Engineering Developments

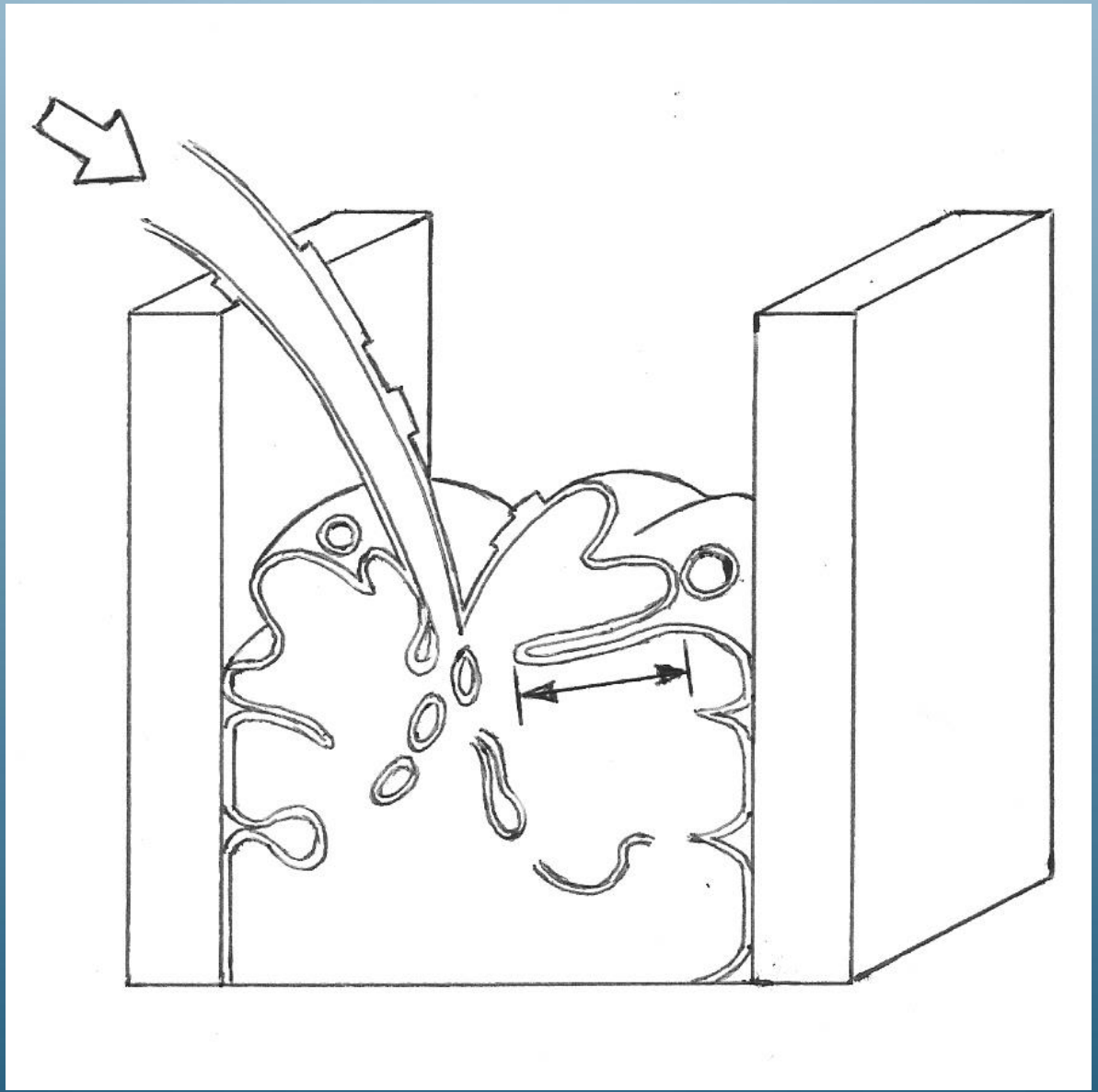
AFI Conference

2020

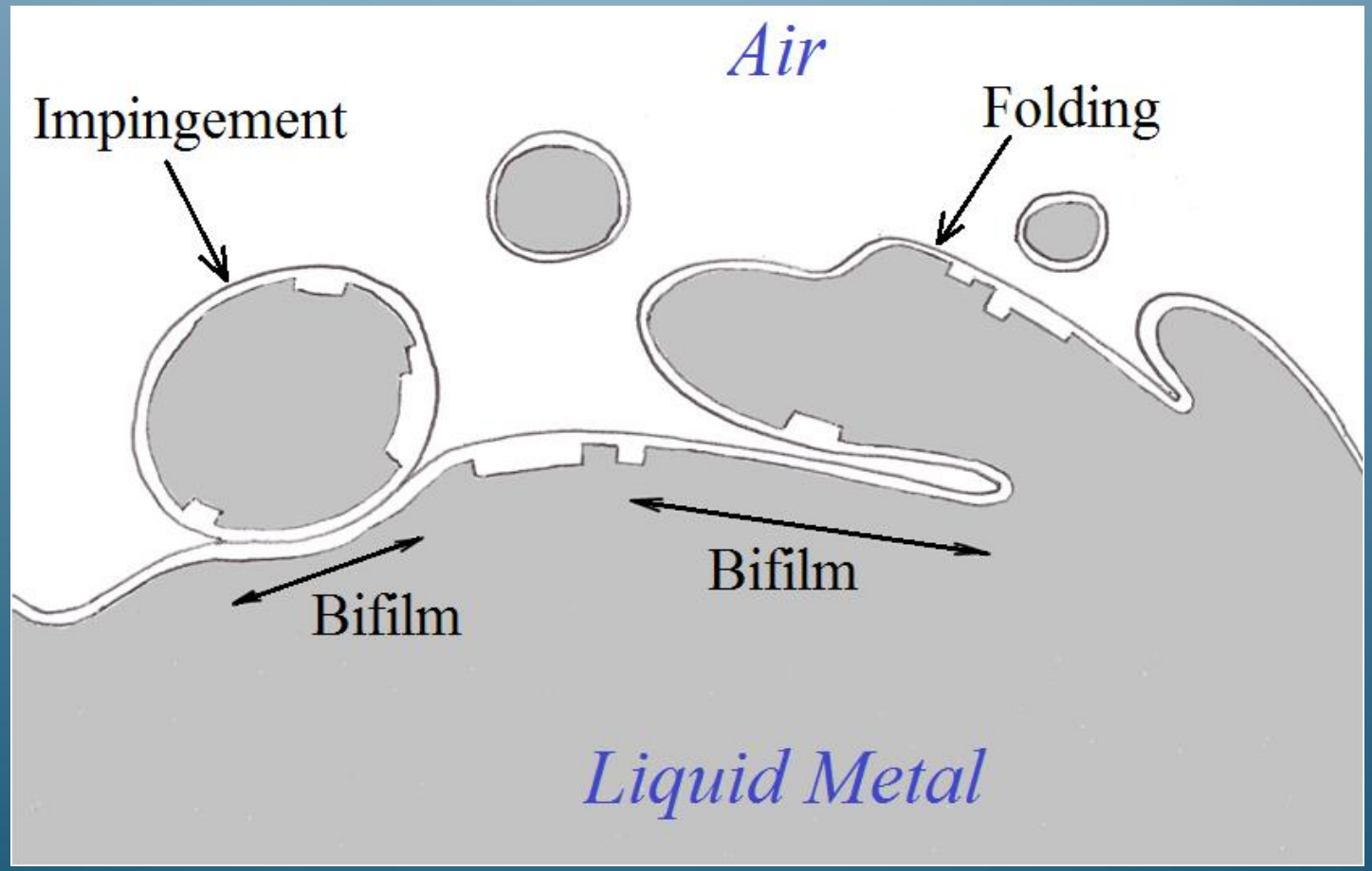
John Campbell

University of Birmingham UK

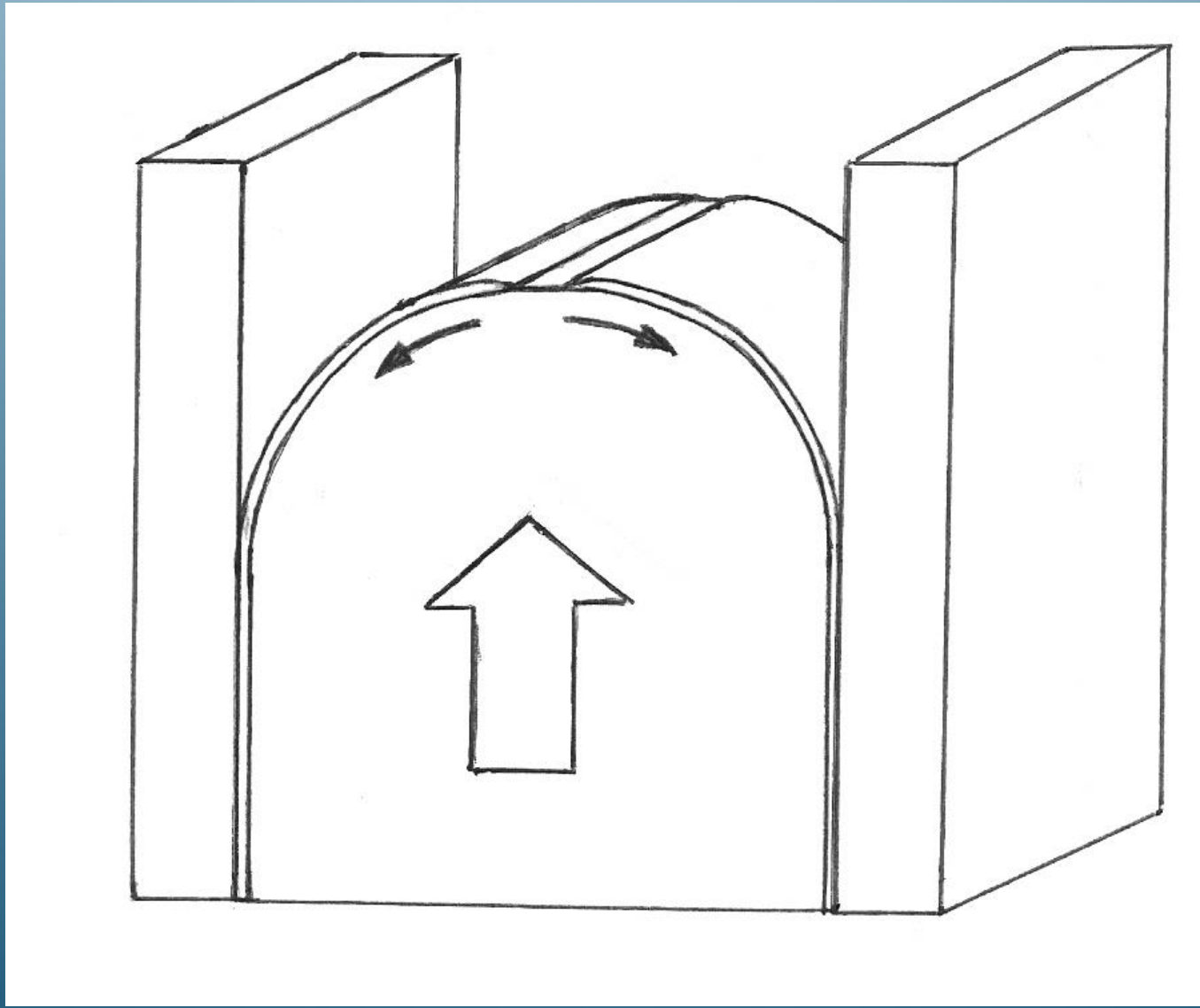
Top gated turbulent filling



Surface Turbulence generating Bifilm Cracks in the Liquid Metal



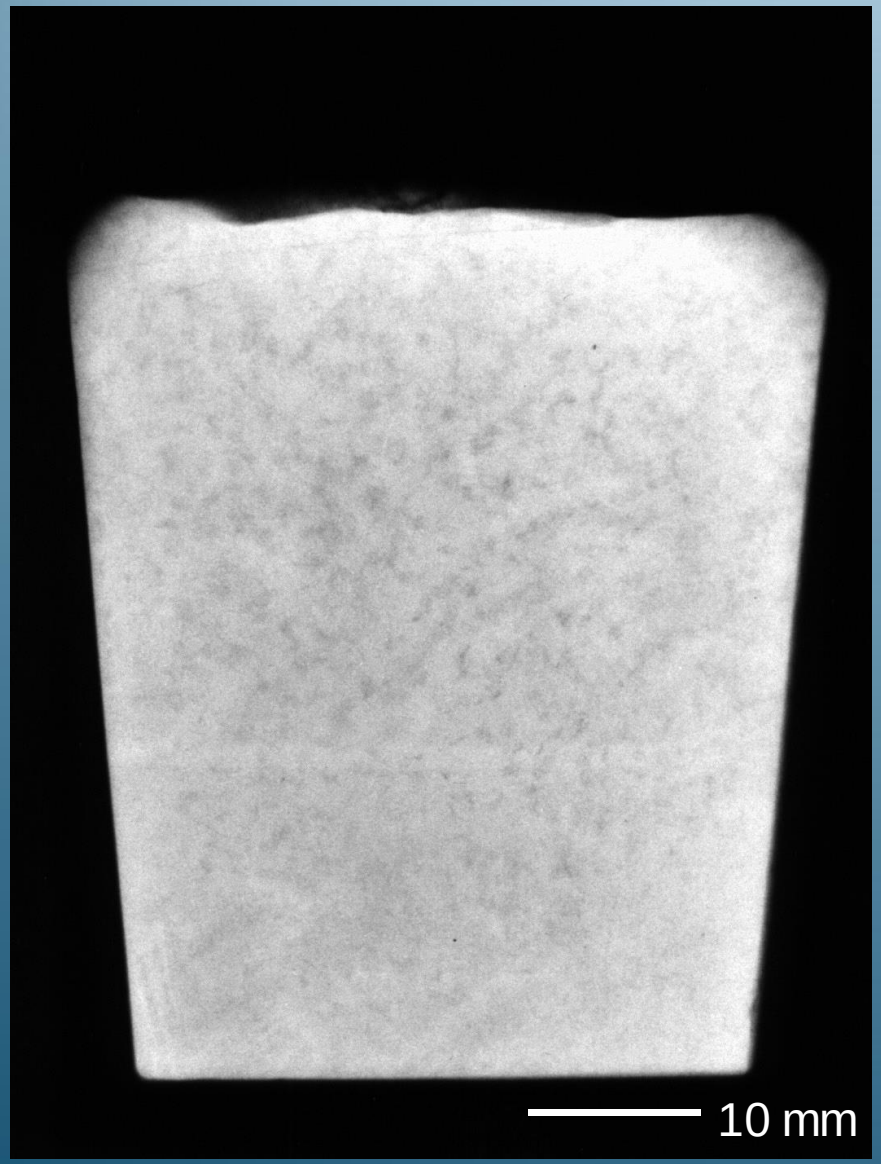
Bottom gated laminar filling



