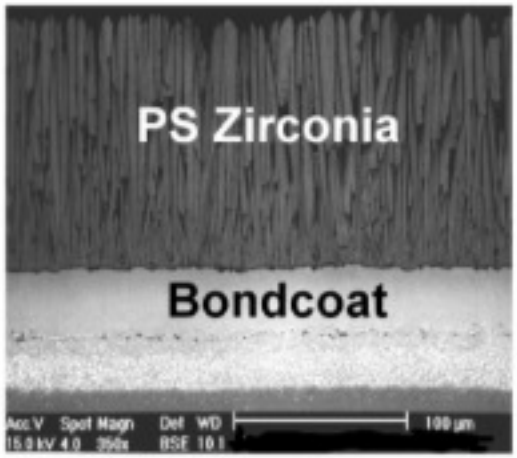

Figure 7: Variation of maximum blade temperature with years and evolution of materials and cooling technologies (left); Turbine blade coated by TBC and scanning electron microscope observation of various layers in the TBC (right).

L. Rémy *et al.*, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 588-603, 2010

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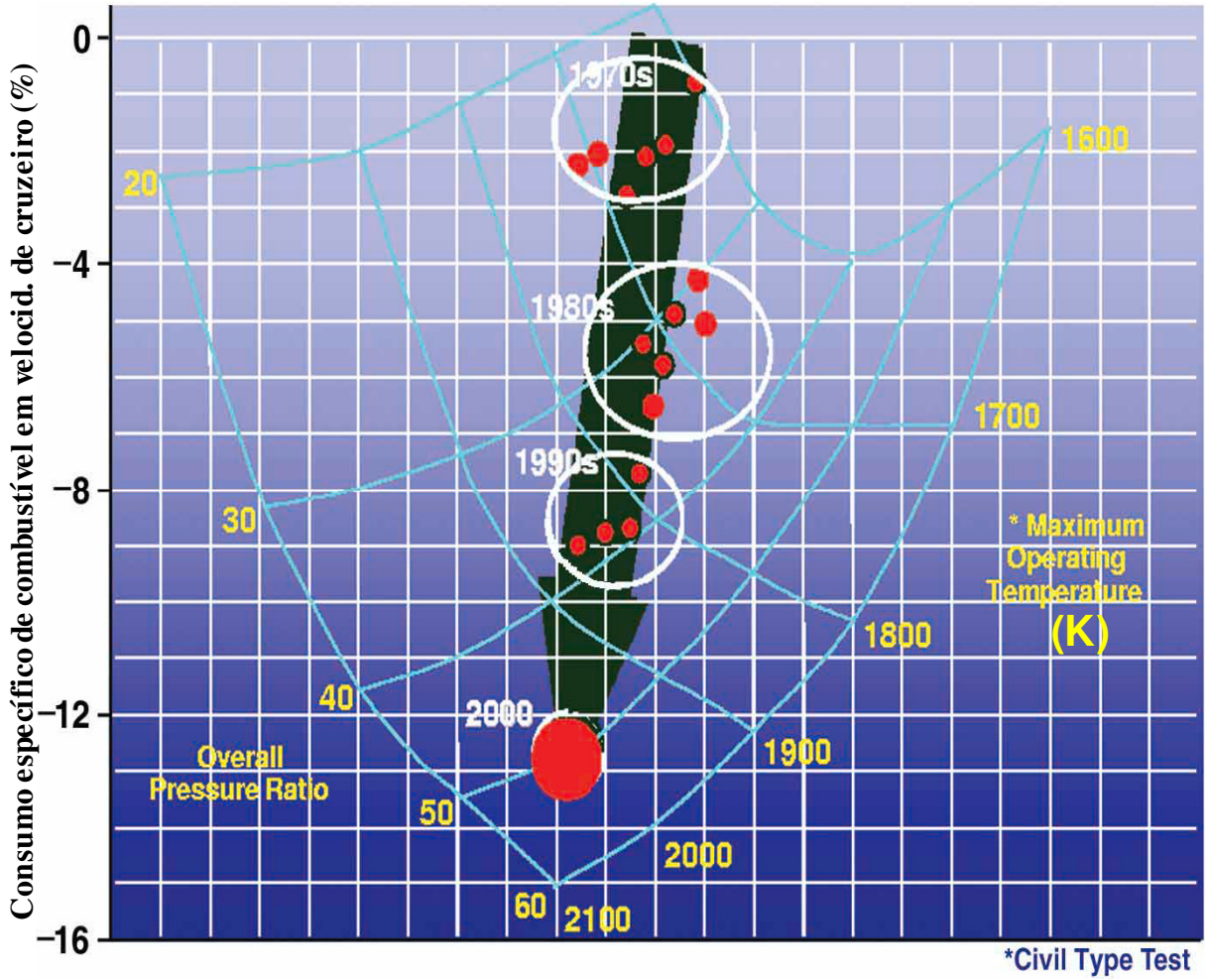

