Aalto University
School of Engineering

unite!
University Network for Innovation, Technology and Engineering

MEC-E6005 Engineering Materials Seminar

Sven Bossuyt
April 20, 2021

Engineering Materials

Materials:

- “The stuff that stuff is made of”

Image from "Alice's Adventures in Wonderland" by Lewis Carroll, 1865 (public domain)

Engineering Materials

Materials:

- “The stuff that stuff is made of”
- **Engineering** the structure-processing-properties relationships

Image from "Alice's Adventures in Wonderland" by Lewis Carroll, 1865 (public domain)

Seminar

engineering materials seminar

- What does that mean to you?
- What do you expect to learn in this course?

http://presemo.aalto.fi/ems

Image from "Alice's Adventures in Wonderland" by Lewis Carroll, 1865 (public domain)

Learning Outcomes

- This course exposes students to state-of-the-art developments in some specific engineering materials, or processes related to engineering materials, and examines the *multicultural* technological, societal, and historical context in which materials research and development occur.

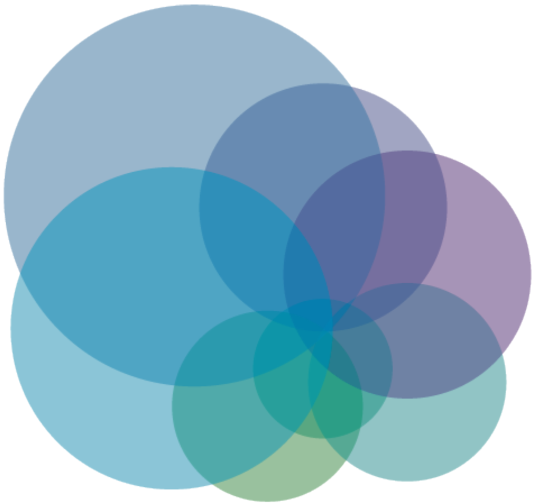
After the course, the student can

1. Summarize the use cases and relevant properties of selected engineering materials or processes related to engineering materials
2. Explain how a material is made and how their performance is evaluated
3. Assess the limitations of a material and drivers for its further development
4. Interpret past and future technological developments improving a material

- During the course, the students will learn to locate and read scientific literature in their field, to critically evaluate it, *they will collaborate and discuss with colleagues whose perspectives are rooted in other languages and cultures,* and they will become familiar with the format and style of scientific literature and conference presentations.

Multilingual

- diversity of resources available when we look beyond English
  - *historical: original sources*
  - *societal: local context and culture*
  - *technological: working language in industry*
- communicating about science and technology to local practitioners and to the general public
- collaborating in a multicultural environment without limiting ourselves to the greatest common denominator



Multicultural?