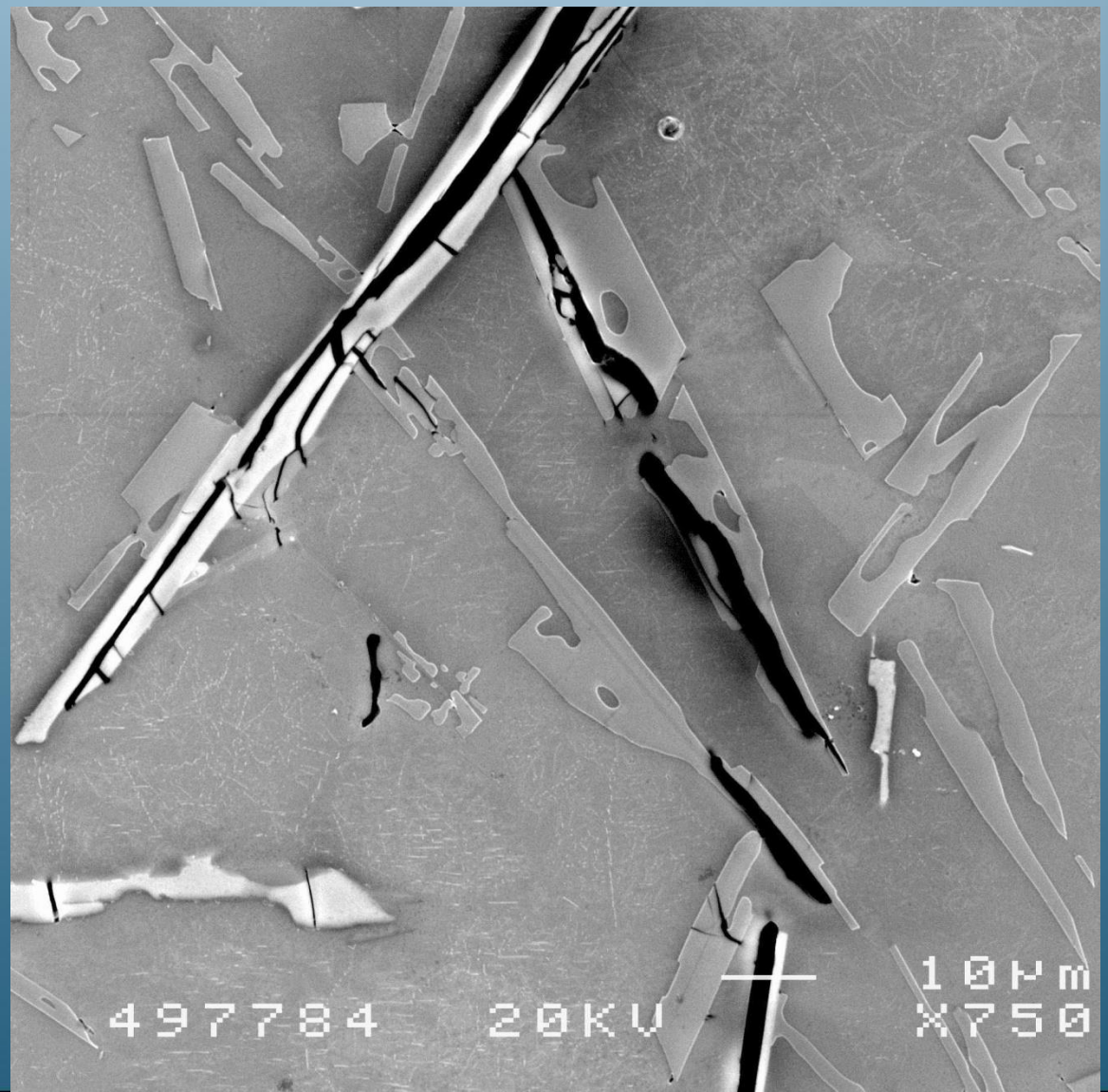
Entrainment Defects

1. Bifilms
2. Bubbles

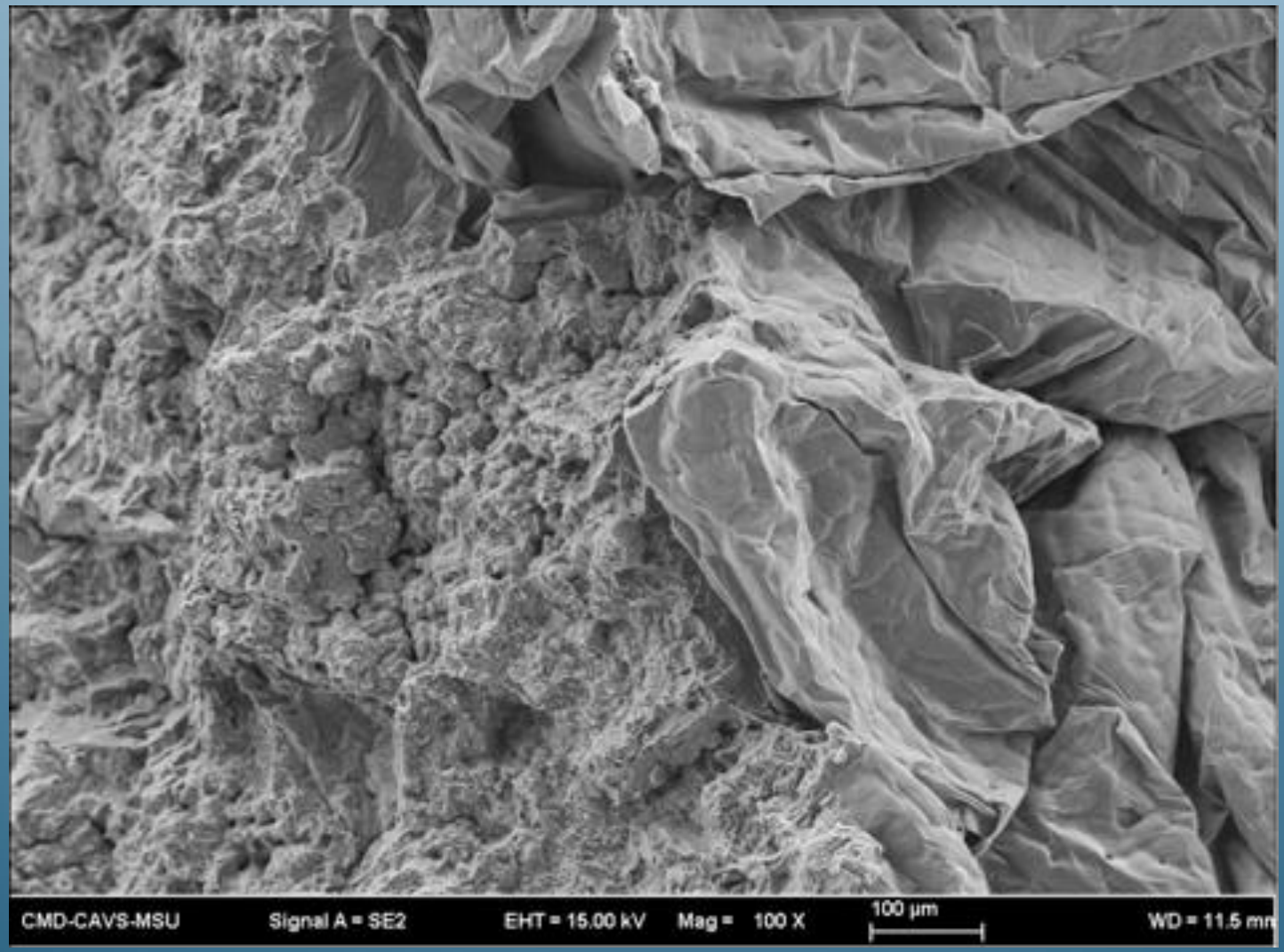
RPT Before and After Reduced Pressure



Cracked bifilm substrates for β-Fe and Si particles

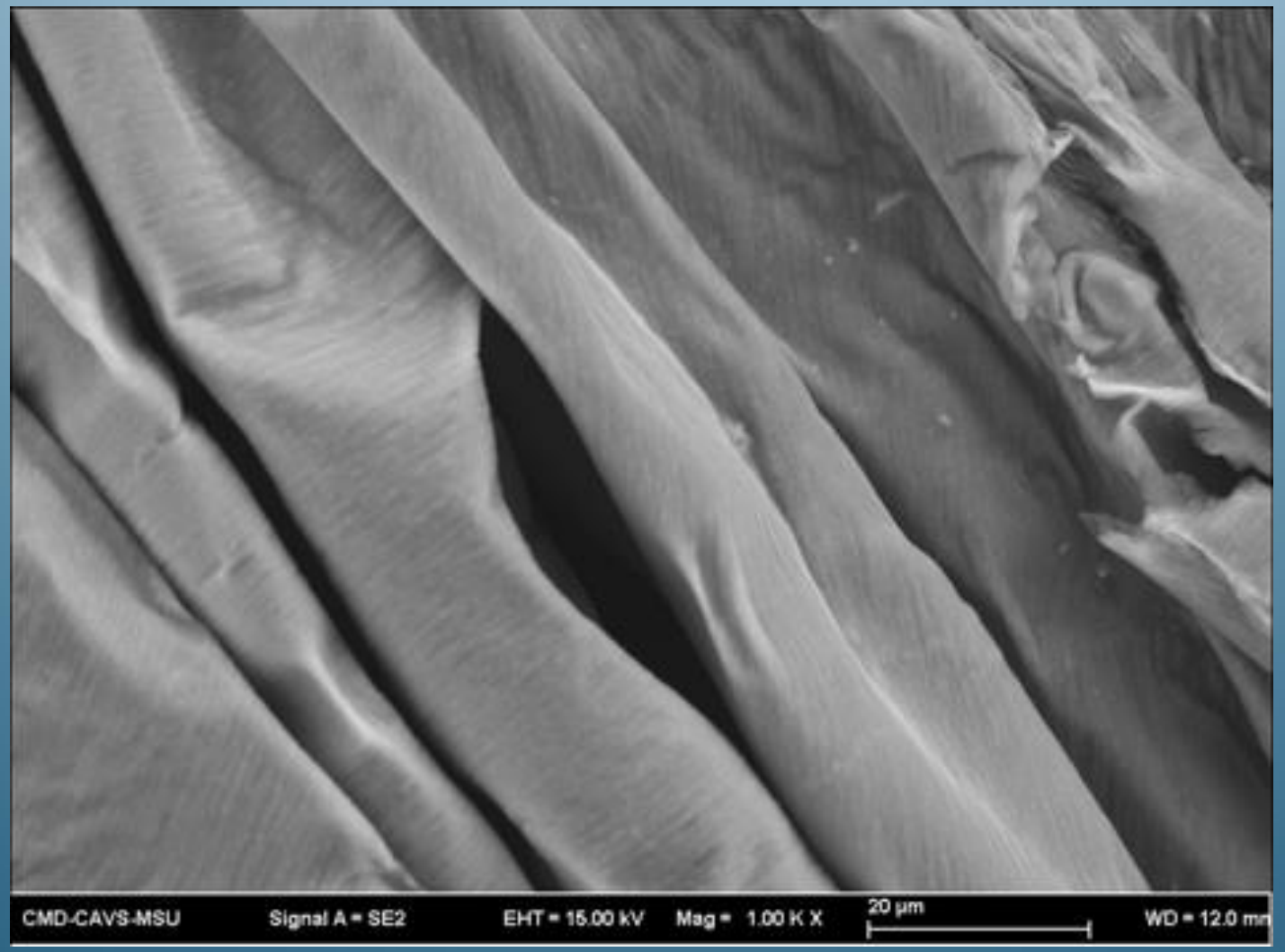


Fracture surface Mg alloy AZ91



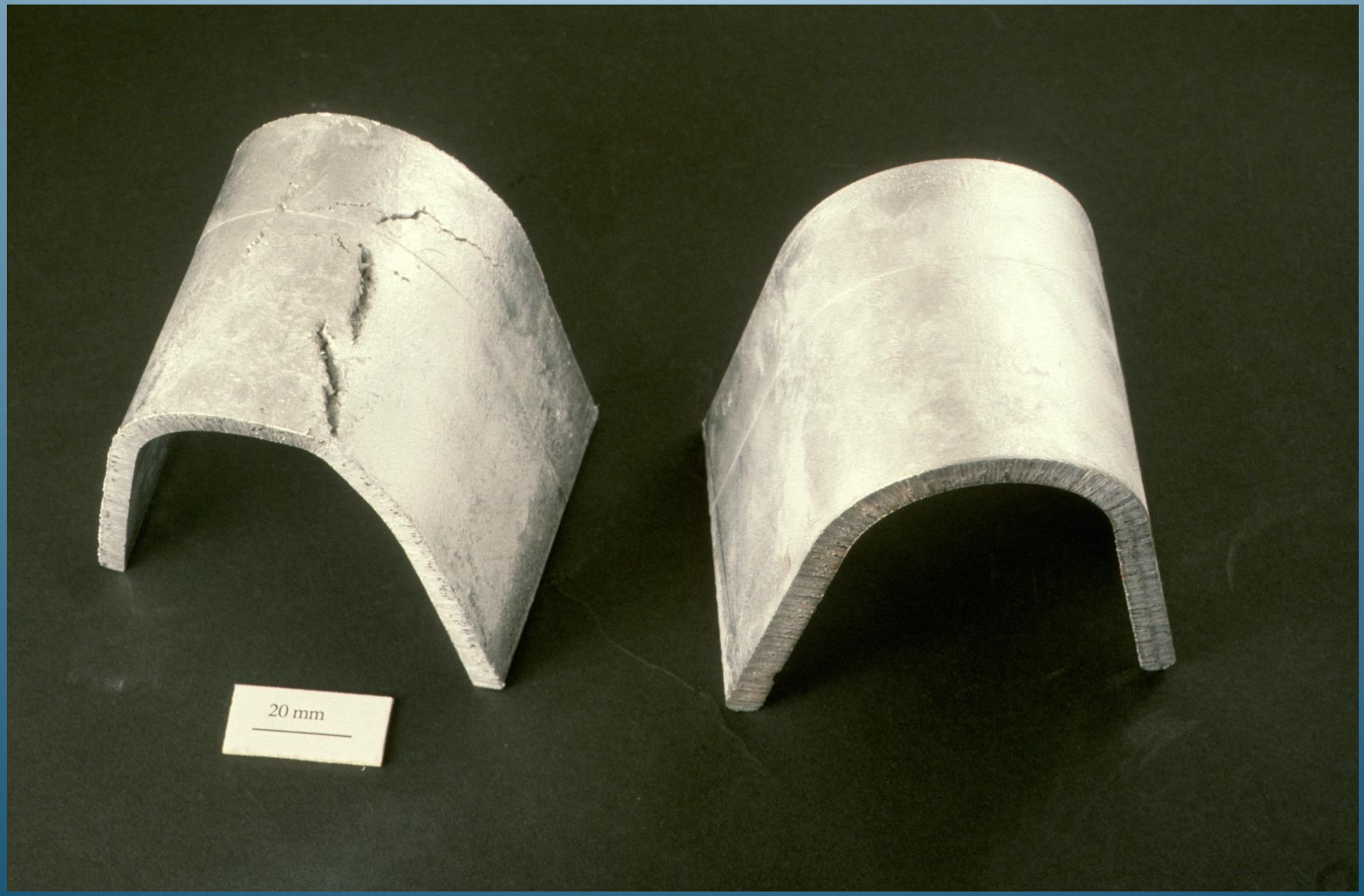
Prof John Berry MSU 2008

Fracture surface Mg alloy AZ91



Prof John Berry MSU 2008