J.R. Nicholls, MRS Bulletin, pp. 659-670, 2003

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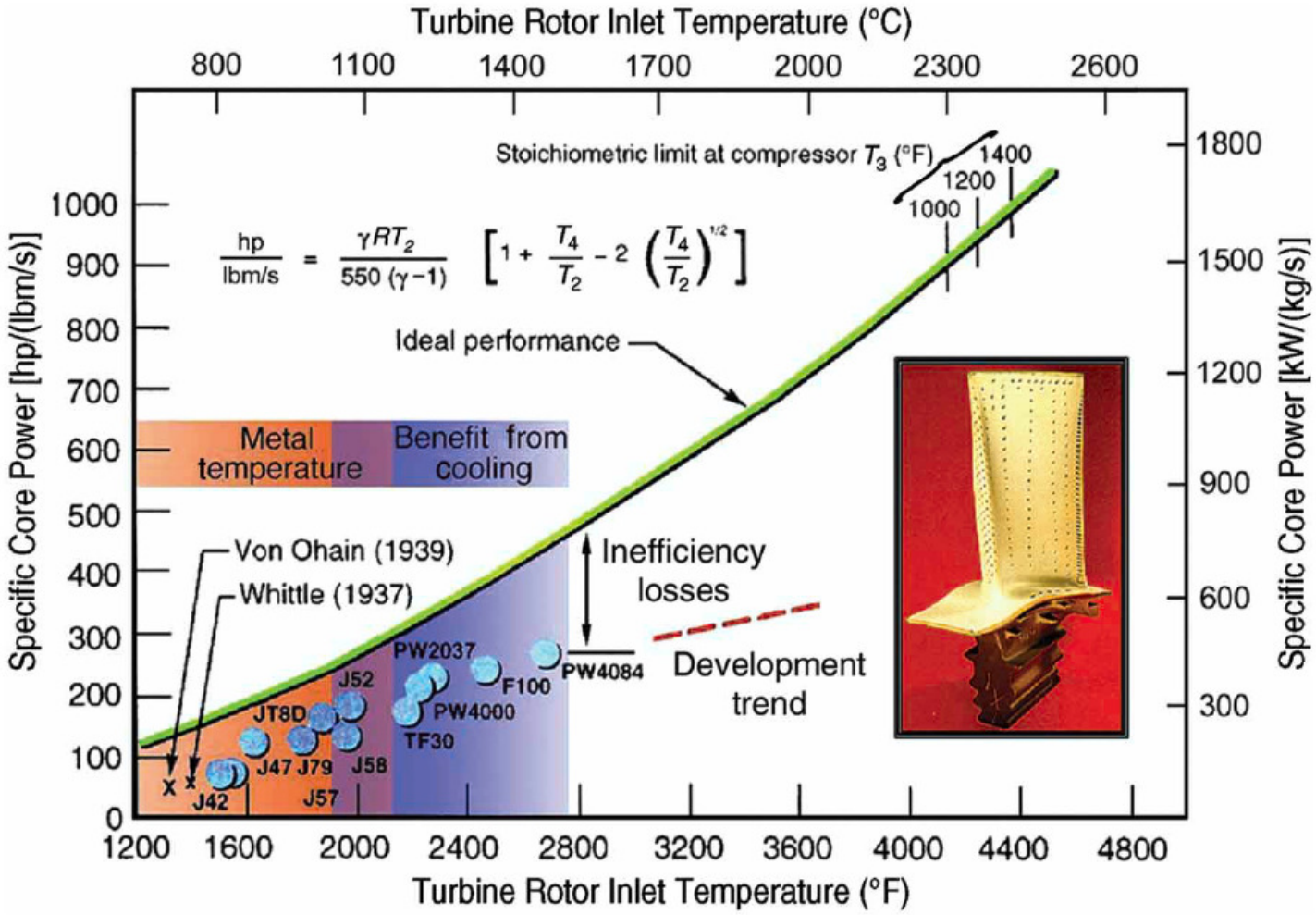
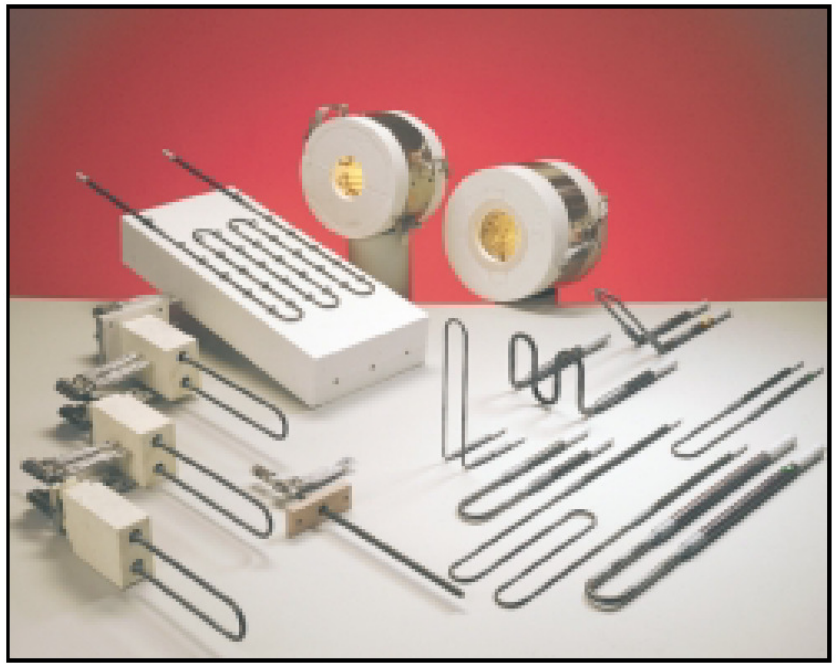


