Institute of Materials Science, Joining and Forming (IMAT)
Graz University of Technology, Austria

# Creep Cavitation in Nickel-Based Alloys

**F. Meixner[1], M.R. Ahmadi[1], C. Sommitsch[1], J. Wirth[2], T. Leissner[3], S. Šimić[4]**

1. *Graz University of Technology,* Institute of Materials Science, Joining and Forming*, Kopernikusgasse 24/I, 8010 Graz, Austria*
2. *Friedrich-Alexander-University,* Center for Nanoanalysis and Electron Microscopy, *Cauerstr. 6a, 91058 Erlangen, Germany*
3. *TU Bergakademie Freiberg,* Institute of Mechanical Process Engineering and Mineral Processing, *Agricolastrasse 1, 9599 Freiberg, Germany*
4. *Austrian Center for Electron Microscopy and Nanoanalysis, Steyrergasse 17, 8010 Graz, Austria*

## INTRODUCTION

Efforts to reduce the production, operating and environmental costs of thermal power plants require materials that can handle the high operating pressures and temperatures. The current paragons of these materials, nickel-based alloys, still however deform at these high temperatures and stresses, a phenomenon known as creep. During service, vacancies accumulate, mostly at grain boundaries, and form small cavities, which grow slowly and eventually coalesce into large cracks causing the material to rupture. Two mechanisms have been proposed to explain the nucleation of these cavities: Classical Nucleation Theory (CNT) and Grain Boundary Sliding (GBS) . Our results support nucleation by the former and growth and coalescence by the latter.

## EXPERIMENTAL RESULTS

We crept a specimen (figure 1) of Alloy 617 (chemical composition in Table 1) at 700°C at 170 MPa until it ruptured after 11577 hours.