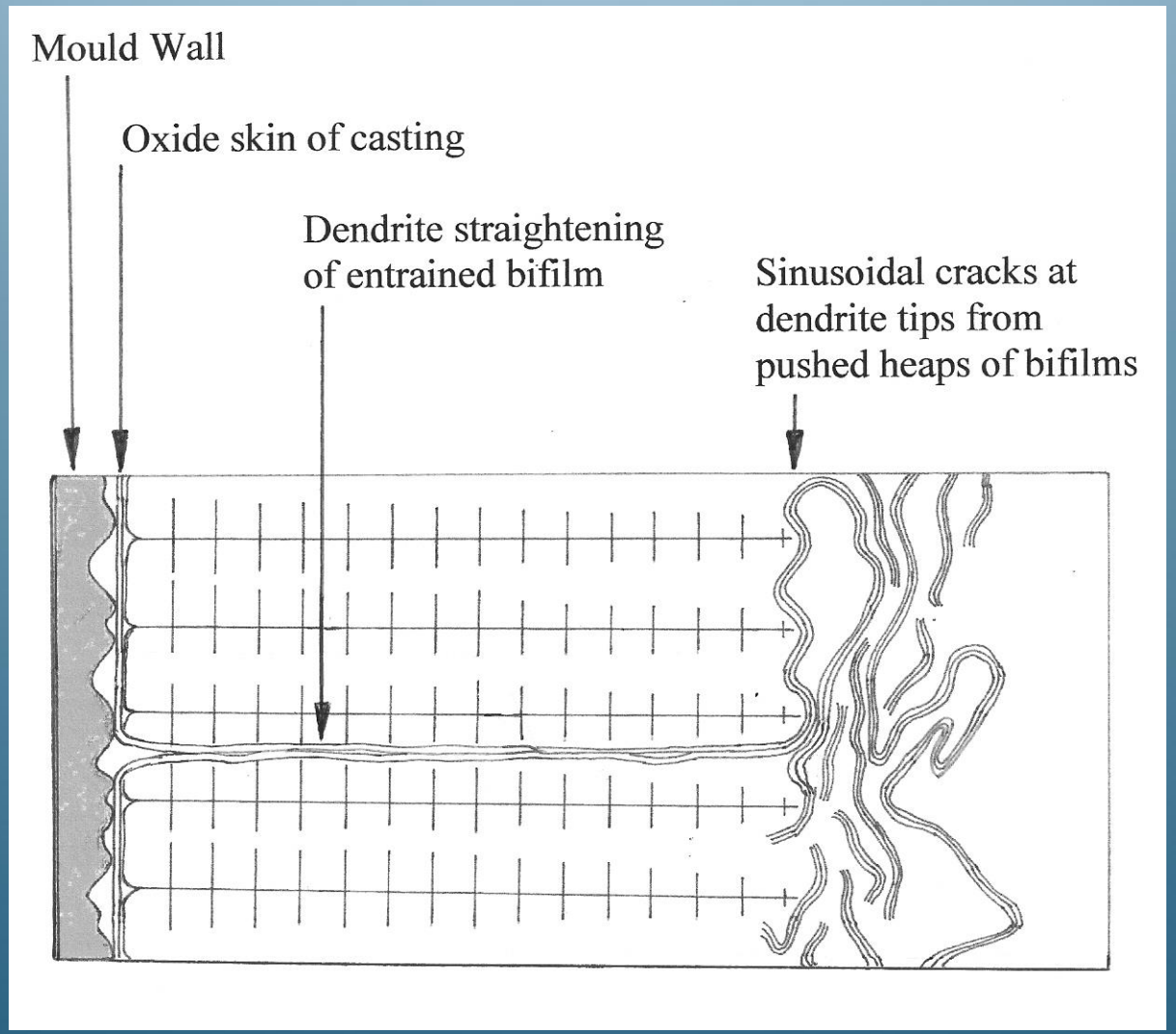
“Before and after”



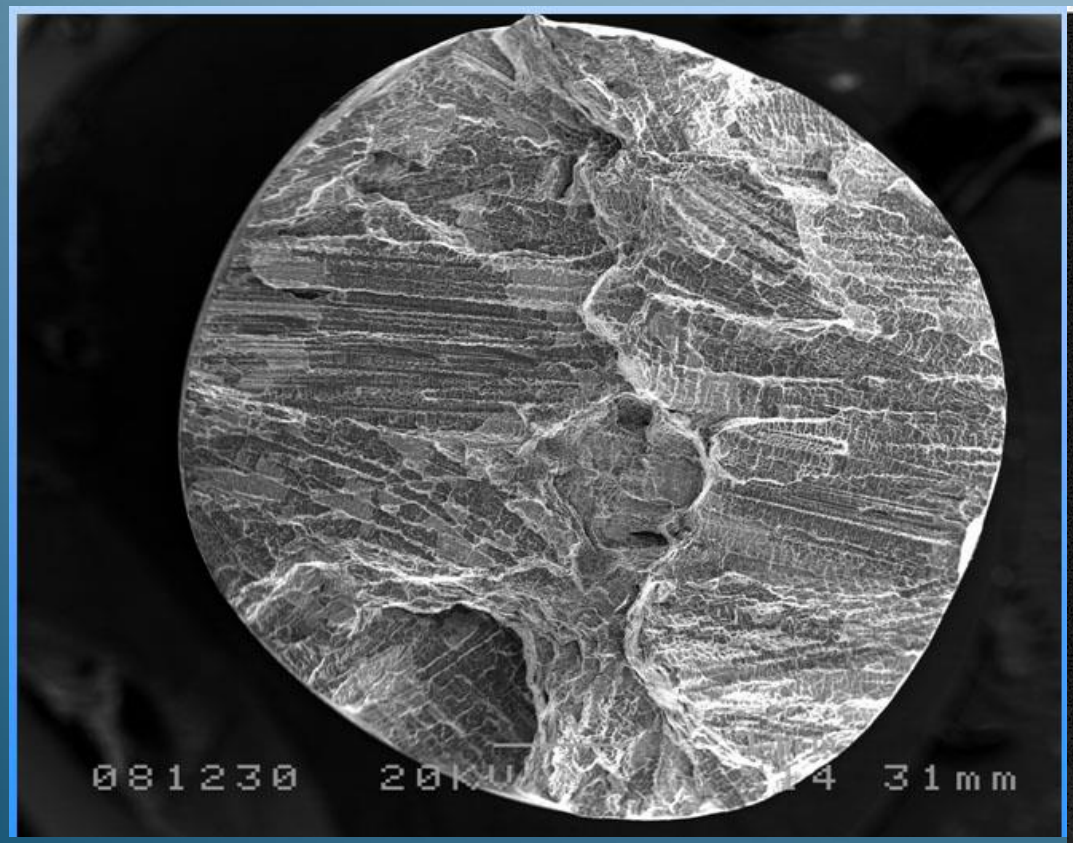
Ni-base CY40

Control of Microstructure and Mechanical Properties by Bifilms

Dendrite straightening of bifilms



Fracture surfaces from parts of the same Al-4.5Cu alloy casting with and without an entrainment event



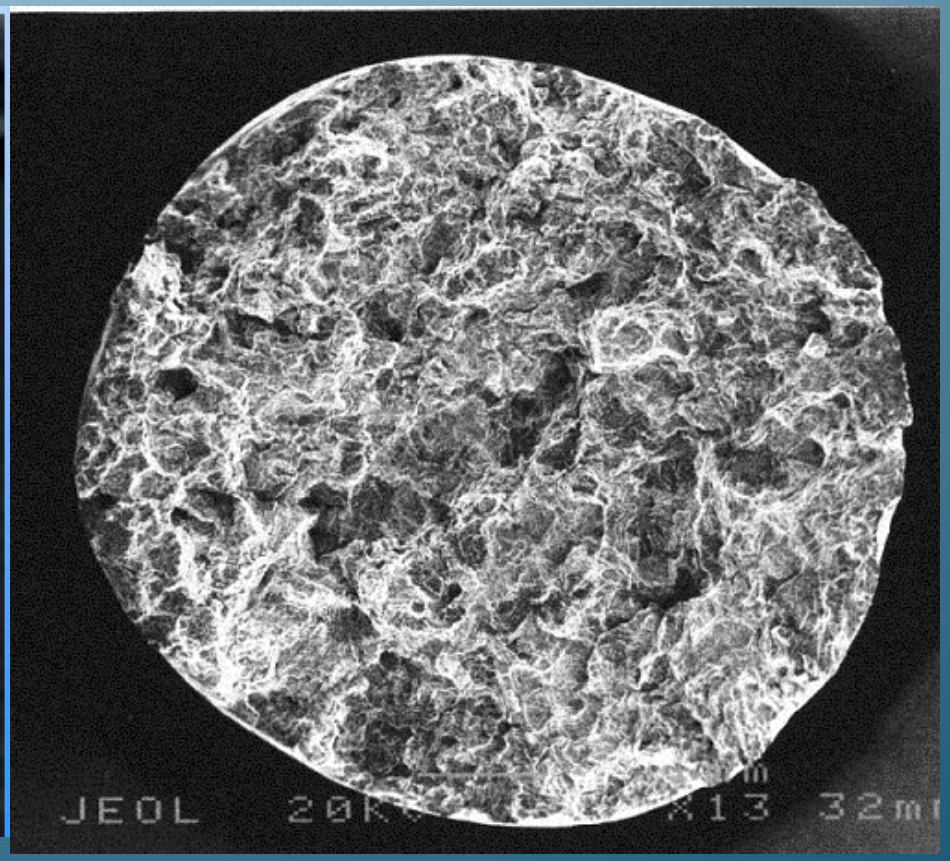
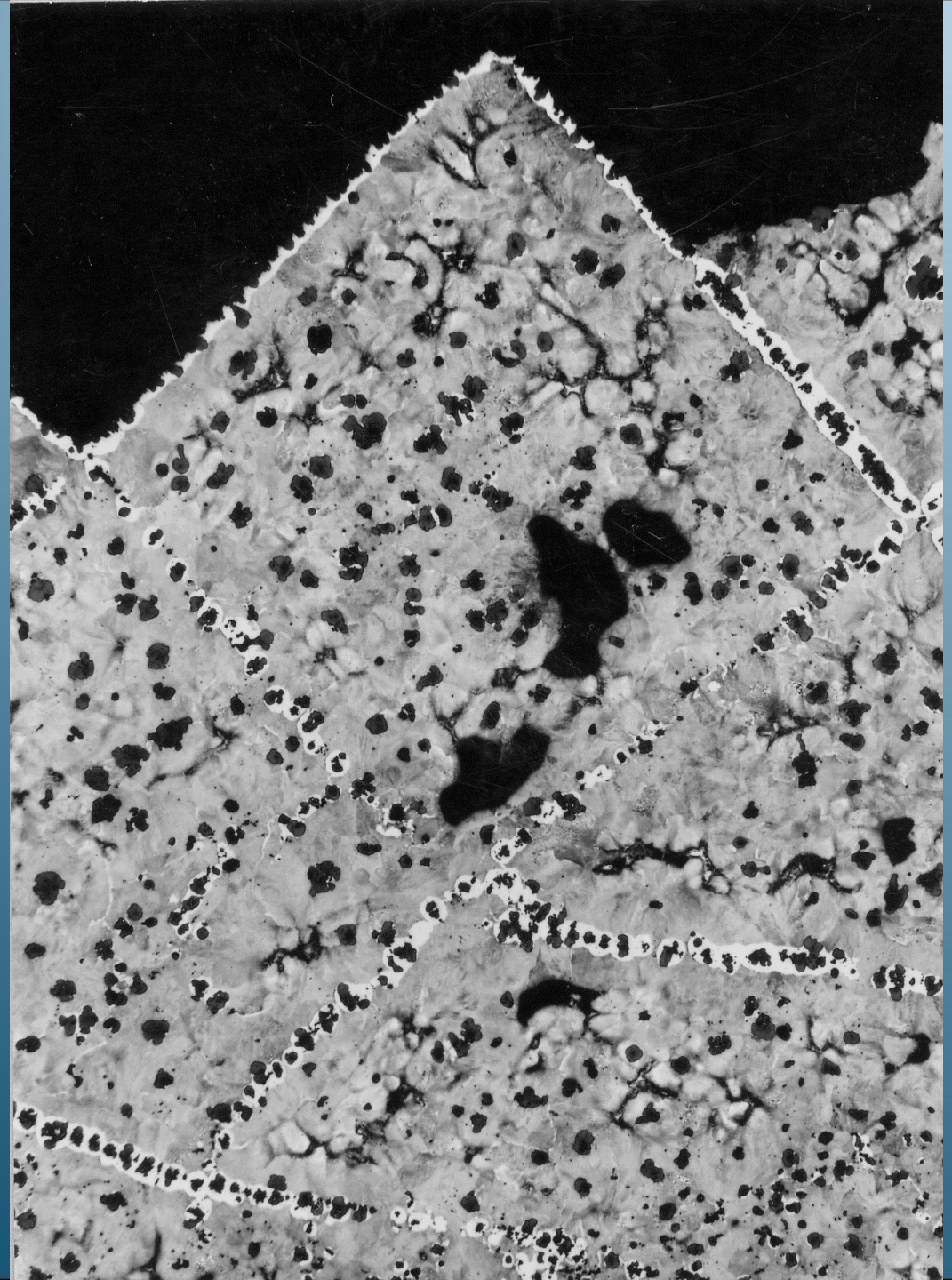