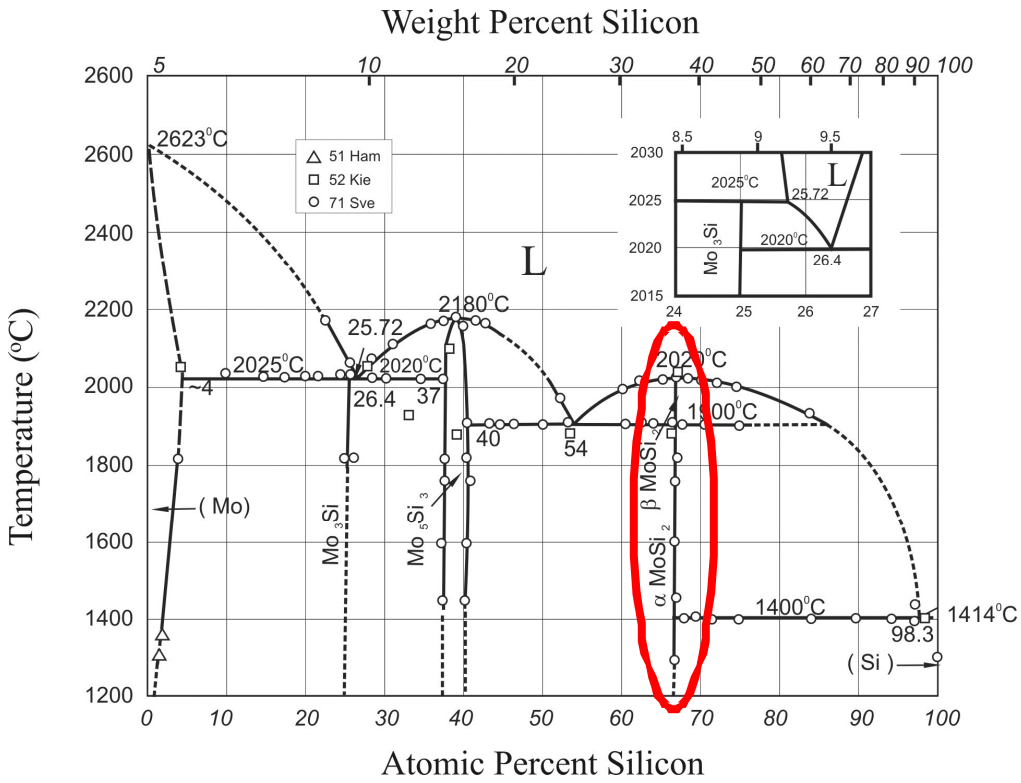
D.M. Dimiduk, J.H. Perepezko, MRS Bulletin, pp. 639-645, 2003

