

Development of ductile Cr-Re alloys for high temperature application in aggressive atmosphere

Mechanical, chemical and thermal shock properties
Results overview

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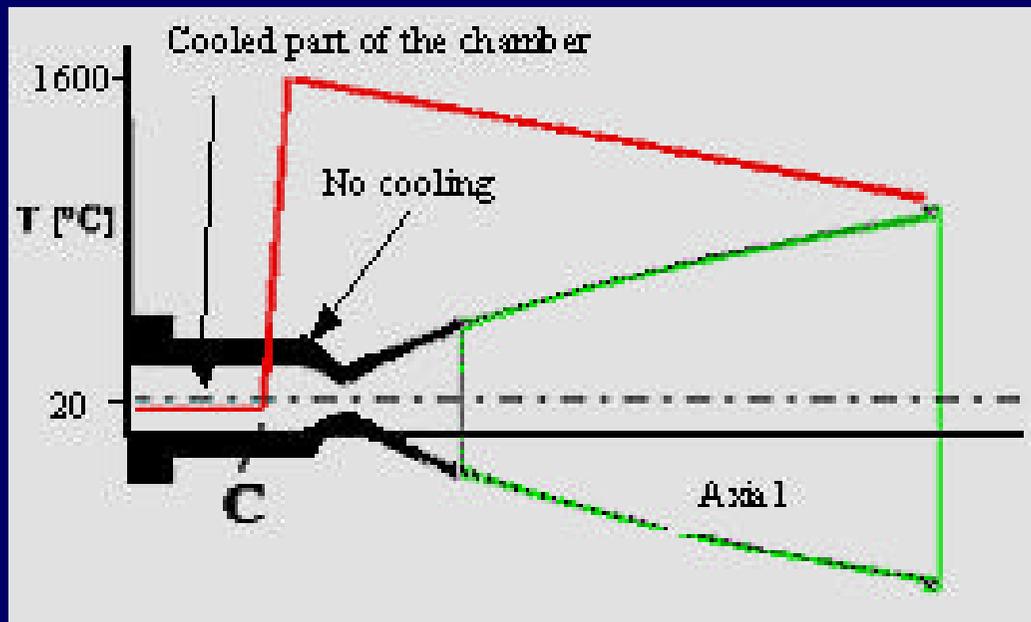
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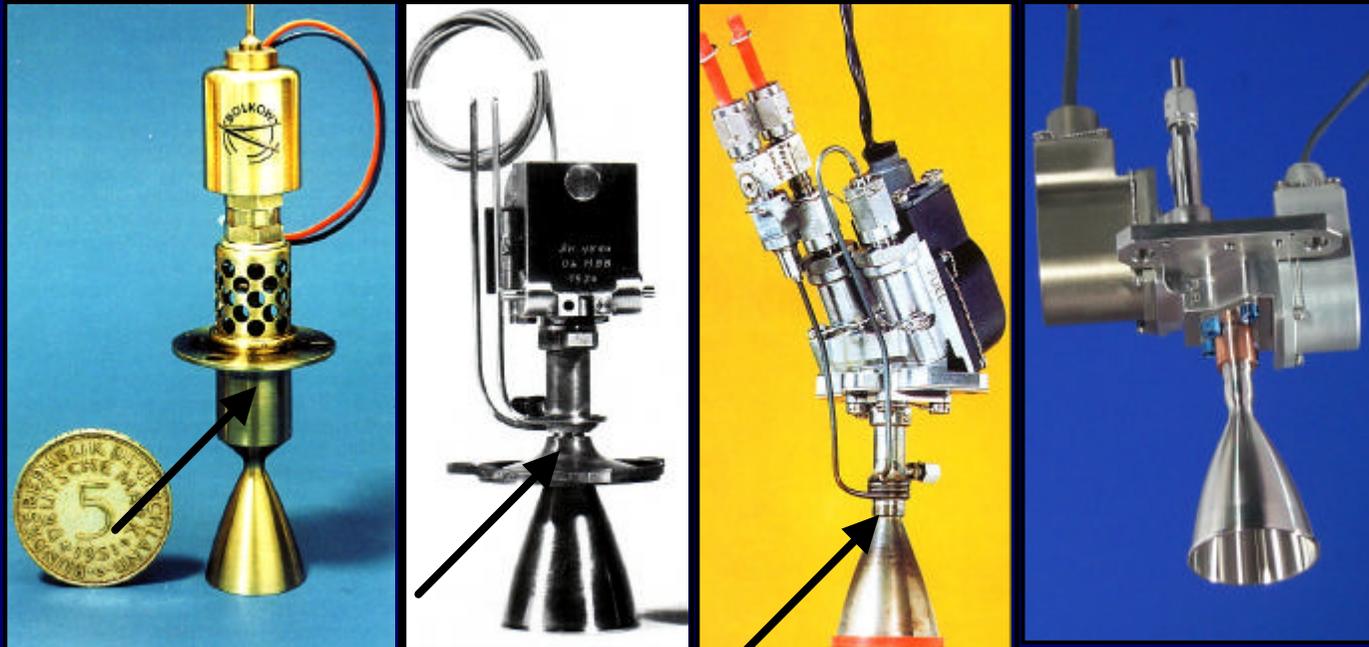
Satellite thruster combustion chambers