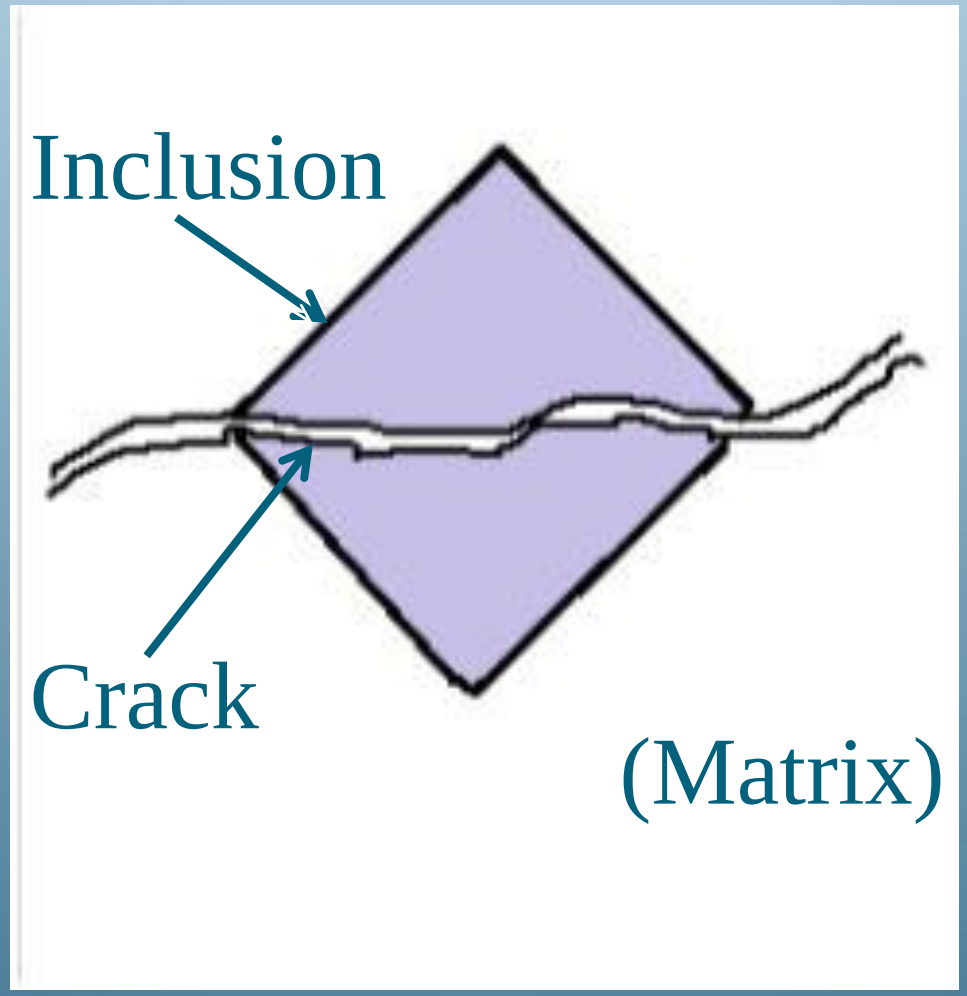
Plate fracture

in

ductile iron



Microstructure of plate fracture in ductile iron



Cracked inclusion

Logic 1

- Inclusion
- Stress
- Crack

Logic 2

- Inclusion
- (no stress)
- Crack

The Ductile / Brittle Behaviour of Engineering Metals

Ductile **Brittle**

	Liquid	Pb	Au	Nb	Pt	Pd	Hf	Ag	Al	Cu	Zr	Ti	Ni	Co	Fe	Mg	Mo	Nd	W	Re	Ir	Cr	Be
μ/B	0	0.12	0.15	0.22	0.22	0.23	0.27	0.29	0.35	0.35	0.39	0.42	0.43	0.45	0.48	0.49	0.48	0.50	0.52	0.54	0.56	0.72	1.42
ν	0.50	0.44	0.42	0.40	0.39	0.39	0.37	0.37	0.34	0.34	0.33	0.32	0.31	0.30	0.29	0.29	0.29	0.28	0.28	0.26	0.26	0.21	0.02

μ/B = Ratio of elastic modulus to bulk modulus

ν = Poissons Ratio

Theoretical Basis of Crack Formation

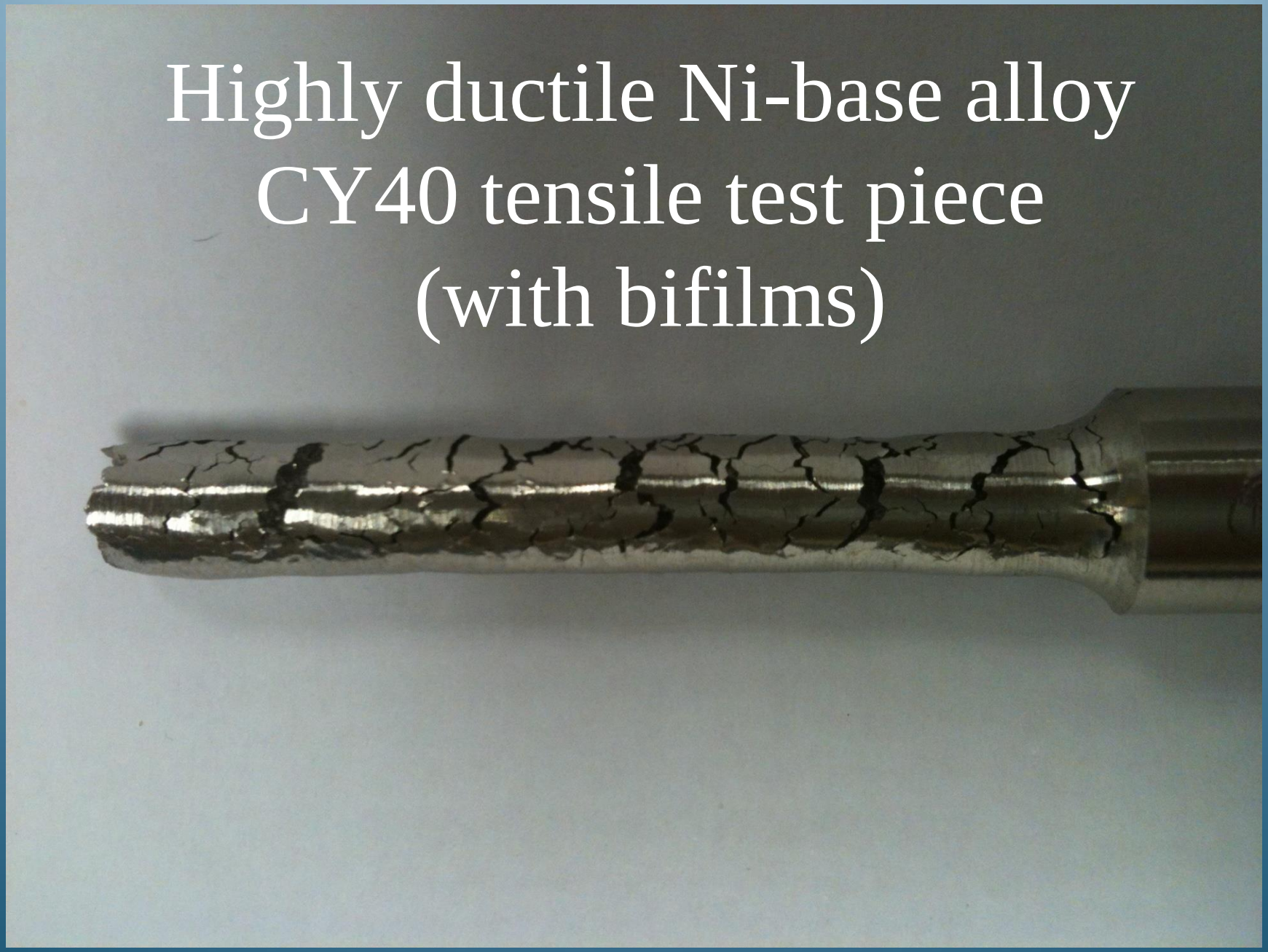
1. Griffith: An Energy criterion.
   No specified geometry

2. Barenblatt: A geometrical model.
   A region of zero cohesion
   surrounded by strong cohesion

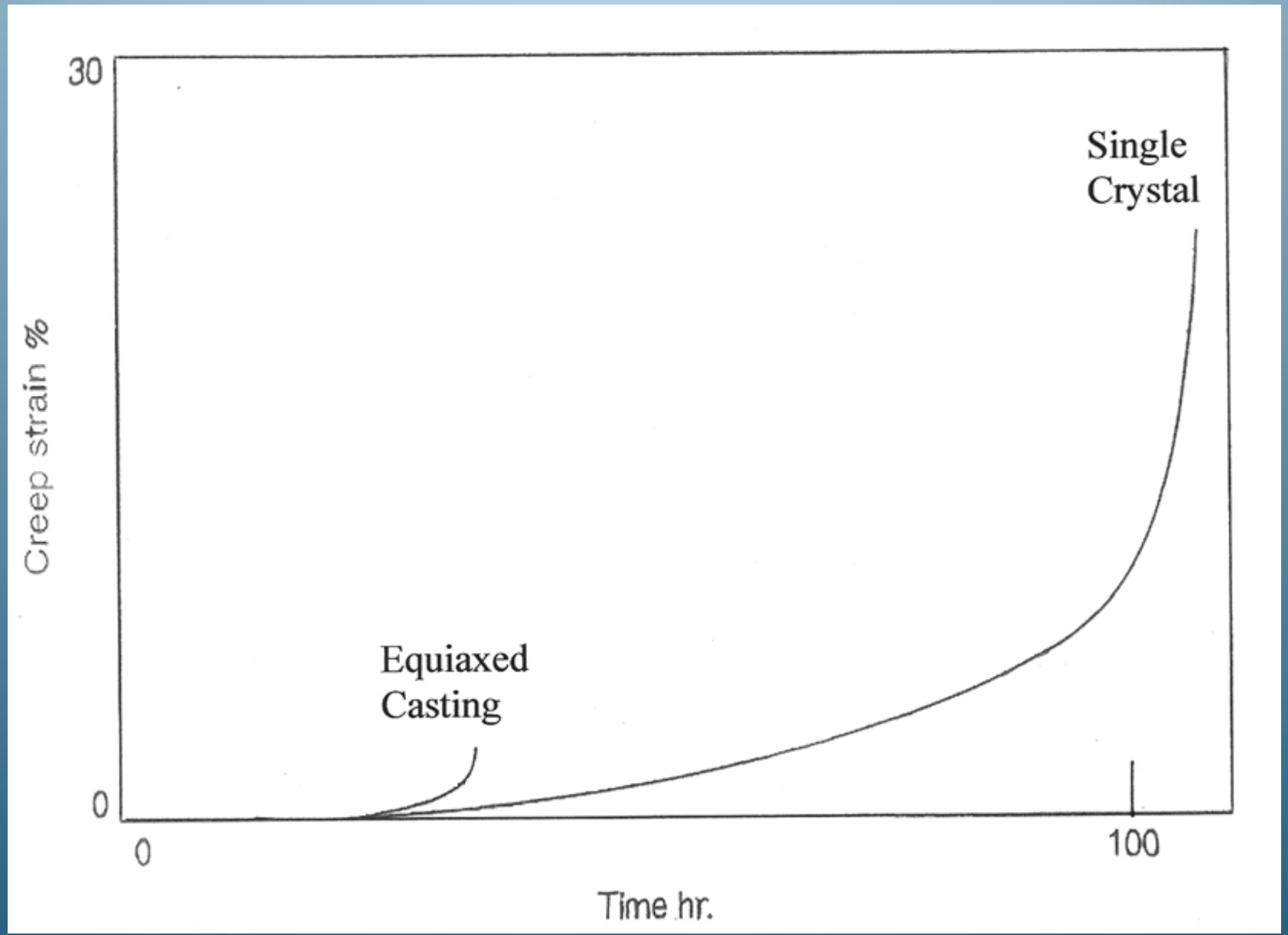
Fracture Processes

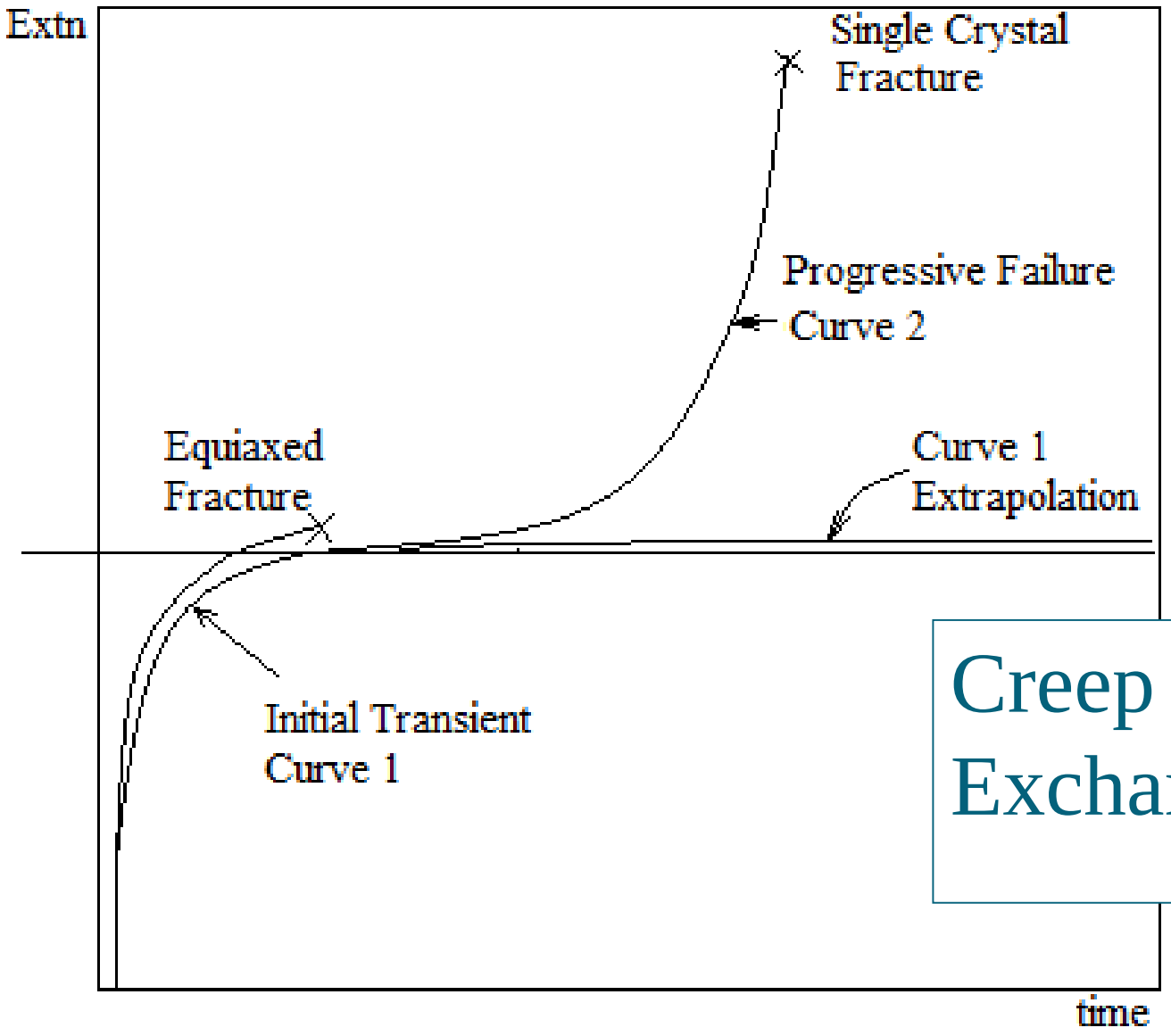
Overload Fracture

Highly ductile Ni-base alloy CY40 tensile test piece (with bifilms)



Creep Deformation and Fracture


30
0
Creep strain %
Single
Crystal
Equiaxed
Casting
0
100
Time hr.