Novos Materiais – Aplicação em Ultra-Altas Temperaturas



From the brochure “Kanthal Super”

www.kanthal.com



Accepted Mo–Si system

A.B. Gockhale, G.J. Abbaschian, ***J. Phase Equilib.*** 12(4) (1991) 493-498

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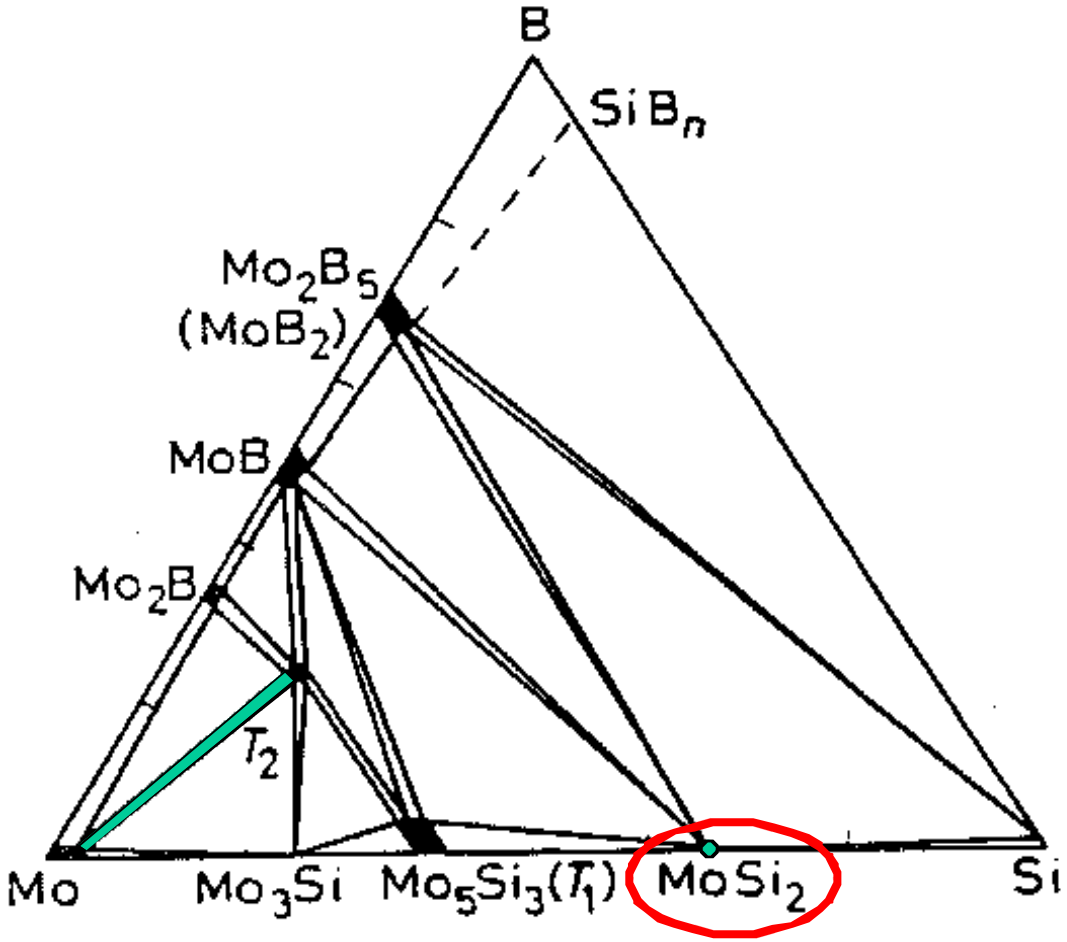

Isothermal Section at 1600ºC.