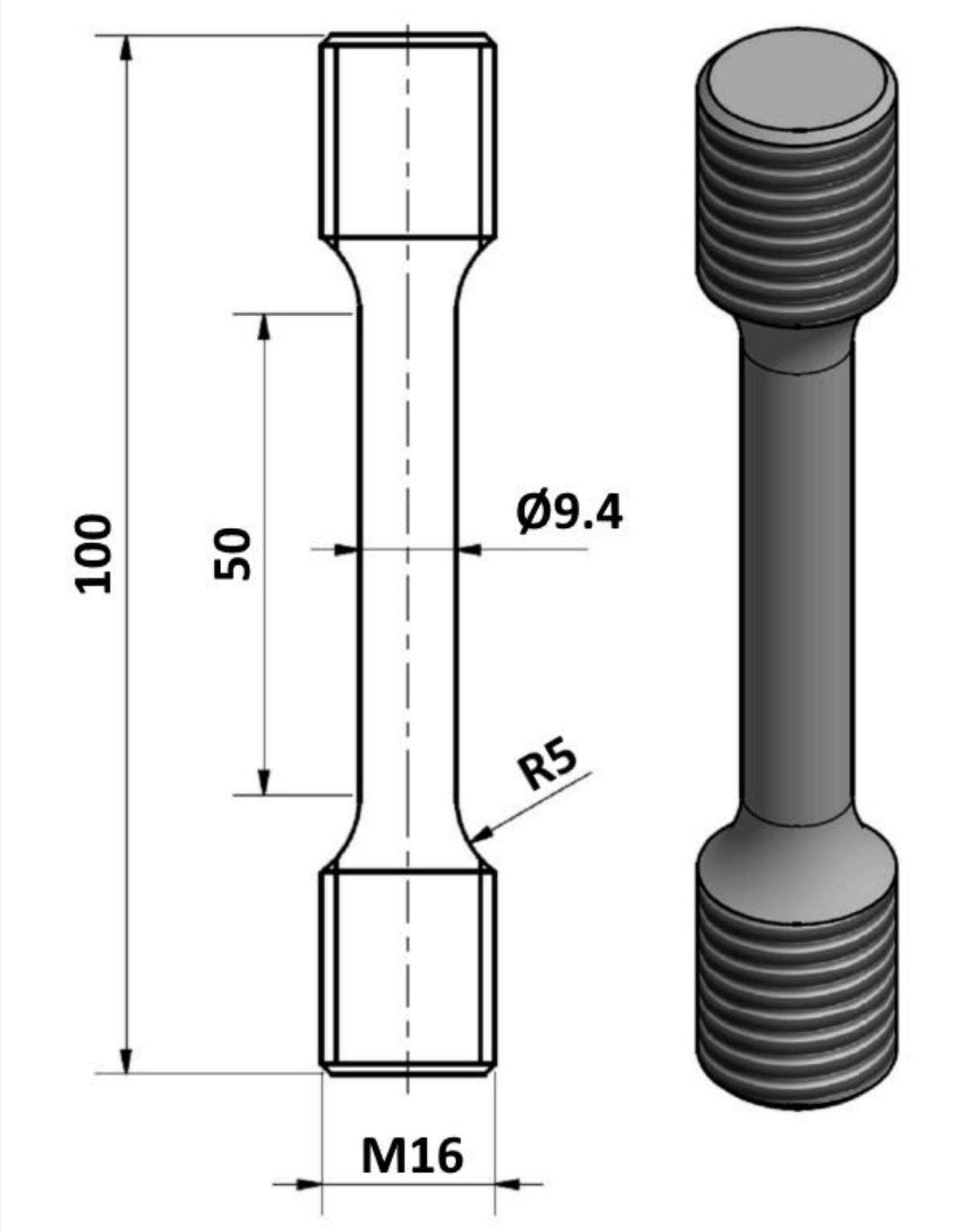

Figure 1: Creep specimen of Alloy 617

| Element | wt% |
|---|---|
| Ni | Bal |
| Cr | 21.94 |
| Mo | 8.64 |
| Co | 1.68 |
| Al | 1.16 |
| Fe | 1.02 |
| Mn | 0.04 |
| Cu | 0.03 |
| Ti | 0.39 |
| Si | 0.08 |
| C | 0.06 |
| B | 0.002 |

Table 1: Composition of Alloy 617

We then investigated the microstructure, looking for cavities and chains of cavities by Scanning Electron Microscopy (Zeiss Ultra 55) and by X-Ray Computer Tomography (Zeiss Xradia 510 Versa and Zeiss Xradia 810 Ultra). The micrographs (figure 2) show the various stages of creep cavitation damage along the grain boundaries.