Creep of Heat Exchanger Steels

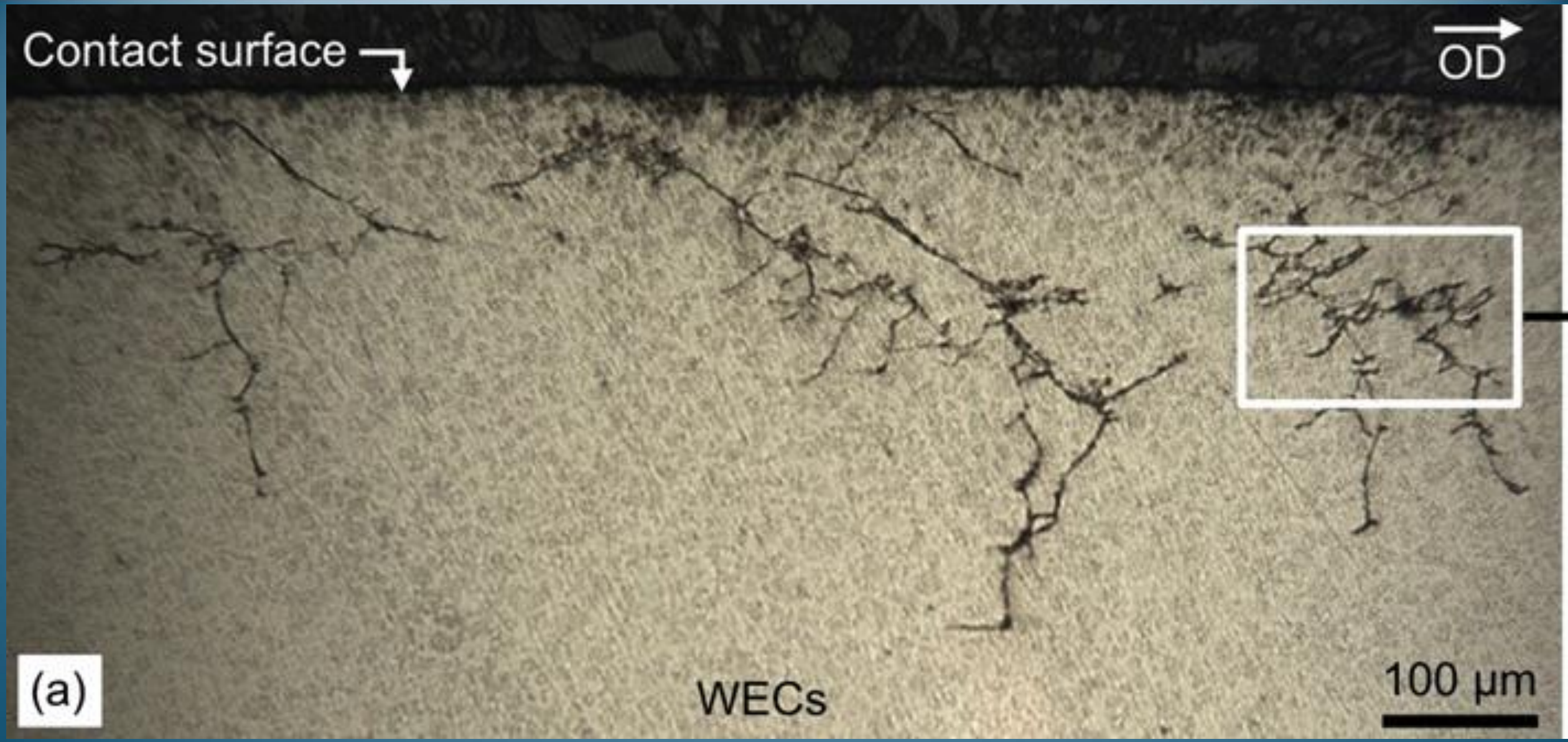
Brian Wilshire

Fatigue Failure

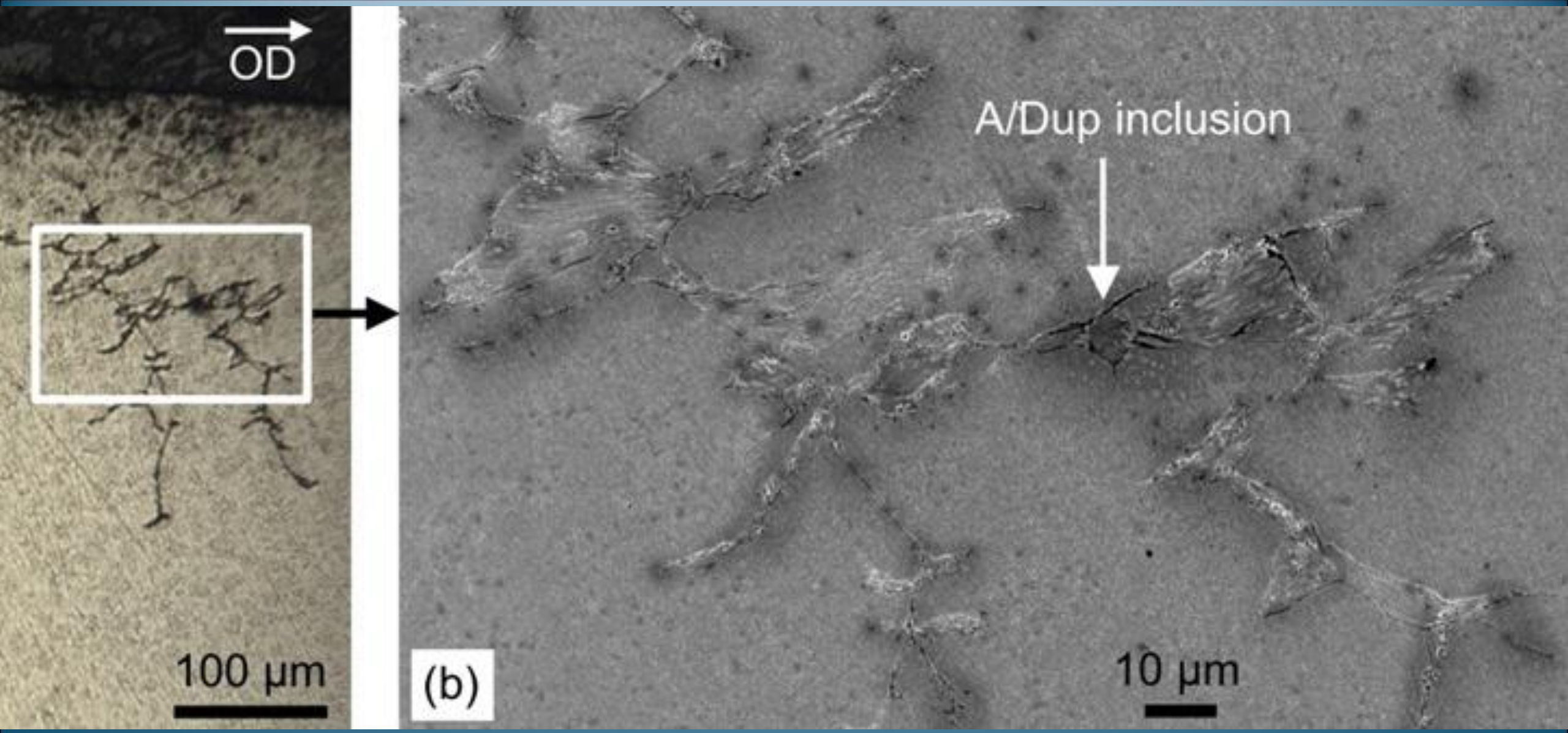
1. Wind Turbine Main Bearing

2. Aero Engine Turbine Blade

3. Helicopter Main Drive Shaft

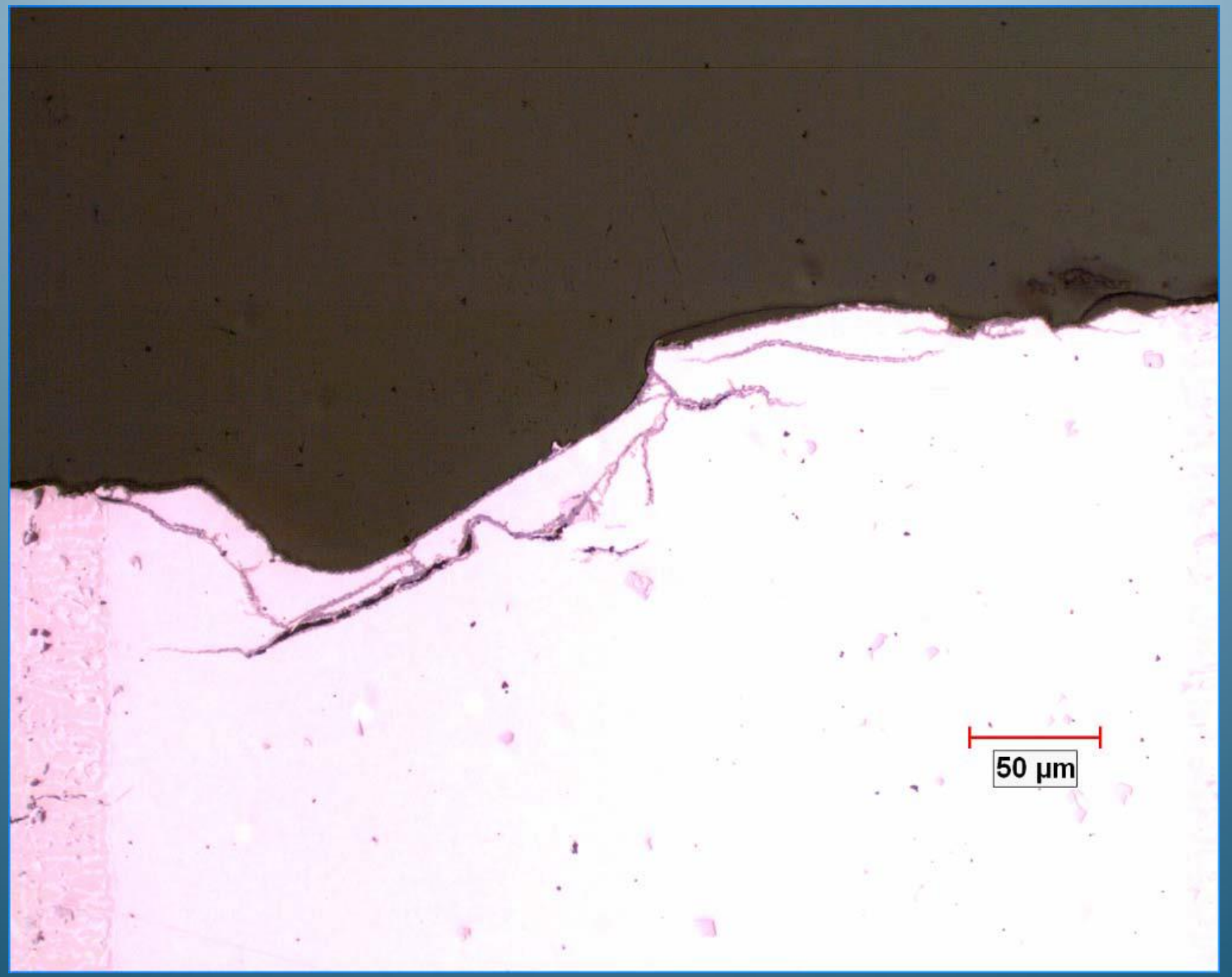


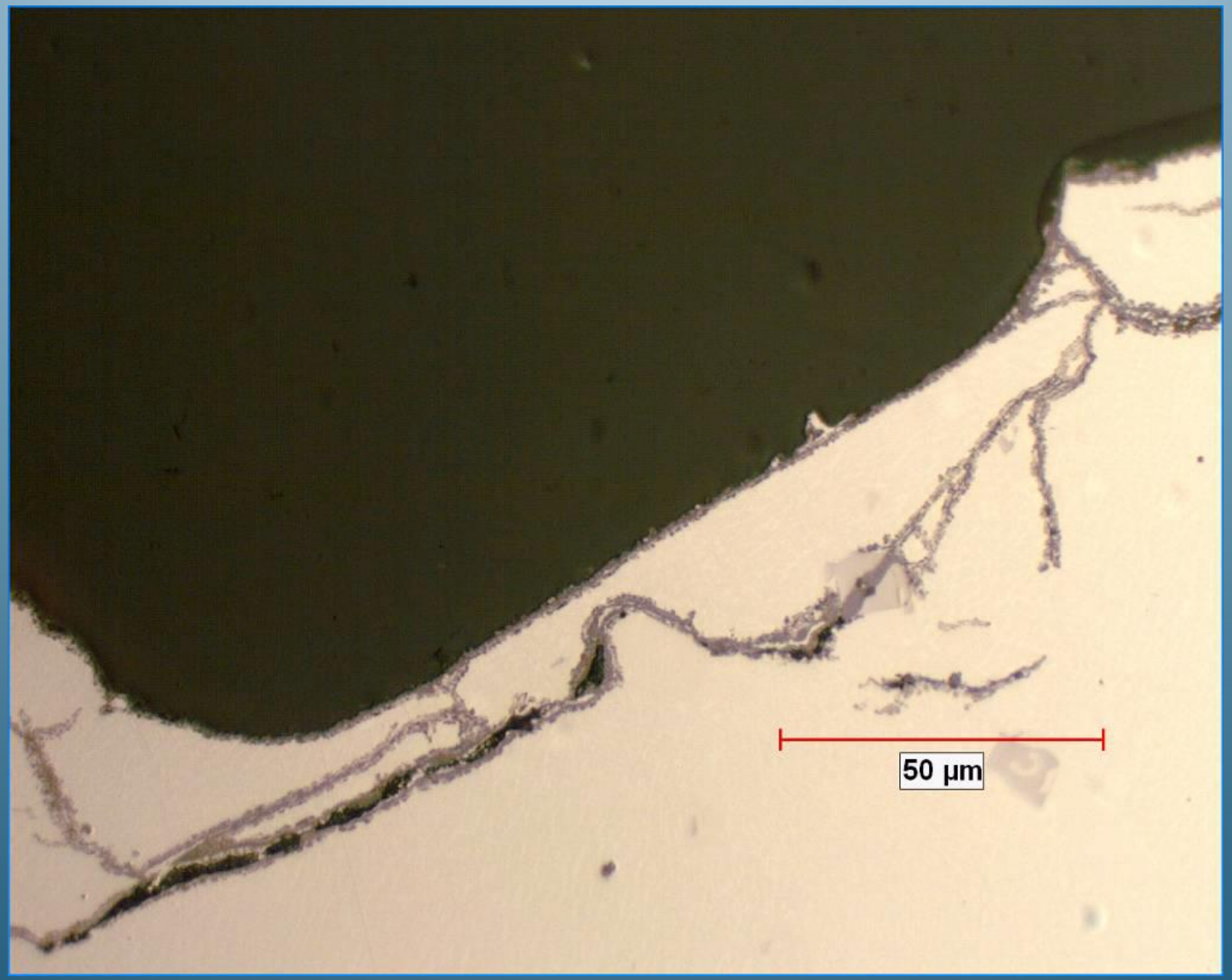
Bearing steel fatigue failure
Martin Evans et al 2012