H. Nowotny et al., ***Monatsh. Chem.*** 88 (1957) 180-192.

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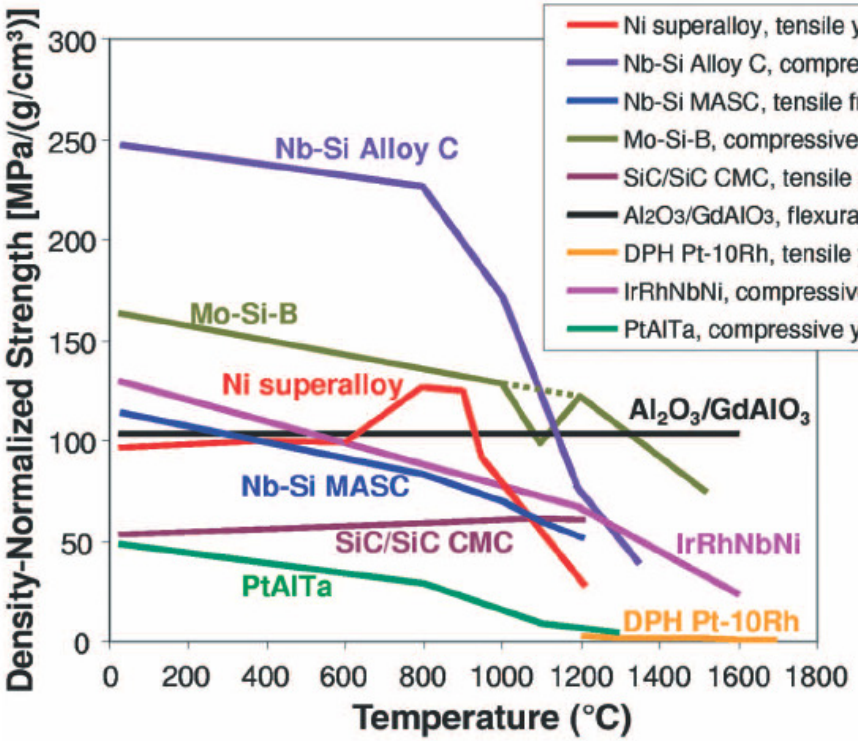

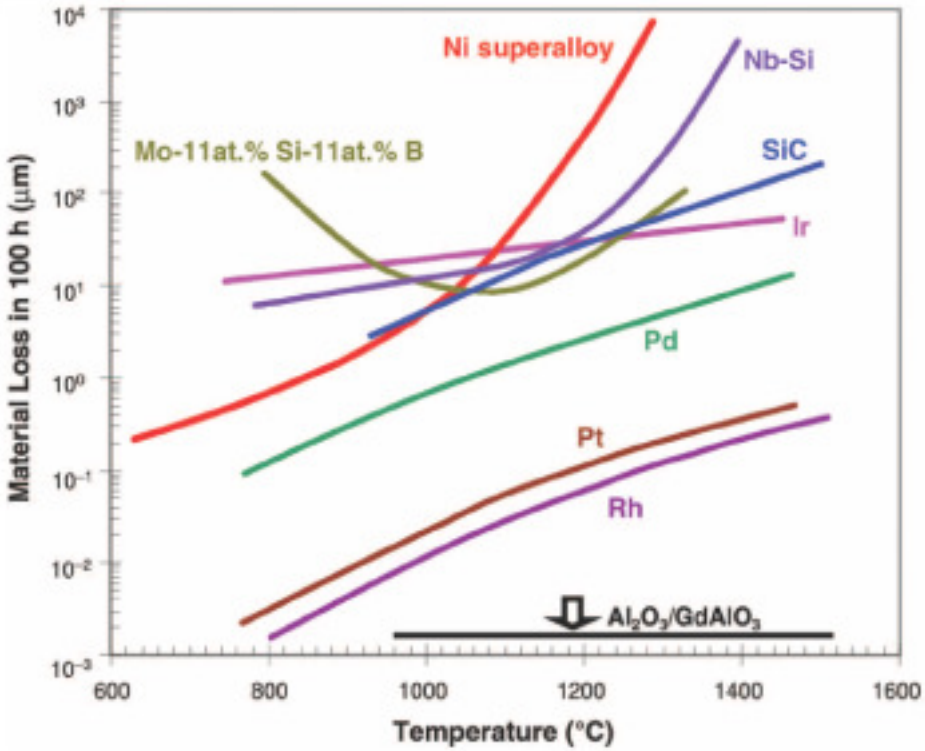

J.C. Zhao, J.H. Westbrooke, MRS Bulletin, pp. 622-630, 2003

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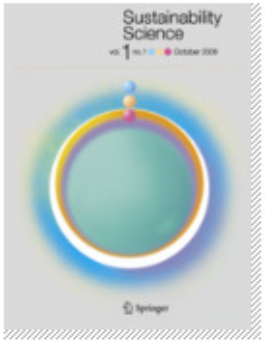