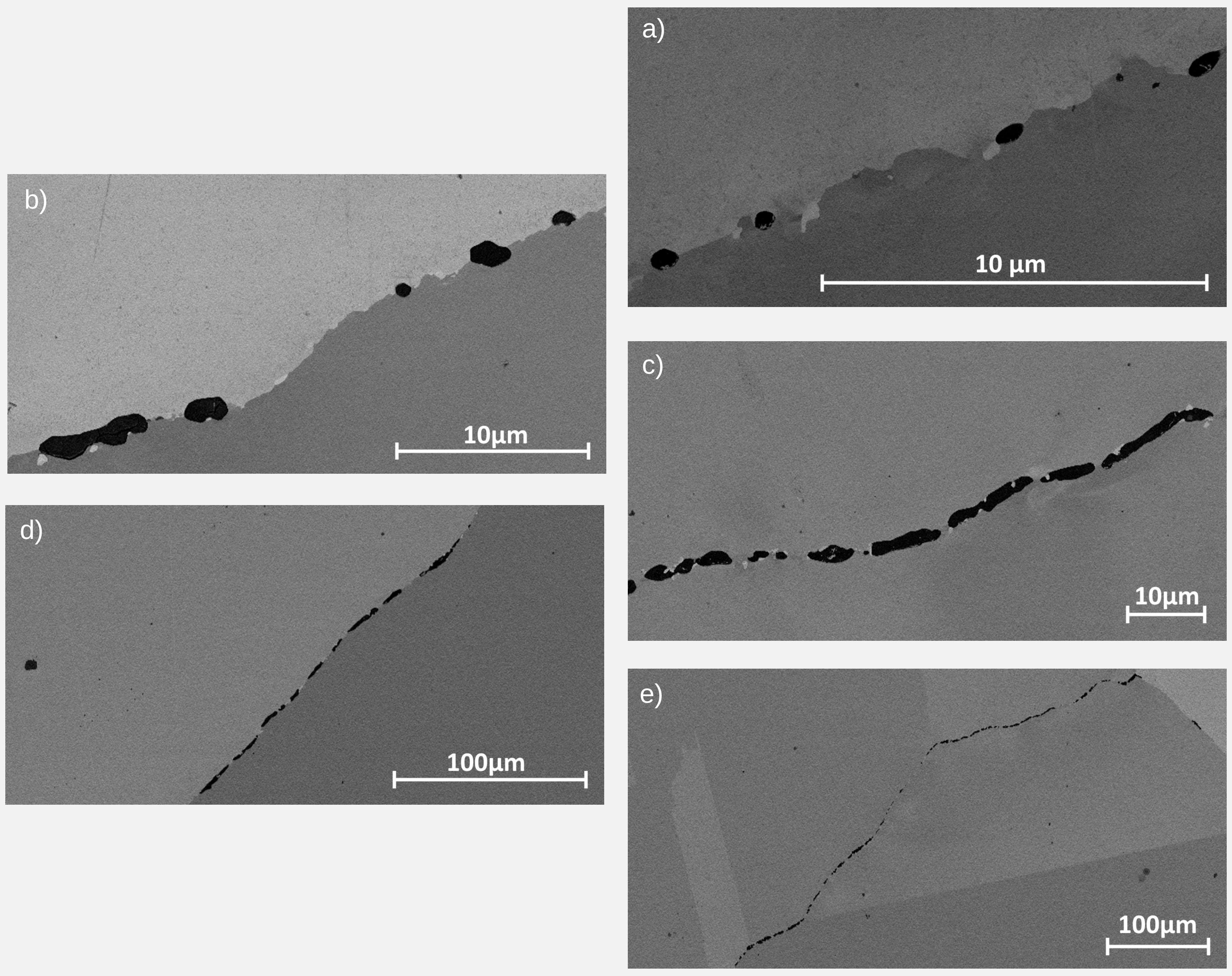

Figure 2: Stages of creep cavitation during creep. Stress was applied in the vertical direction

The 3D volume and analysis of the cavities' directions in the creep specimen were generated using Dragonfly software, Version 2020.2 for Windows (Object Research Systems Inc, Montreal, Canada)

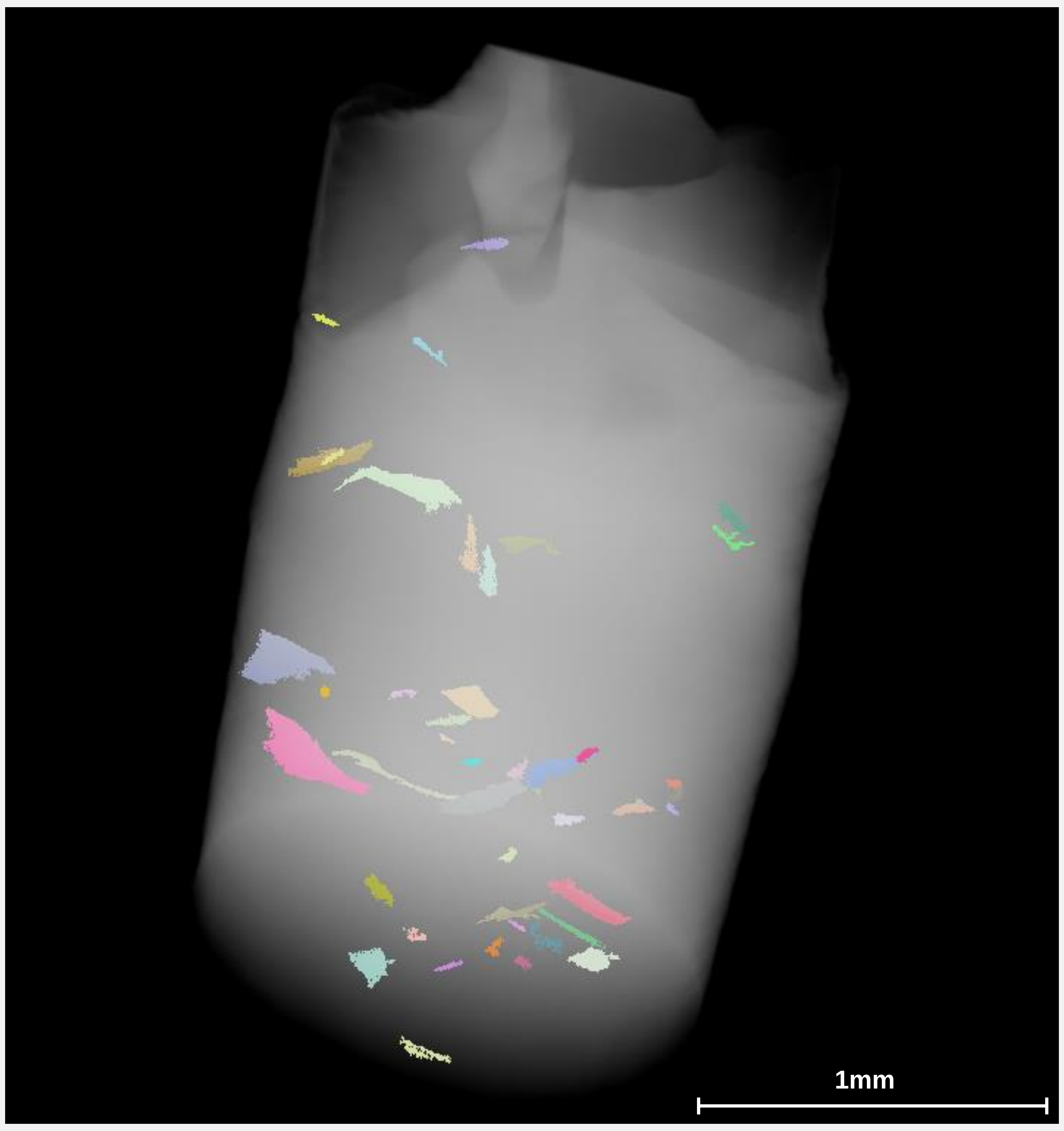

Figure 3: Chains of cavities covering grain boundaries in a fragment (⌀1.5mm) of the creep specimen. Stress was applied along the longitudinal axis