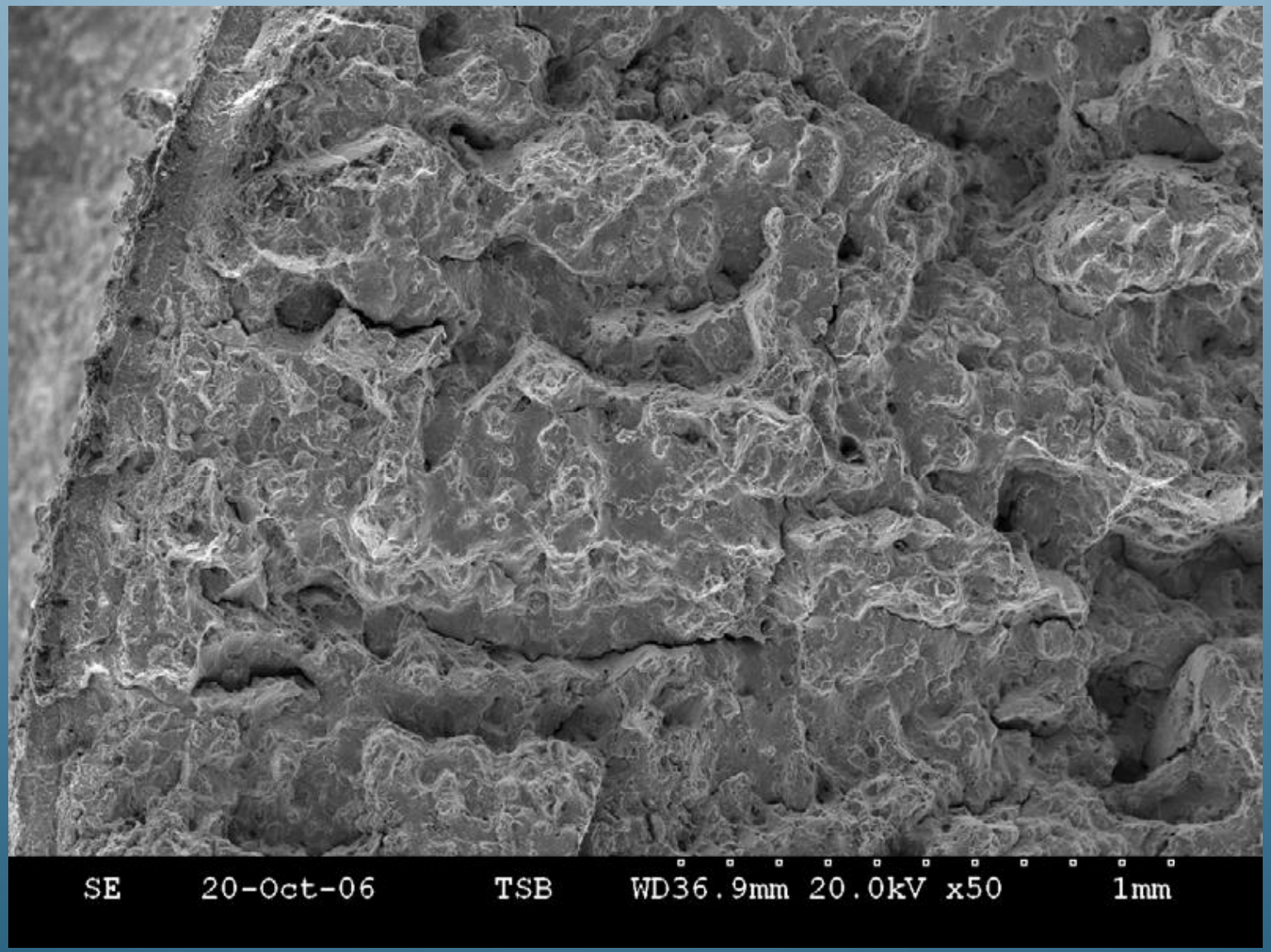


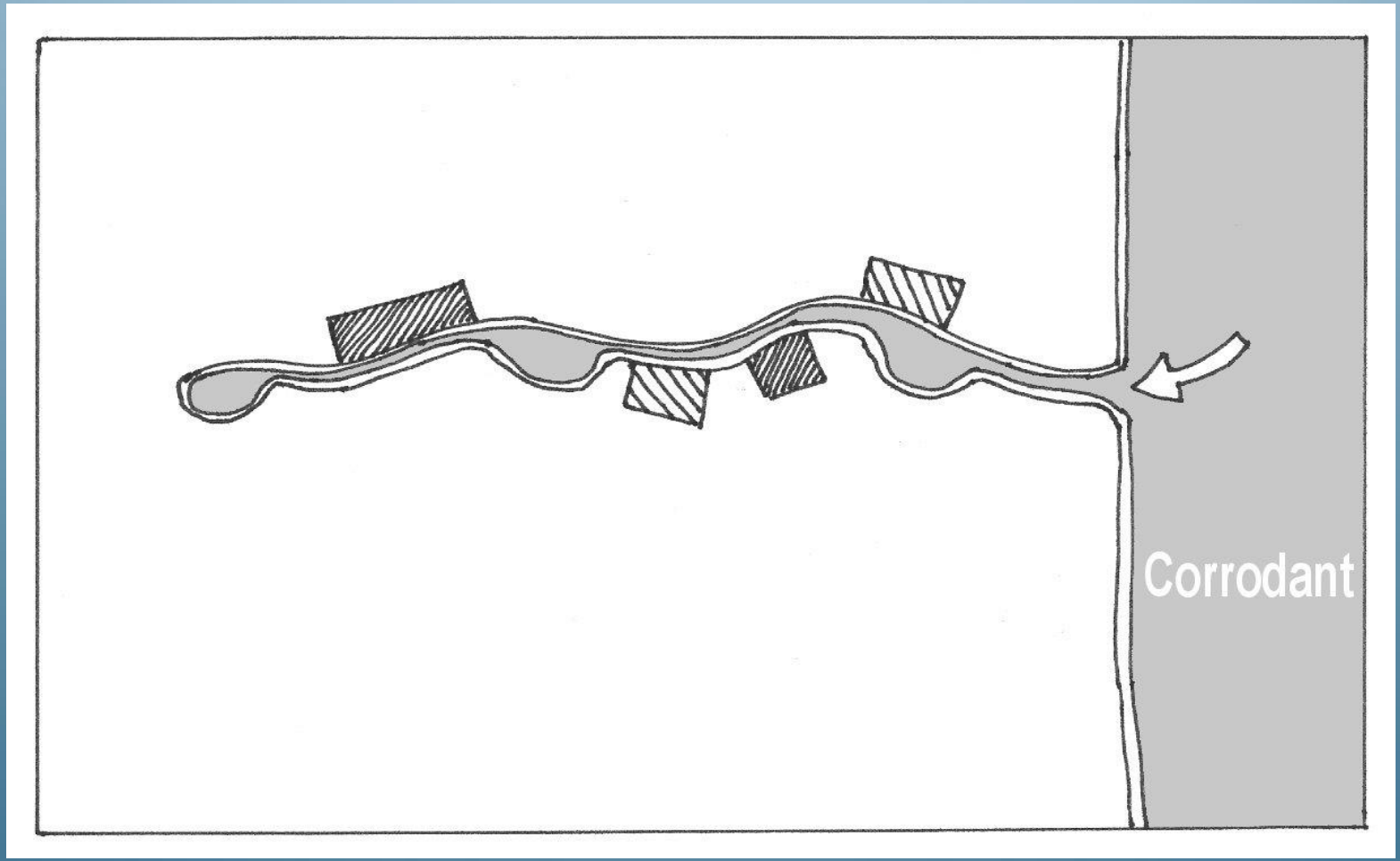
Bearing steel fatigue failure
Martin Evans et al 2012