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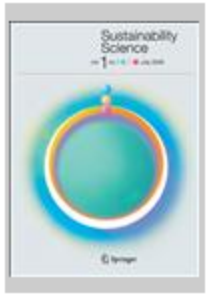

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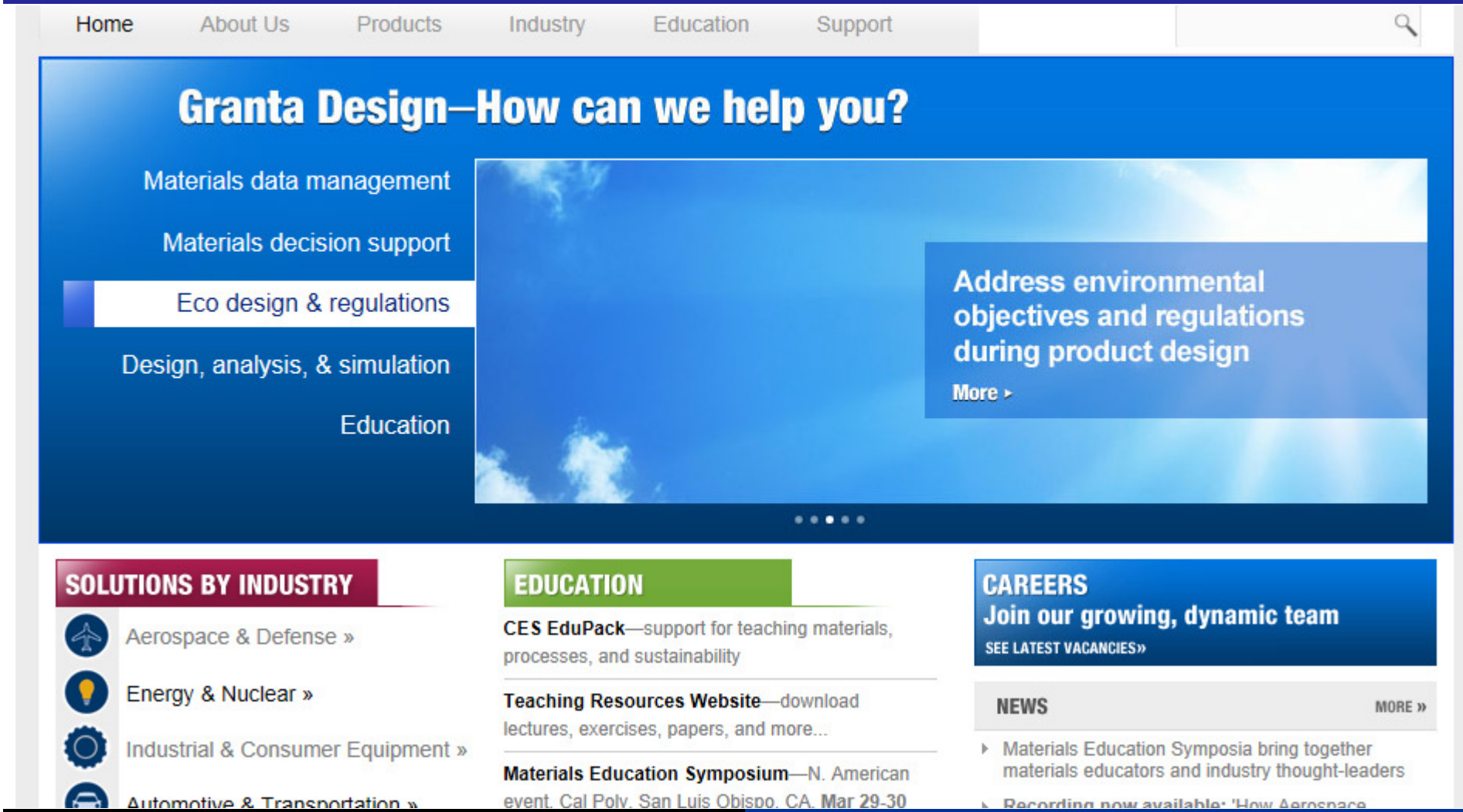

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Ciência **DOS MATERIAIS** para o Desenvolvimento Sustentável: Possível e Urgente!