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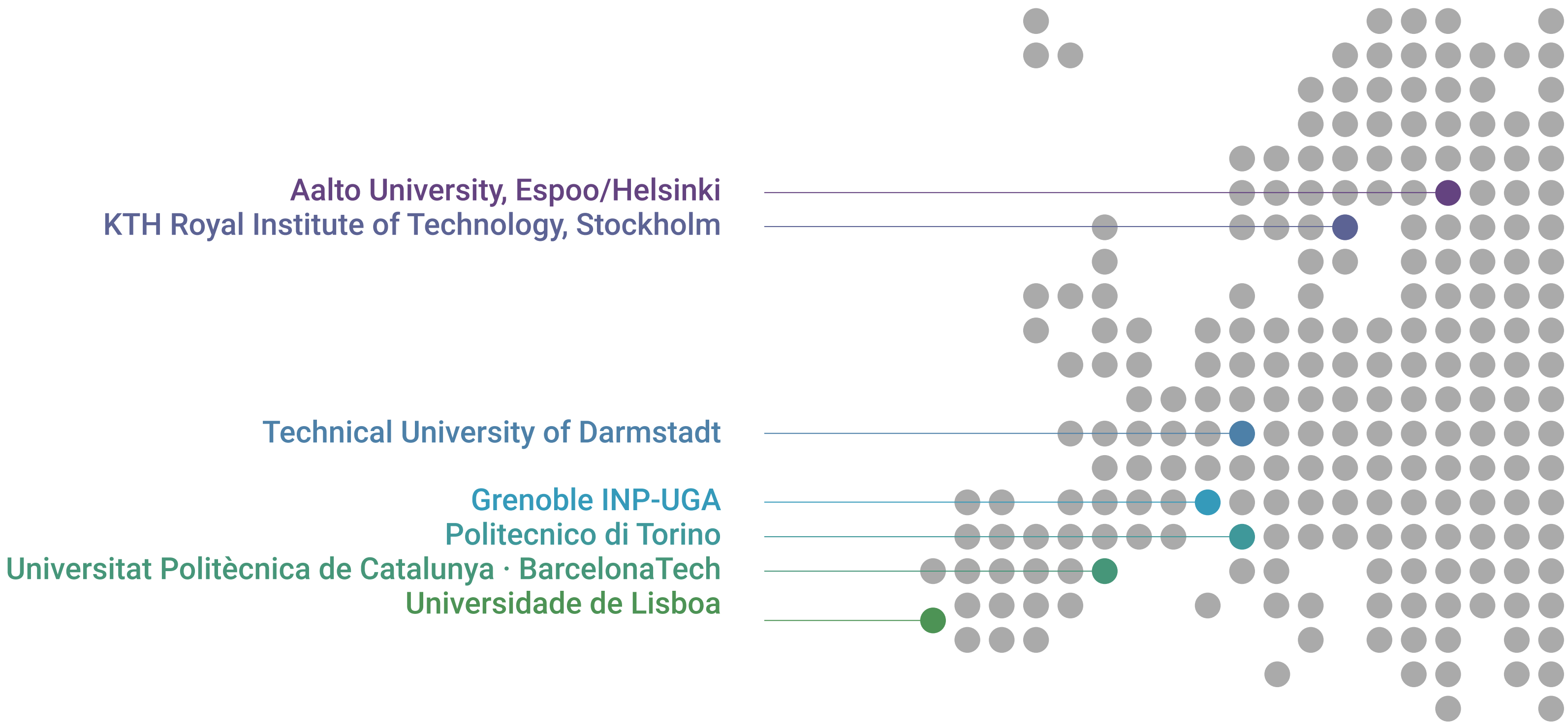

Multicultural!

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Aalto University

KTH

TECHNISCHE UNIVERSITÄT DARMSTADT

Grenoble INP | UGA

POLITECNICO DI TORINO

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

LISBOA | UNIVERSIDADE DE LISBOA

unite!

Seminar concept

- mock **conference**
- each student *or team* picks a **topic**
  - *read literature*
  - *write a paper*
  - *give a seminar presentation*
- **collaborate**
  - *co-authors provide constructive criticism*
  - *help improve other authors' paper and reflect on your own writing*
- **peer review**
  - *phase in mock conference*
- **course grade**
  - *final paper and presentation*
  - *peer review of the collaboration*
  - *peer review of the peer review*

Practical Issues

Administration

- Everyone should be automatically registered in MyCourses

Contact information

- Sven Bossuyt <sven.bossuyt@aalto.fi>
    - *online "office hours" by appointment*

Conference Management System

- <www.easychair.org>
- We will send invitations for both author and reviewer roles to your aalto email.
- Final papers are to be submitted in MyCourses after the seminar presentations as well as in EasyChair before the seminar presentations.
- Evaluation of the peer review your paper received in EasyChair happens in MyCourses

Timetable

- ✗ EasyChair
- ✗ contact hours
- ✗ MyCourses

Week	Phase	EasyChair	Contact hours	MyCourses
W16	abstracts		kick-off meeting	topic proposals
W17	writing	abstracts due		co-authors assigned; progress check
W18	writing			progress check
W19	writing			progress check
W20	review	papers due		
W21	rebuttal	reviews due		
W22	seminar	rebuttals due	seminar	final due date

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Abstract

- 300-500 words (not including references)

  The abstract should give the reader a clear idea of the topic you will present, including the main conclusions.