Hydrazine based propellants:

- HNO_3 atmosphere at more than $1500\text{ }^\circ\text{C}$
 - 40 at % free nitrogen
 - 2 at % free oxygen
- Longitudinal temperature gradient of 500 K/mm
- Heating kinetics of 500 K/s (700 cycles)



Materials history



1960
Cobalt base
800 °C

1970
Nickel base
1000 °C

1990
Platinum base
1700 °C

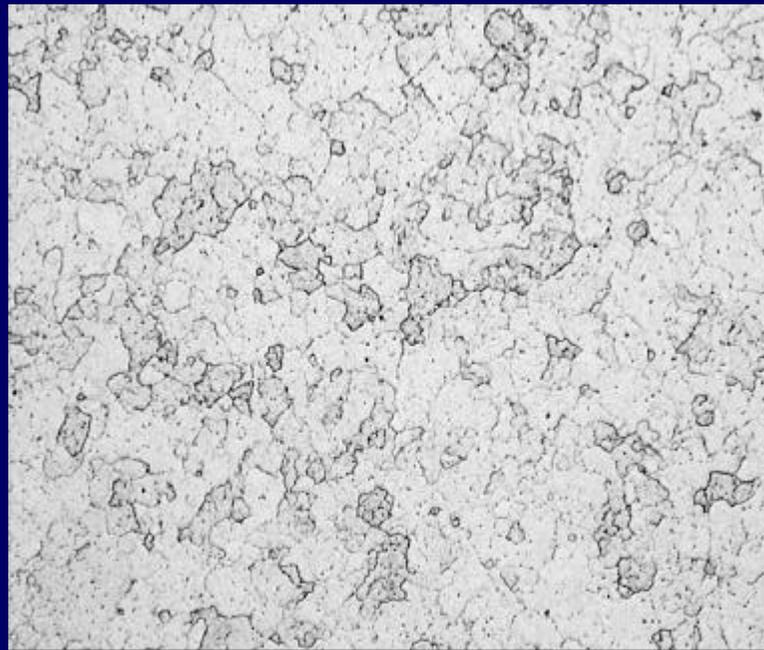
Investigated / Qualified materials

- Qualified materials
 - : Nb coated with quartz
 - : Re coated with Ir
- Materials under qualification
 - : Re coated with Ir (PM)
 - : Ta/W coated with Re/Ir
- Previous experience at EADS
 - : Ta/W coated with Al_2O_3
- No coating needed
 - : Pt based alloys, (qualified)
 - : Cr based alloys