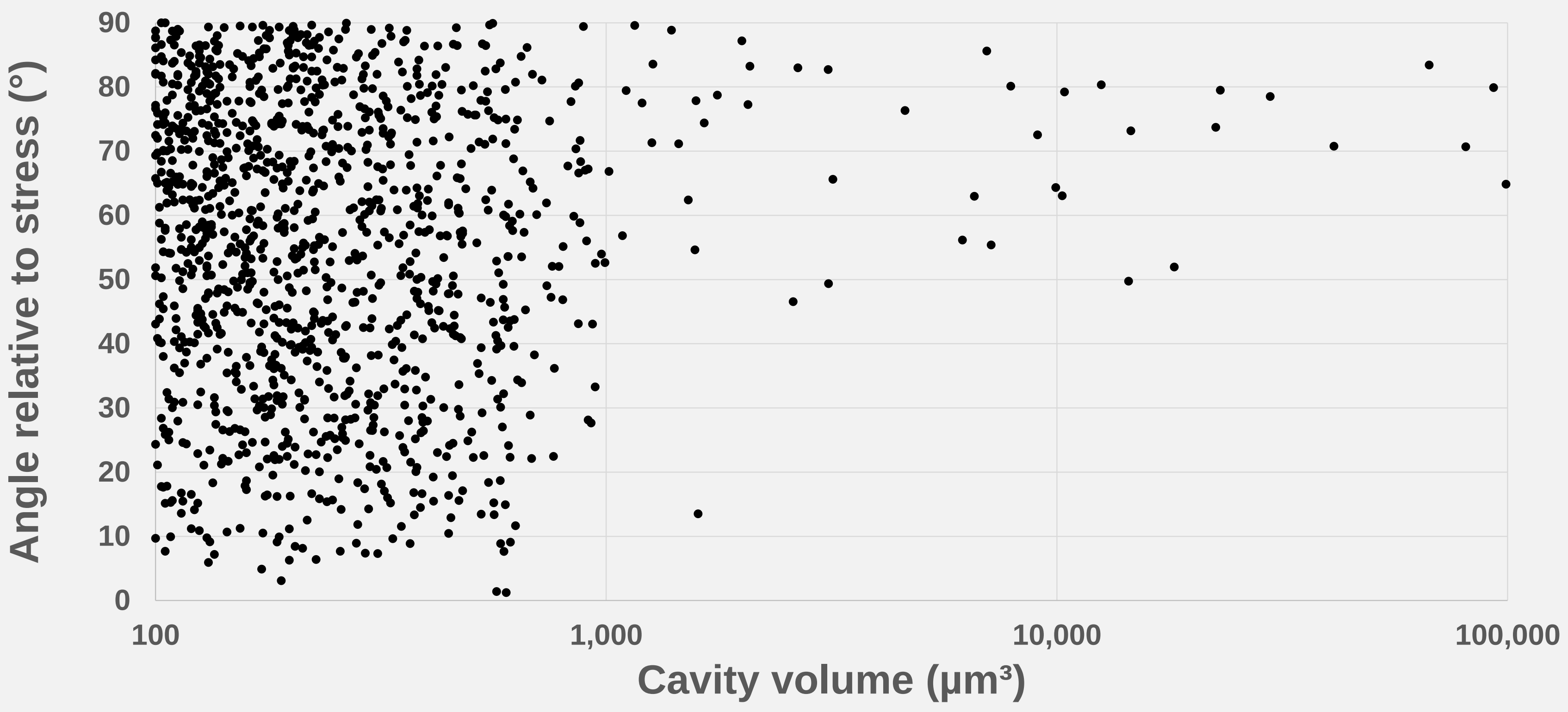

Figure 4: Small cavities grow on any grain boundary, while large chains prefer grain boundaries at oblique angles relative to the principal stress

## CONCLUSIONS

The micrographs (Figure 2) and especially the analysis of the cavities in the 3D volume (Figure 4) show small cavities (<1000µm³) evenly distributed along grain boundaries of all orientations. This is consistent with Classical Nucleation Theory which presumes the uniaxial tension as the global driving force for nucleation throughout the microstructure. Large chains of cavities (>1000µm³) grow along grain boundaries which experience more shear stress (>45°), which is the driving force for Grain Boundary Sliding. As such it seems that both theories are needed to fully explain creep cavity nucleation and growth which could lead to failure of power plant components.

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