    - *N.B.: the abstract in the final paper may differ substantially from the initial abstract you submit for approval of the topic*

- references to literature you intend to use

    - *searchable databases of scientific literature (including citations)*

        - <http://www.webofknowledge.com/>
        - <http://www.scopus.com/>
        - <http://scholar.google.com/>

    - *guidance from Aalto University Library <http://libguides.aalto.fi/informationretrieval>*

Paper

Format

- maximum 6 pages (*including references and figures*)
- two columns, margins and fonts as defined in the template
- final versions to be collated and published to MyCourses
    - *permission to publish*

Collaboration

- use whatever collaboration tools you like
  (*e.g. Microsoft OneDrive, DropBox, Google Docs, padlet…*)
    - *keep backups!*
- features for change tracking and commenting will be useful
    - *accept changes at each progress check*
- each author is solely responsible for their paper,
  co-authors give constructive criticism and feedback
- get feedback on rough outlines and drafts

TurnitIn

Final papers

- to be submitted to TurnitIn assignment in MyCourses
  - *if you haven't used TurnitIn before, read the instructions <https://wiki.aalto.fi/display/turnitin/Turnitin+for+Students>*

Conference papers

- to be submitted in EasyChair

Weekly checkpoints

- for early feedback
  - *draft papers submitted to TurnitIn*
  - *TurnitIn report helps co-authors separate your own writing from cut-and-pasted text*
  - *"PeerMark" questions for feedback*

Peer review

Early feedback from co-authors

- use online collaboration tools
- summarise and document at weekly checkpoints

Phase in mock conference

- using EasyChair conference management system
- rebuttals and revised papers

Rubrics and evaluation criteria

- questions guiding what to pay attention to
- also relevant for self-evaluation of your own papers

Assessment criteria

Papers & Seminar Presentation

- References
- Language (*Readability*)
- Presentation (*Formatting*)
- Content (*Clarity of message*)
- Scientific quality (*Quality of message*)

Collaboration

- Quantity of feedback
- Quality of feedback
- Timeliness of feedback
- \+ Helpfulness

Review Form
HTML document

These are the questions from the review form that will be used for peer review in EasyChair, as a standalone file so you can see what the questions are without needing access to the EasyChair systems. The questions for the progress checks for the paper submission here in MyCourses are based on these questions.

constructive feedback
PDF document

This is an extract from a slide set by Päivi Kinnunen about giving and receiving feedback, with a word cloud based on people's descriptions of feedback they found useful, and some concepts about what makes feedback constructive.

Individual Papers

Responsibilities

- **each author is solely responsible for writing their own paper**
- **co-authors provide feedback and constructive criticism**

Senior co-author

- doctoral student
  or master's degree student with significant research experience
- *knows their topic so well that writing the paper is easy*
- *uses this course to practice and receive feedback on giving useful feedback*

Junior co-authors

- master's degree students
- will need more time and effort to find and read references for their topic
- can also give useful feedback

Group formation

- pre-questionnaire in MyCourses on the basis of which to assign co-author groups

Joint Papers

Responsibilities

- **each author is jointly responsible for writing the main paper and abstract in English**
- **co-authors each write an abstract for the paper in a different language, other than English**

Group formation

- pre-questionnaire in MyCourses on the basis of which to assign co-author groups

Advantages

- closer collaboration in early writing stages
- more cross-cultural examination of the topic
- wider range of scientific literature and local context

Team evaluation

- one grade for the joint paper, but multiplied by a factor based on each co-author's contribution
    - *timeliness*
    - *participation*
    - *quality*
    - *communication*

Scientific Writing

M.Sc. thesis introduction

- current situation → problem [→ new approach] [→ your solution]
- distinction between purpose, aims, and contribution
- support claims with evidence, reasons, or examples
- cite literature appropriately

MEC-E6005 Seminar paper

- current situation [→ problem] [→ new approach]
- you do not provide a contribution to the field for this course

Figures and tables

- provide some kinds of information more compactly and more effectively than descriptions do
- need to be referred to in the text, at the place in the text where the information from the figure or table belongs
- captions effectively describe and provide support for some claim
  - *discussed in more detail and with more context in the text*

  <https://www.e-education.psu.edu/styleforstudents/node/1794>

  <http://abacus.bates.edu/~ganderso/biology/resources/writing/HTWtablefigs.html#compound_figure>

Aalto Language Center

- Academic Writing in English web pages: <http://sana.aalto.fi/awe/>
- Writing clinic: Kenneth Pennington <ken.pennington@aalto.fi>