EADS experience with Cr based alloys

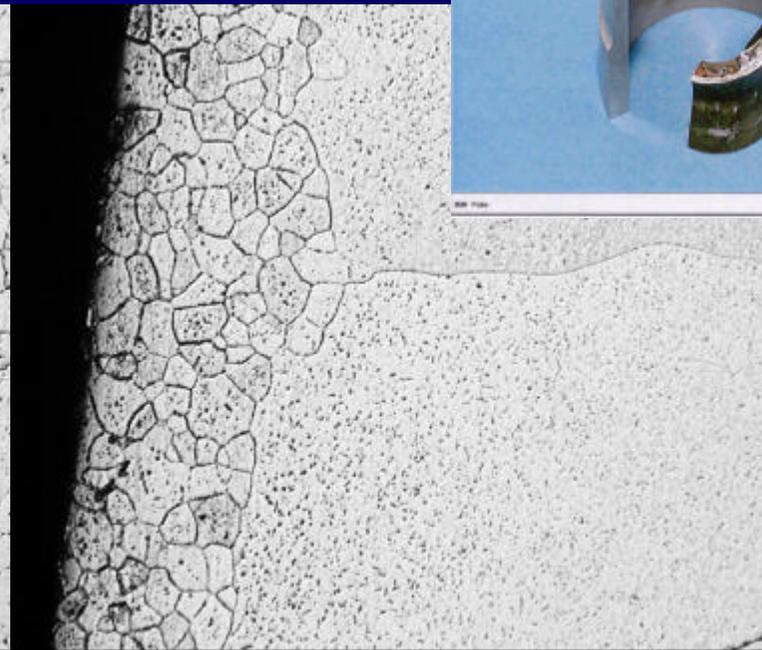
Firing experiences (1500 °C) in 1992

- Brittle fracture due to excessively high DBTT
- Microstructural instability at high T (Rec / GG)



3181-6 Probe: TRANSROHR Mitte

0 [µm] 150

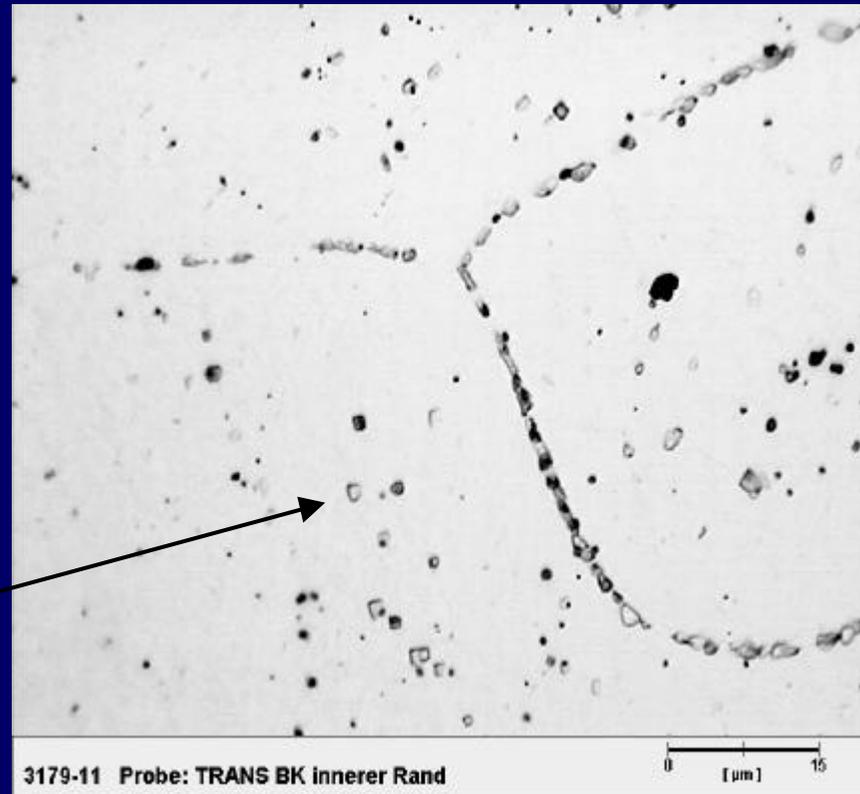
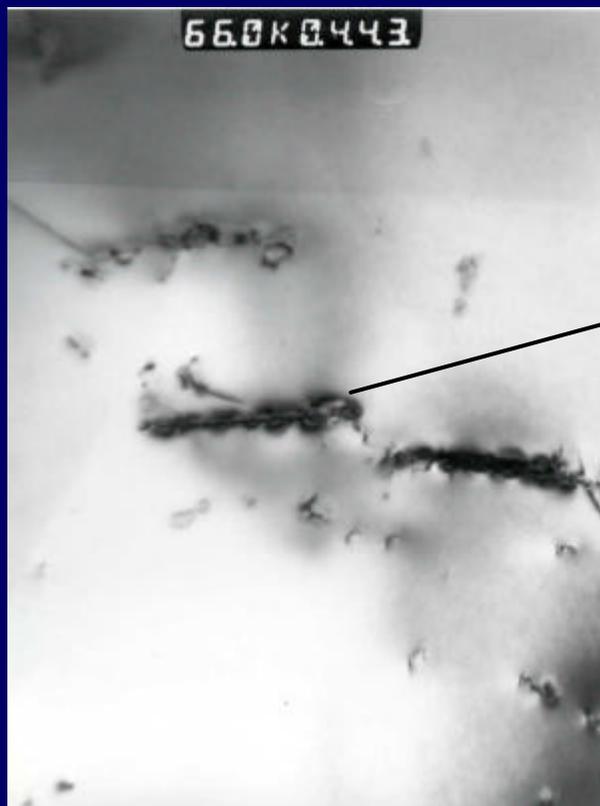