Compresser Failure
Sessna 208B
21 Jan 2006

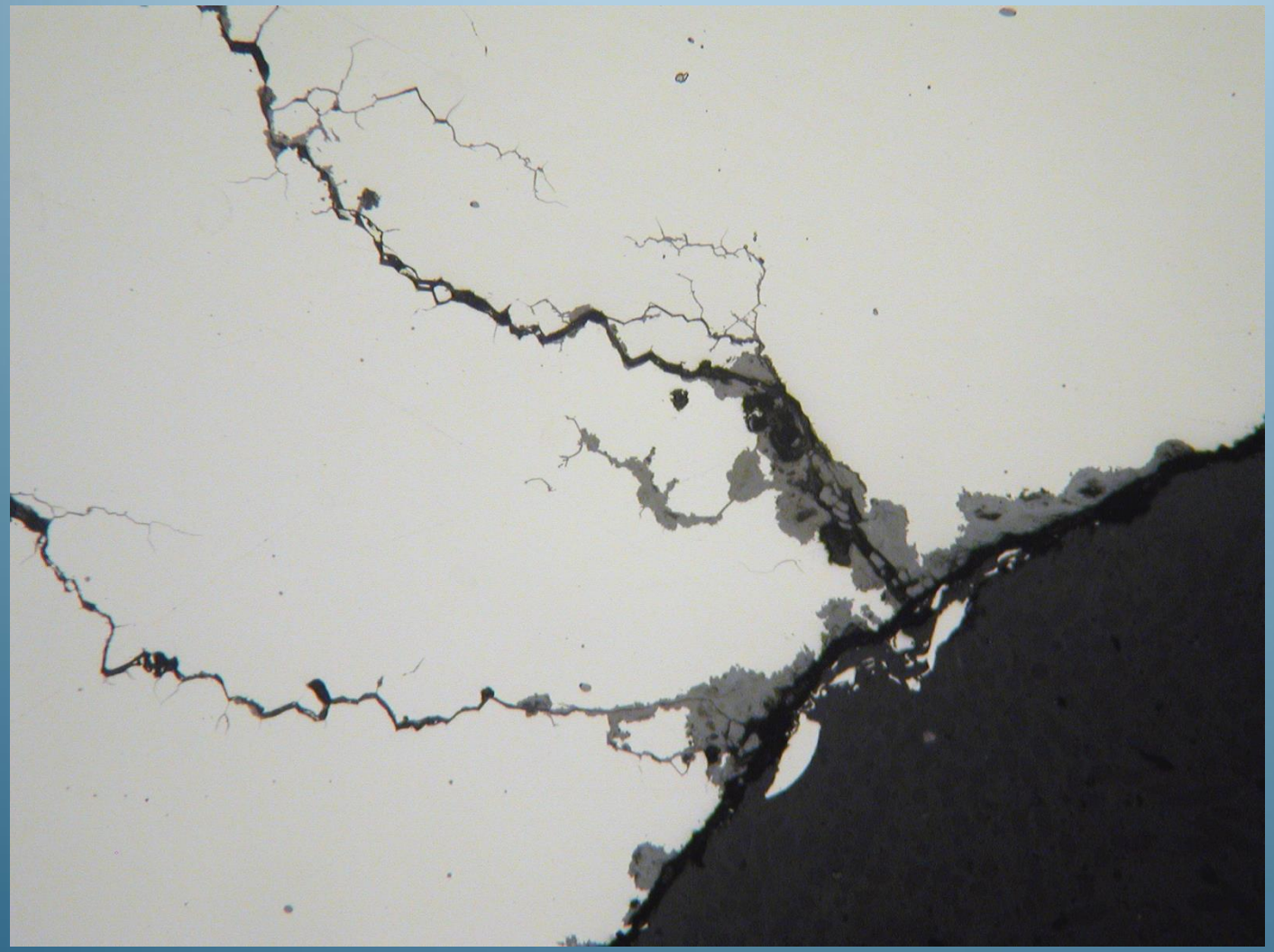

50 µm


50 µm


SE 20-Oct-06 TSB WD36.9mm 20.0kV x50 1mm

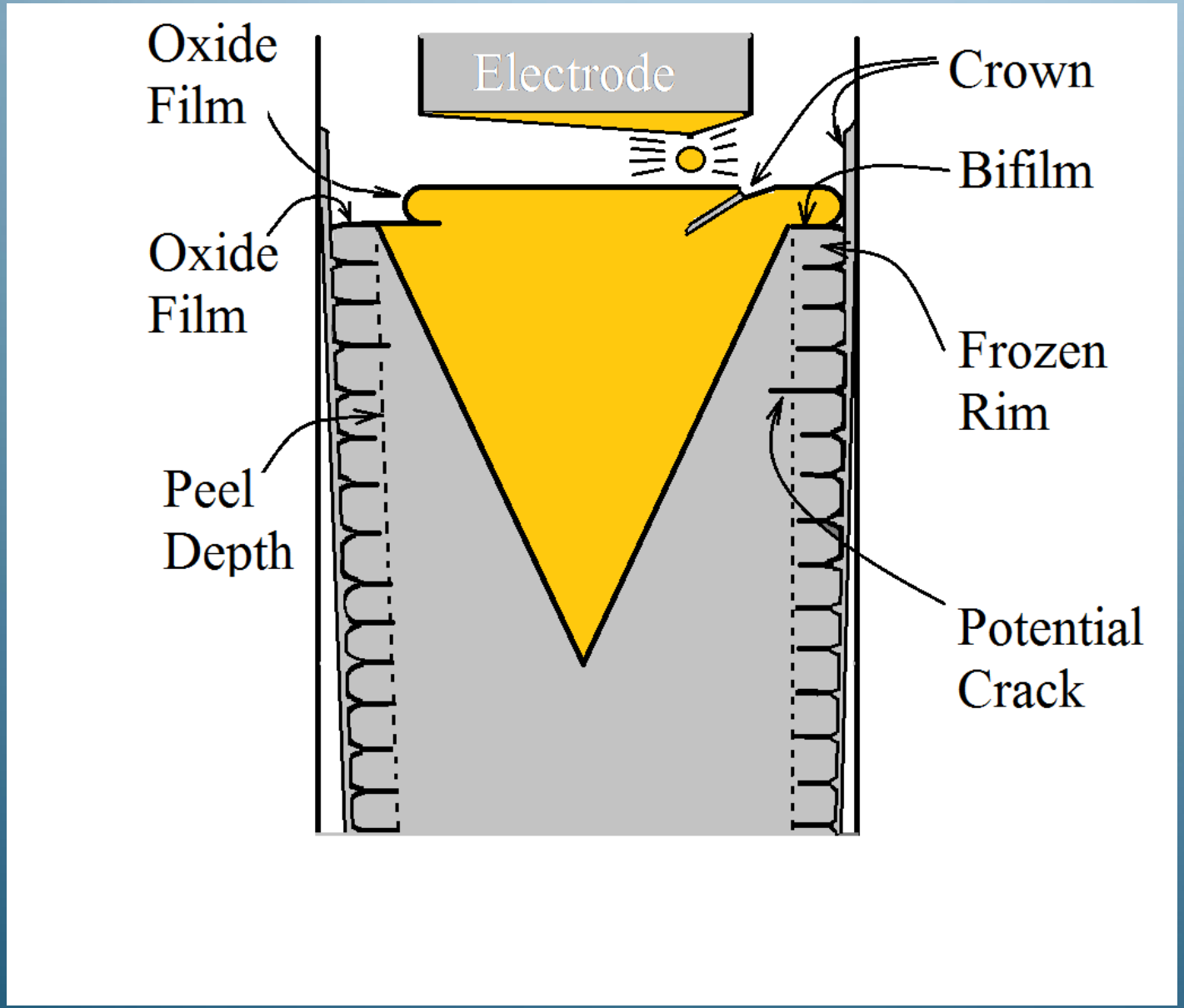


Initiation of a Corrosion Pit

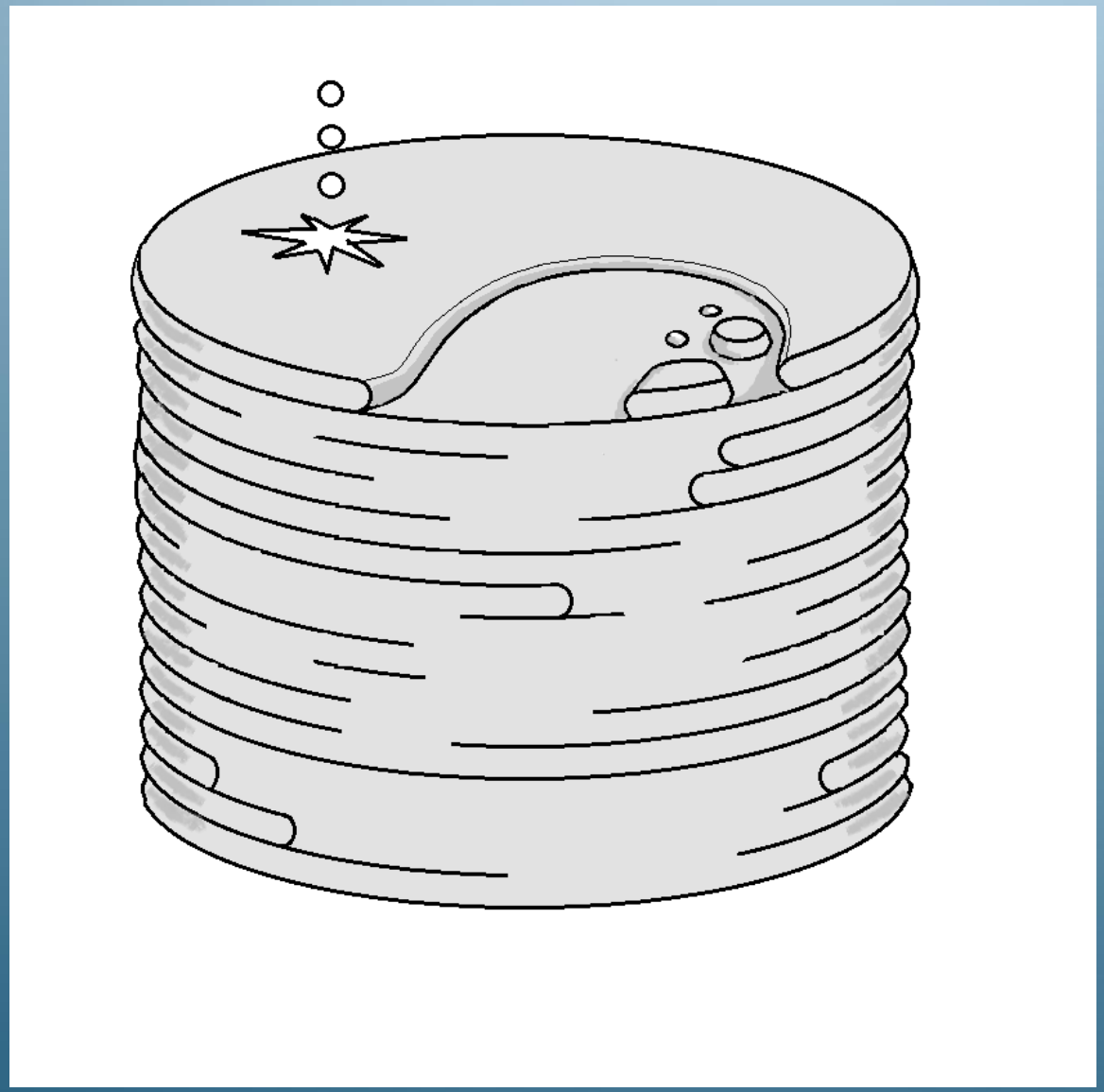


ETCH PIT
(formed where bifilm intersects surface)

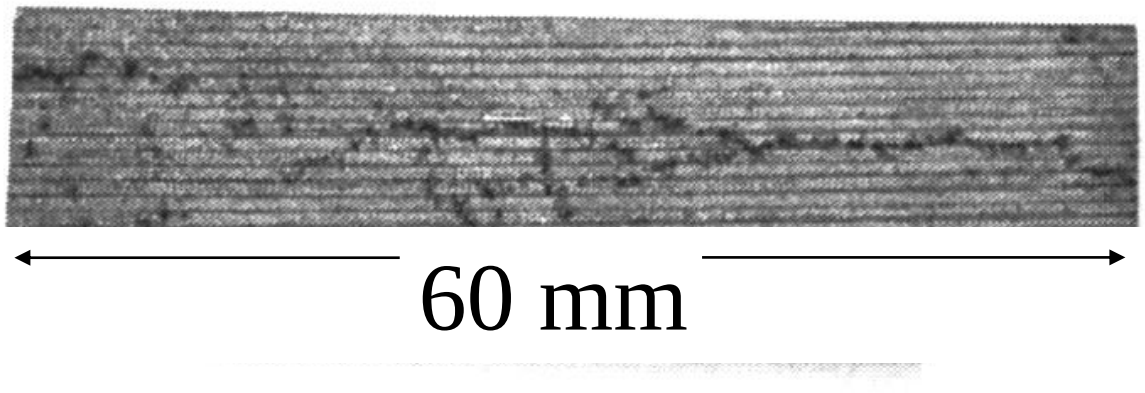
Image courtesy Metallurgical Associates Inc 2015

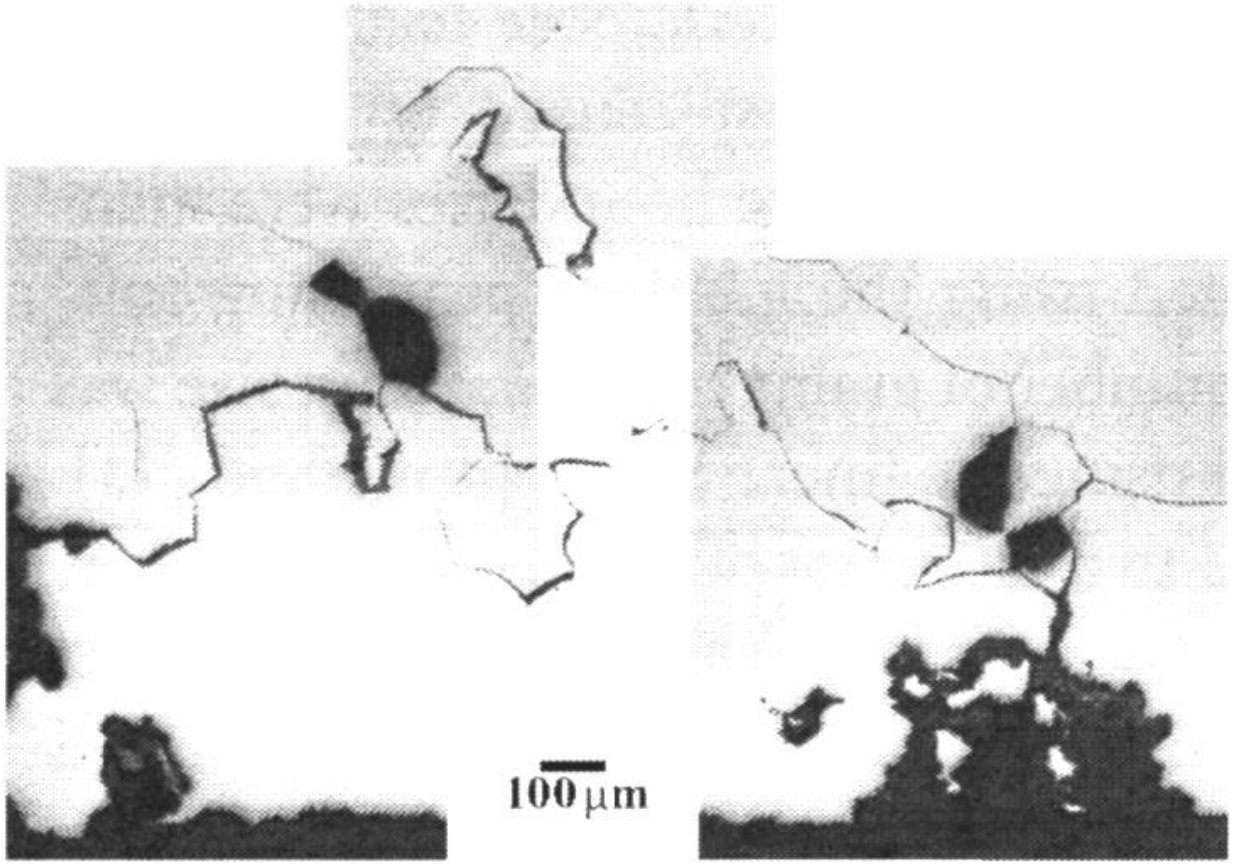


VAR Crack defects



Production of VAR Ingot





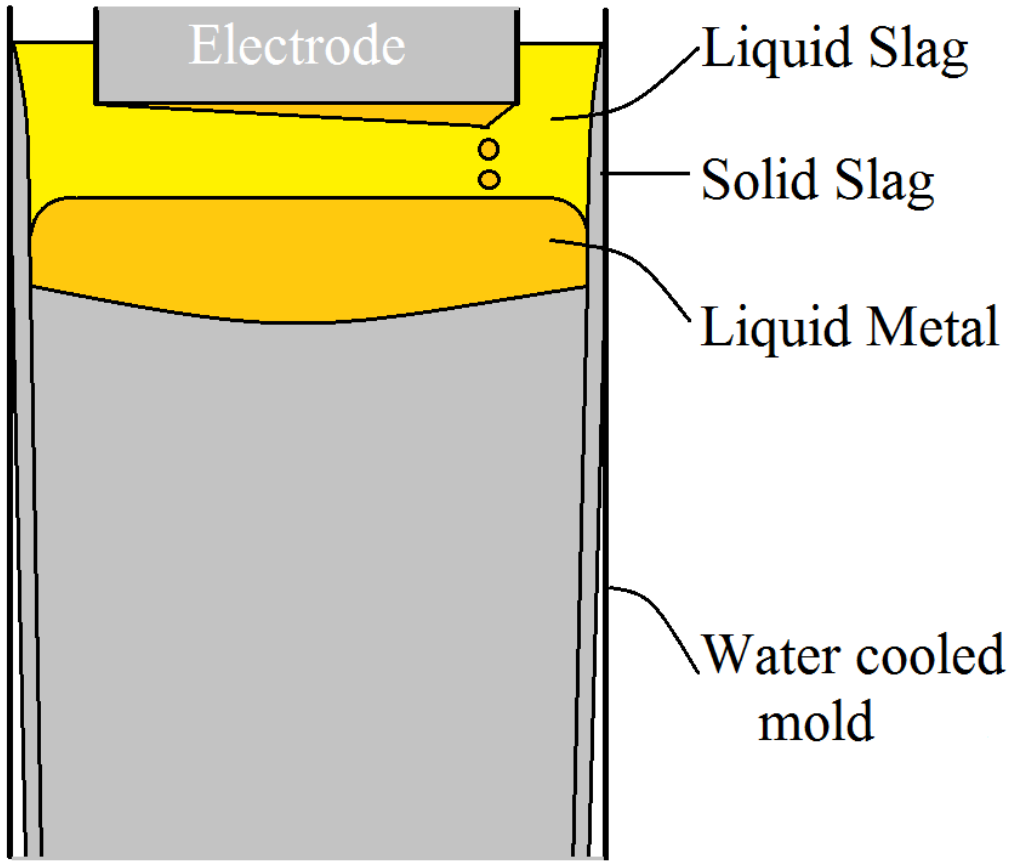
Crack in VAR ingot observed after salt bath heat treatment.

Peet & Bhadeshia 2017

Helibras HM-1 Pantera under construction in Brazil

Year	Flight	Location	Helicopter Type	Fatalities	Cause
1977	Service flight 451	Norway Norwegian Sea	Eurocopter AS 332L1 Super Puma	12	Fatigue crack in the spline which ultimately caused the power transmission shaft to fail.
1978	Service flight 165	Norway North Sea	Sikorsky S-61	18	Rotor blade loosened after fatigue to the knuckle joint
2009	Service flight	North Sea	Super Puma	14	Gearbox failure
2012 May	Service flight	North Sea	Bond Super Puma Eurocopter EC255	0	Gearbox cracks due to corrosion
2012 October	Service flight	North Sea	Bond Super Puma Eurocopter EC255	0	Gearbox cracks due to corrosion
2016	Service flight	Norway coast	Eurocopter EC255	13	Fatigue of rotor shaft and loss of rotor
2018	Military test	Korea	Marineon MUH-1	5 fatalities 1 injured	Fatigue of rotor shaft (plus faulty spares from Airbus!)
2019	Private use	Leicester City Stadium	AugustaWestland AW169	5 (Owner plus family/friends)	Failure of shaft controlling the tail rotor blade pitch

