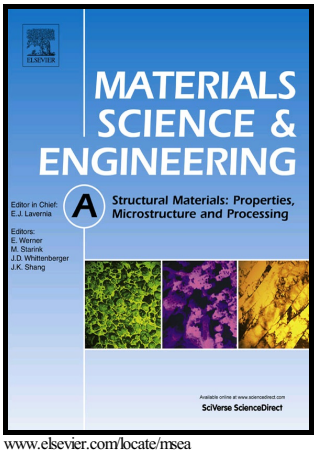


www.elsevier.com/locate/msea

# Creep deformation of Co-Re-Ta-C alloys with varying C content – investigated in-situ by simultaneous synchrotron radiation diffraction

Lukas Karge, Ralph Gilles, Debashis Mukherji, Andreas Stark, Premek Beran, Norbert Schell, Michael Hofmann, Pavel Strunz, Johannes Häusler, Joachim Rösler

PII: S0921-5093(18)30192-8
DOI: https://doi.org/10.1016/j.msea.2018.02.009
Reference: MSA36096

To appear in: *Materials Science & Engineering A*

Received date: 6 November 2017
Revised date: 1 February 2018
Accepted date: 2 February 2018

Cite this article as: Lukas Karge, Ralph Gilles, Debashis Mukherji, Andreas Stark, Premek Beran, Norbert Schell, Michael Hofmann, Pavel Strunz, Johannes Häusler and Joachim Rösler, Creep deformation of Co-Re-Ta-C alloys with varying C content – investigated in-situ by simultaneous synchrotron radiation diffraction, *Materials Science & Engineering A,* https://doi.org/10.1016/j.msea.2018.02.009

# Creep deformation of Co-Re-Ta-C alloys with varying C content – investigated in-situ by simultaneous synchrotron radiation diffraction

Lukas Karge[a,*], Ralph Gilles[a], Debashis Mukherji[b], Andreas Stark[d], Premek Beran[c], Norbert Schell[d], Michael Hofmann[a], Pavel Strunz[c], Johannes Häusler[a], Joachim Rösler[b]

[a]*Heinz Maier-Leibnitz Zentrum (MLZ), Technische Universität München, Lichtenbergstr. 1, 85747 Garching bei München, Germany*
[b]*Technische Universität Braunschweig, Zentrum für Werkstoffe, Langer Kamp 8, 38106 Braunschweig, Germany*
[c]*Nuclear Physics Institute of the CAS, Řež 130, 25068 Řež, Czech Republic*
[d]*Institute of Materials Research, Helmholtz-Zentrum Geesthacht, Max-Planck-Strasse 1, 21502 Geesthacht, Germany*

**Abstract**

The creep deformation of precipitation hardened Co-Re-Ta-C alloys is investigated during in-situ synchrotron diffraction experiment at 1373 K. At room temperature, the alloys have a structure consisting of $\epsilon$-Co (hcp) and metastably retained $\gamma$-Co (fcc) and are strengthened by precipitates of the mono-carbide of Ta, which are finely dispersed in the alloy matrix. The alloy exhibits an allotropic $\epsilon \rightarrow \gamma$-Co phase transformation when heating to > 1173 K. A lower C content in the alloy generally promotes this transformation. It is shown that this transformation is strongly influenced by application of compressive load. The transformation $\epsilon \rightarrow \gamma$-Co at high temperature under load leads to microstructure refinement and subsequently to dissolution of hardening precipitates. This results in a considerable acceleration of the creep rate. Further, the equilibrium ratio of $\gamma/\epsilon$-Co phase is significantly altered under compressive load. This behavior is attributed to a volume relaxation as the $\epsilon$- and $\gamma$-Co phase have different unit cell volumes.

*Keywords:* High temperature creep, Co alloys, Synchrotron diffraction, Neutron diffraction, Dilatometer

## 1. Introduction

Co-Re base alloys show promise for high temperature application in gas turbines, due to their relatively high melting range (1760 K-1830 K) compared to modern Ni-base superalloys [1–4]. One of the primary requisites in such application is a good creep resistance. The Co-Re alloys are precipitation strengthened by a fine (∼ 30 nm) dispersion of TaC precipitates. It was shown that TaC particles in this morphology effectively interact with dislocation during high temperature creep exposure [5]. The TaC precipitates are stable in volume fraction up to temperature of 1473 K in the Co-Re matrix [6]. Further, the C/Ta ratio is a crucial parameter for the strengthening, since it influences size and volume fraction of strengthening TaC precipitates [7]. Lower C content results in a lower volume fraction of precipitates but also in a slightly lower coarsening rate of the precipitates.

Pure Co exists in the two allotropic forms $\epsilon$-Co (hexagonal close-packed crystal structure) at temperature $\leq$ 690 K and $\gamma$-Co (face centered cubic structure) at higher temperatures. In alloys containing 17 atomic percent Re the allotropic transformation temperature is above 1480 K, as Re stabilizes the hcp phase [8–10]. The transformation exhibits a hysteresis upon cooling down to 1400 K. During fast cooling, generally some of the $\gamma$-Co phase is metastably retained at room temperature (RT). Therefore, the Co-Re matrix is present as a mixture of $\gamma$+$\epsilon$-Co phases (with metastable $\gamma$-Co) in initial solution heat treated condition. When heating to the temperature interval 1173-1373 K, the metastable $\gamma$-Co transforms over time to the thermodynamic equilibrium $\epsilon$-Co phase. Up to a temperature of ∼ 1500 K, $\epsilon$-Co phase is dominant in the matrix and only a low amount of $\gamma$-Co phase remains in equilibrium. The exact microstructure is sensitive to the holding time at a respective temperature and the C content has an influence on the allotropic matrix phase transformation temperature.

The matrix structure and the evolution of the hardening TaC phase have a strong influence on the creep behavior of the alloy and can only be understood if

*Corresponding author