3179-6 Probe: TRANS BK äußerer Rand

0 [µm] 150

Chemical instability

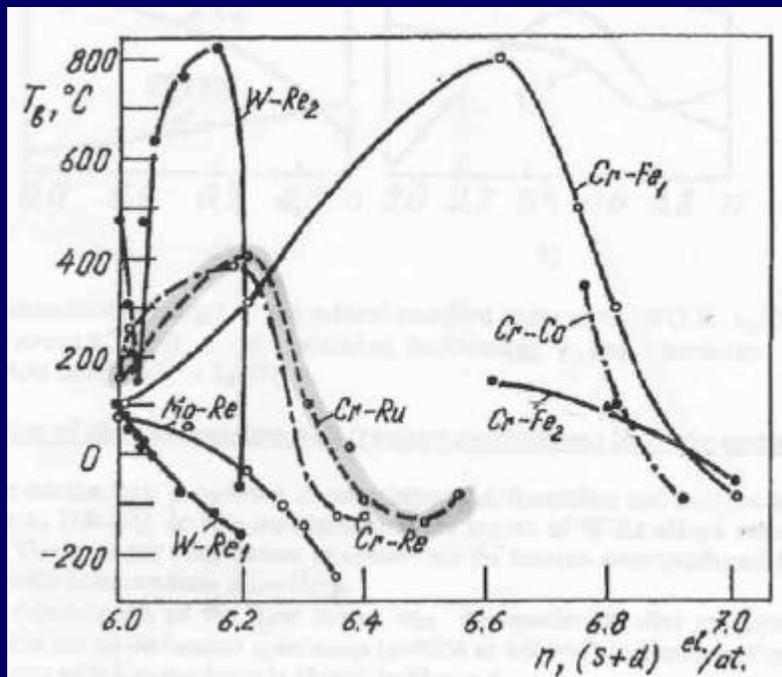
Precipitation of a second phase in grain boundaries and internal defects



	C	H	O	N
Before	7	2	35	53
After	9	2,5	87	145

The Re effect on BCC refractory metals

- Three Re effects:
 - I Increase of low temperature ductility and strength (VIA)
 - II Increase of the strain hardening rate (VIA)
 - III Increase high temperature strength and creep resistance
- Case of Cr : Increase of recrystallisation T and melting point