ESR

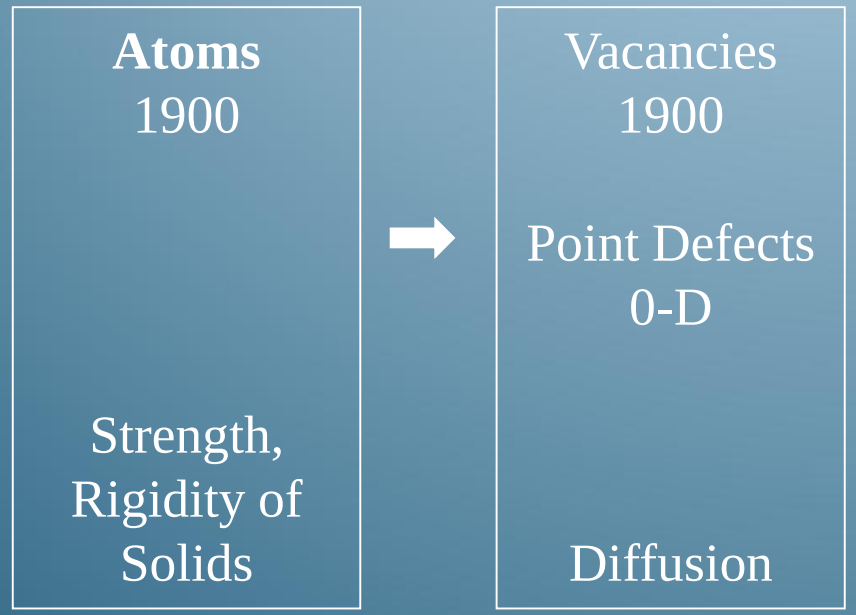

Electrode
Liquid Slag
Solid Slag
Liquid Metal
Water cooled mold

A History of Metallurgy

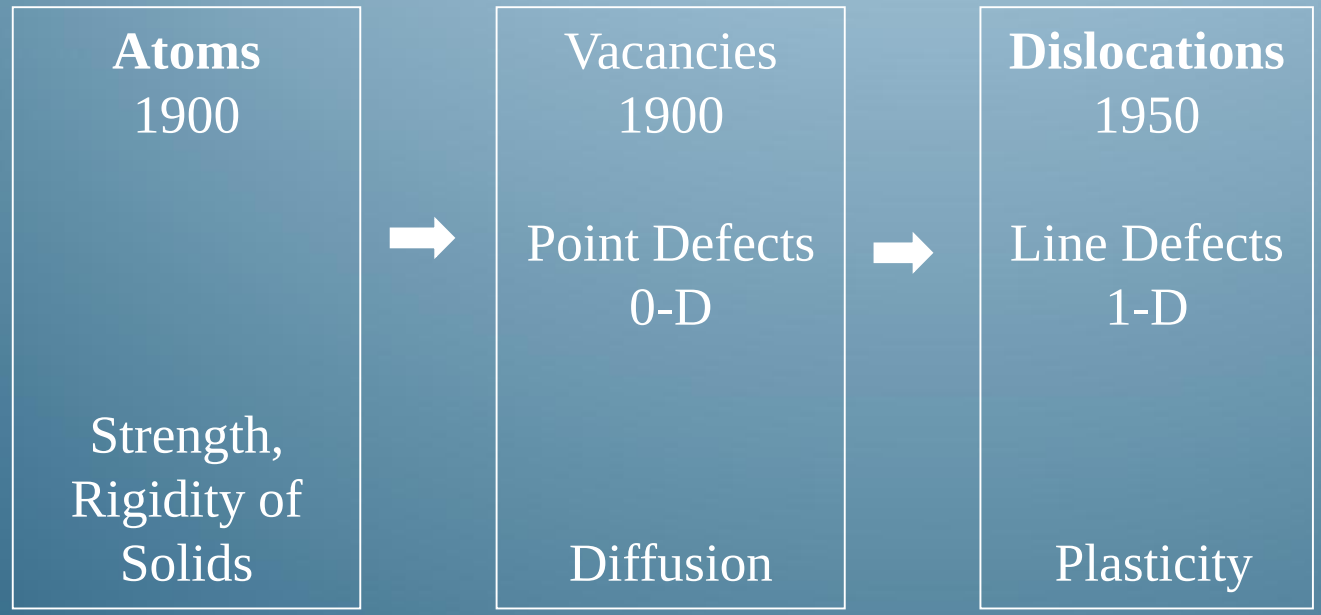
Atoms
1900

Strength, Rigidity of Solids

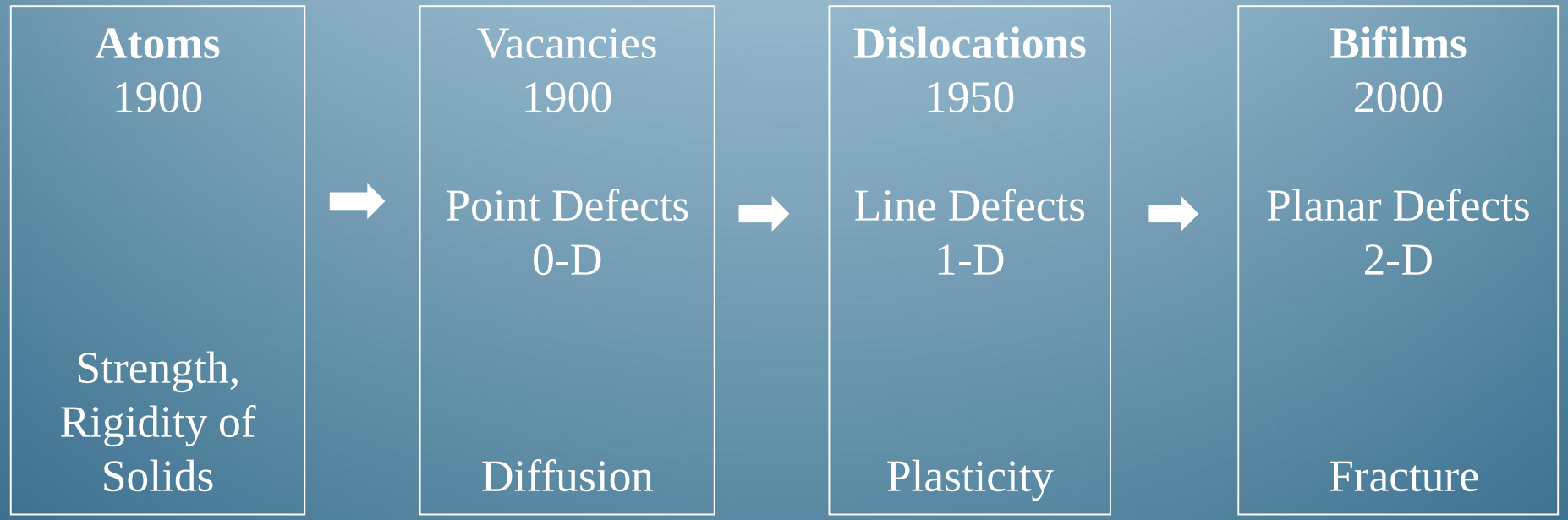
A History of Metallurgy

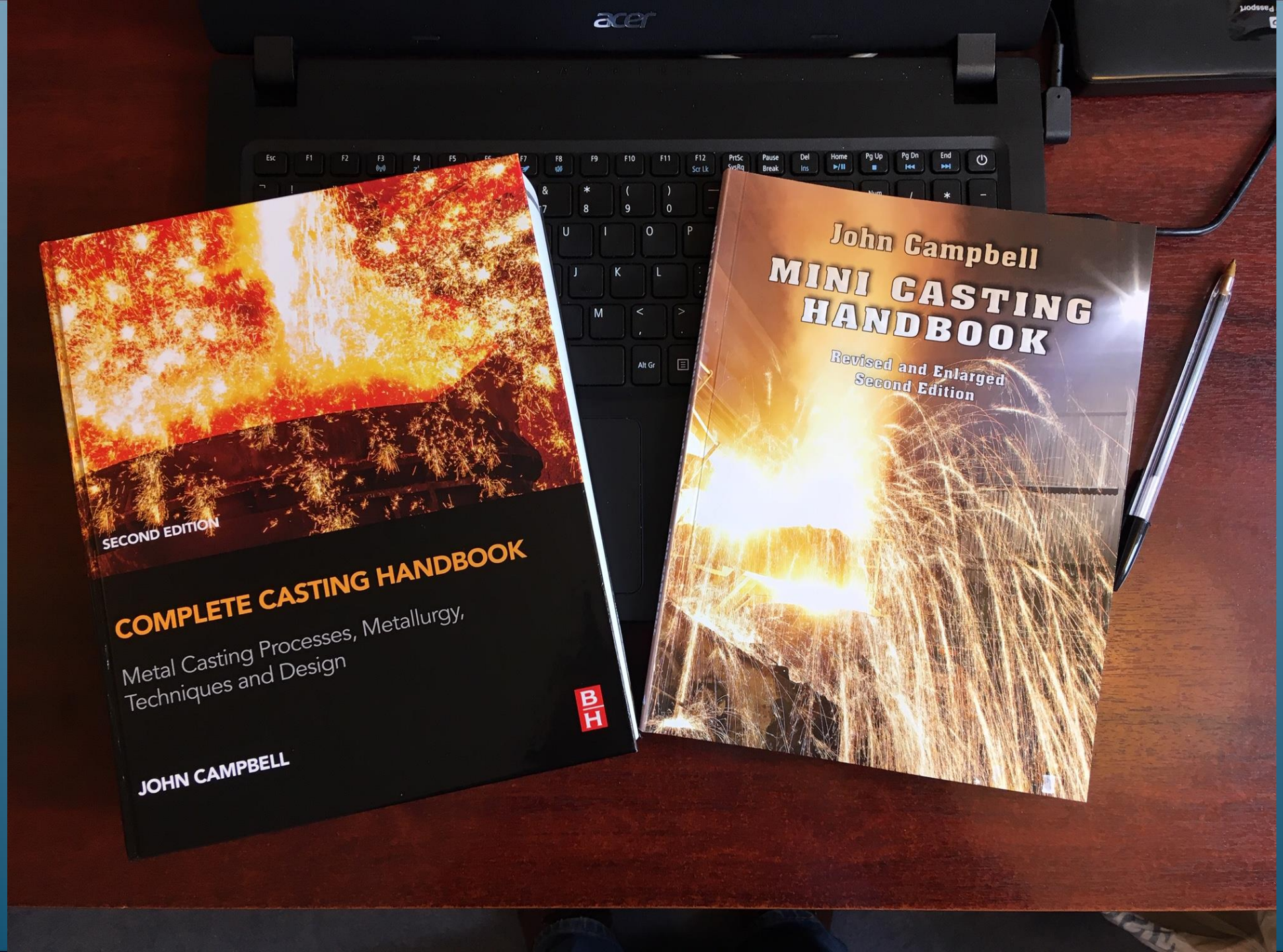


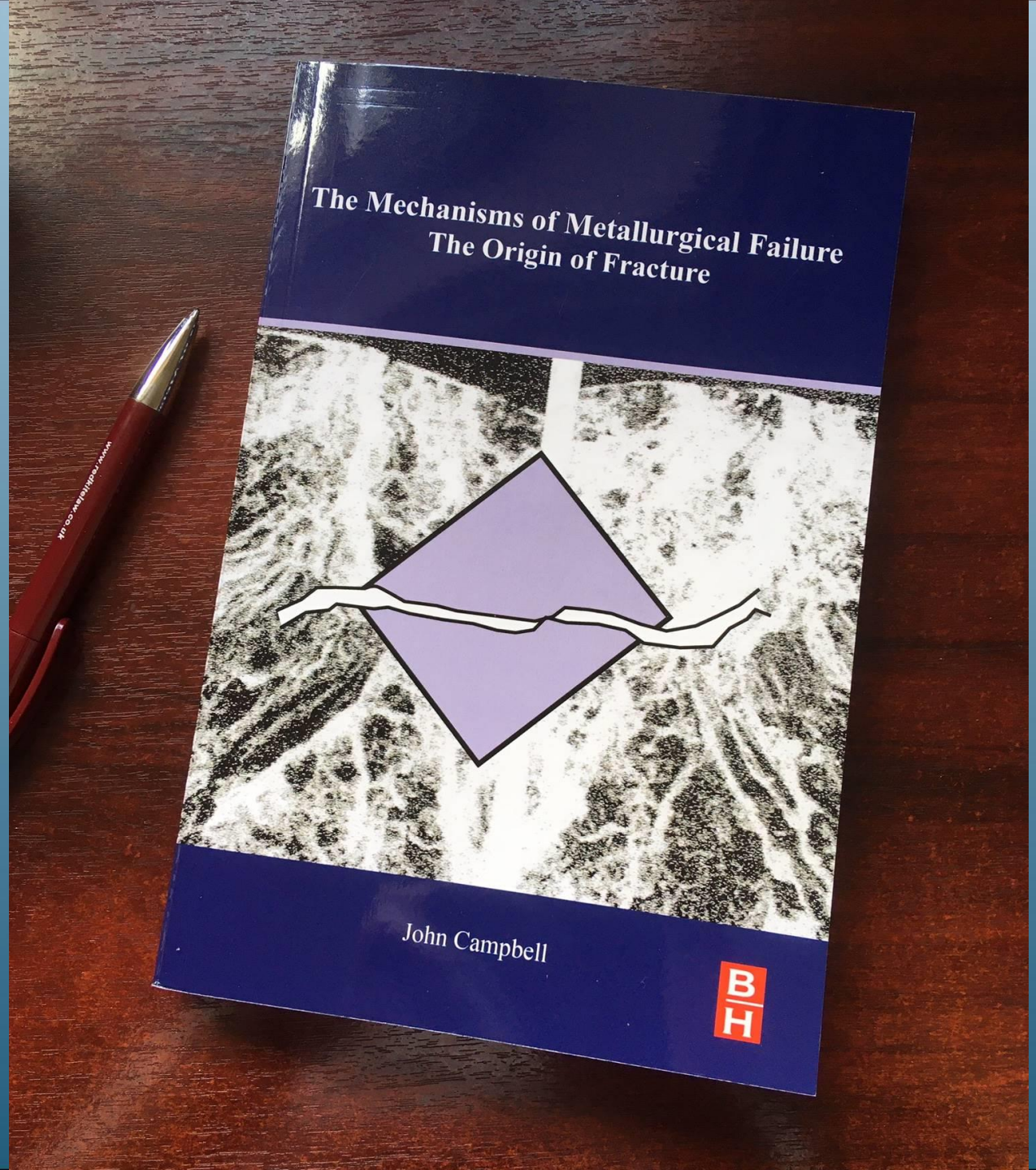
A History of Metallurgy



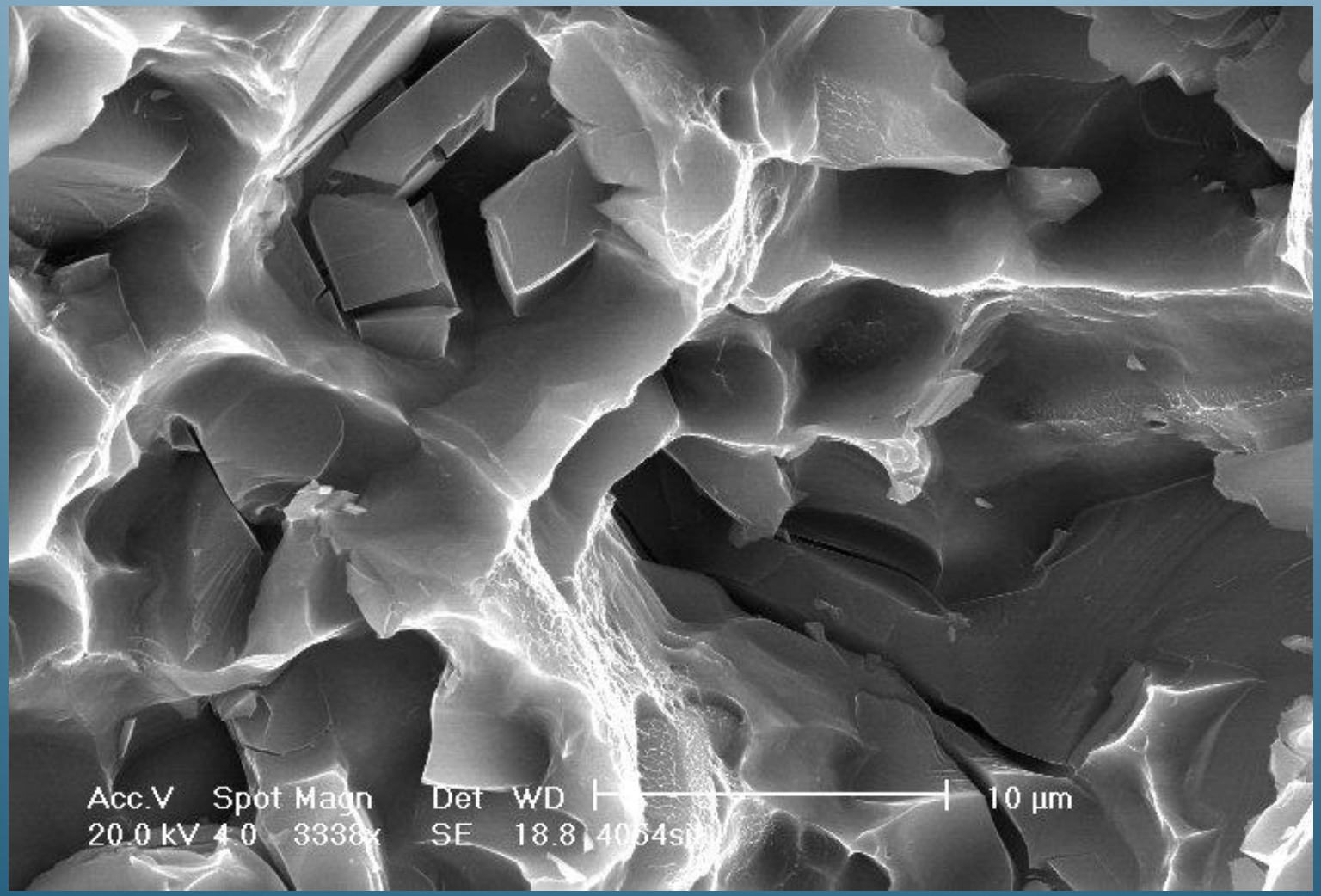
A Tentative History of Metallurgy




SECOND EDITION
COMPLETE CASTING HANDBOOK
Metal Casting Processes, Metallurgy, Techniques and Design
JOHN CAMPBELL
John Campbell
MINI CASTING HANDBOOK
Revised and Enlarged
Second Edition


The Mechanisms of Metallurgical Failure
The Origin of Fracture
John Campbell
B
H

Ductile Dimple Fracture Surface in an Al-Si Alloy



Zhu Zhang 2007