No database on the properties of the alloys

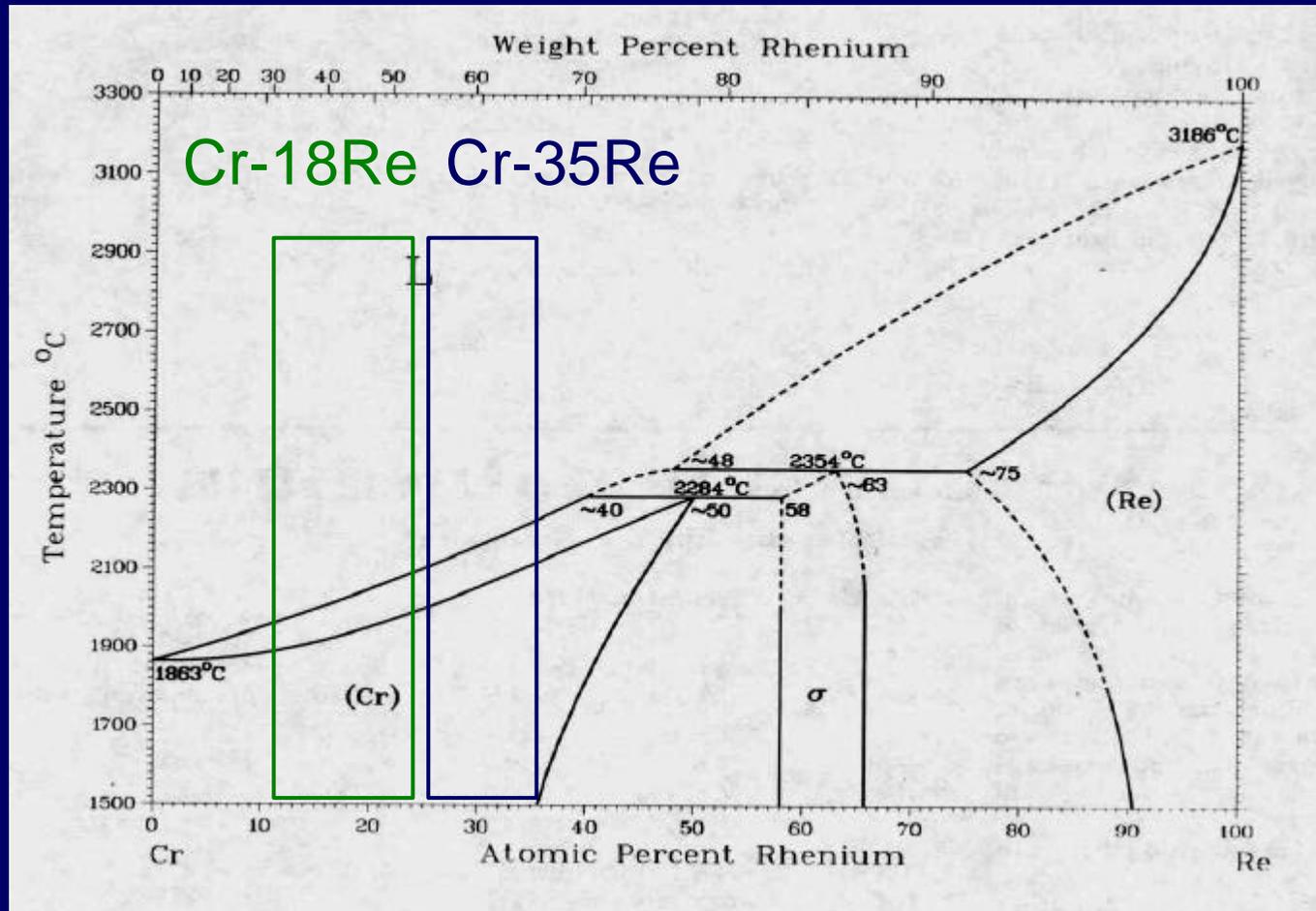
Mechanical
Chemical
Thermal

Thermal shock
Particular properties

Systematic study of Cr-Re solid solution alloys

- Selection of a tailored Cr-Re alloy for satellite thruster combustion chambers
 - Manufacturing method
 - Mechanical properties (cryogenic up to 1800 °C)
 - Oxidation/nitridation resistance (up to 1600 °C)
 - Thermoshock and thermal gradient to 500 K/s; 500 K/mm
 - Thermal properties (up to 1600°C)
 - Joining and welding
 - Resistance to propellant
 - Thermomechanical fatigue

The demonstration alloys



Manufacturing method

Powder Metallurgy

VS

Ingot Metallurgy

- Short to mid term: Ingot Metallurgy
 - Prototype alloys by Arc Melting
 - Production by Induction Melting and casting

- Mid to long term: Powder Metallurgy

Arc molten alloys