Suitable topics

Engineering Materials
- widely used materials
- high-performance materials
- emerging materials

Applications
- requirements for specific applications
- materials for extreme environments
- role of materials in technological developments

Processes
- related to engineering materials

Seminar formats

~~Presented in person in an auditorium~~
- not possible due to covid
- needs some remote participation for Unite! participants

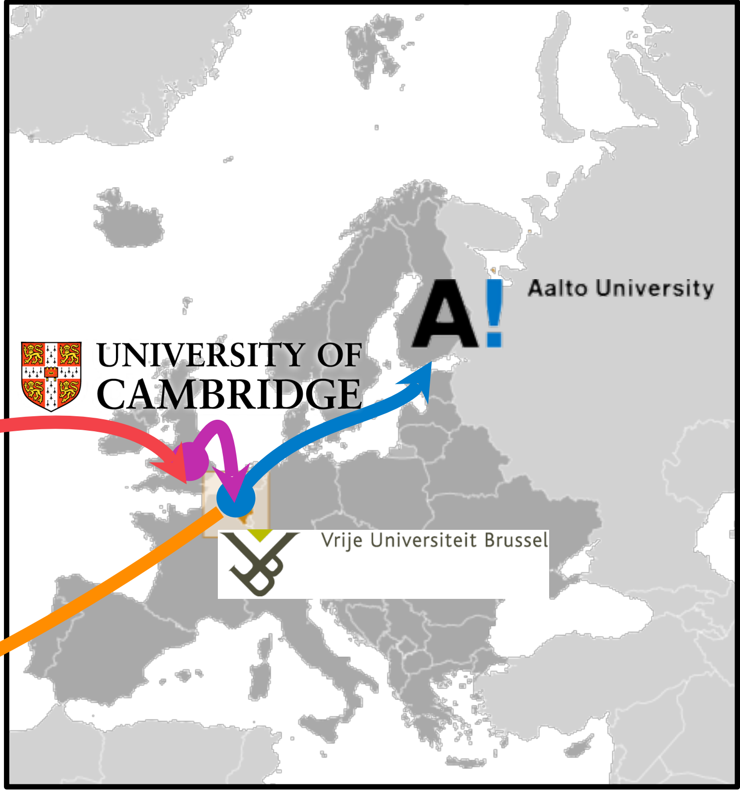
Presented live via Zoom
- most like traditional conference
- attention wanes after too many presentations

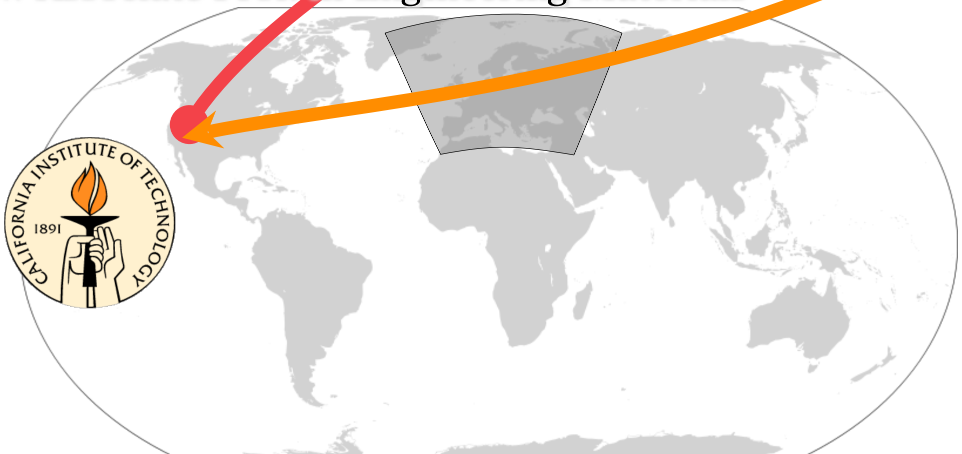
Recorded videos followed by Q&A via Zoom
- flexible timing for making the presentation
- lack of context for Q&A

Recorded videos with brief summary via Zoom
- hybrid format also used in some conferences during covid
- extra work to make both full presentation and summary

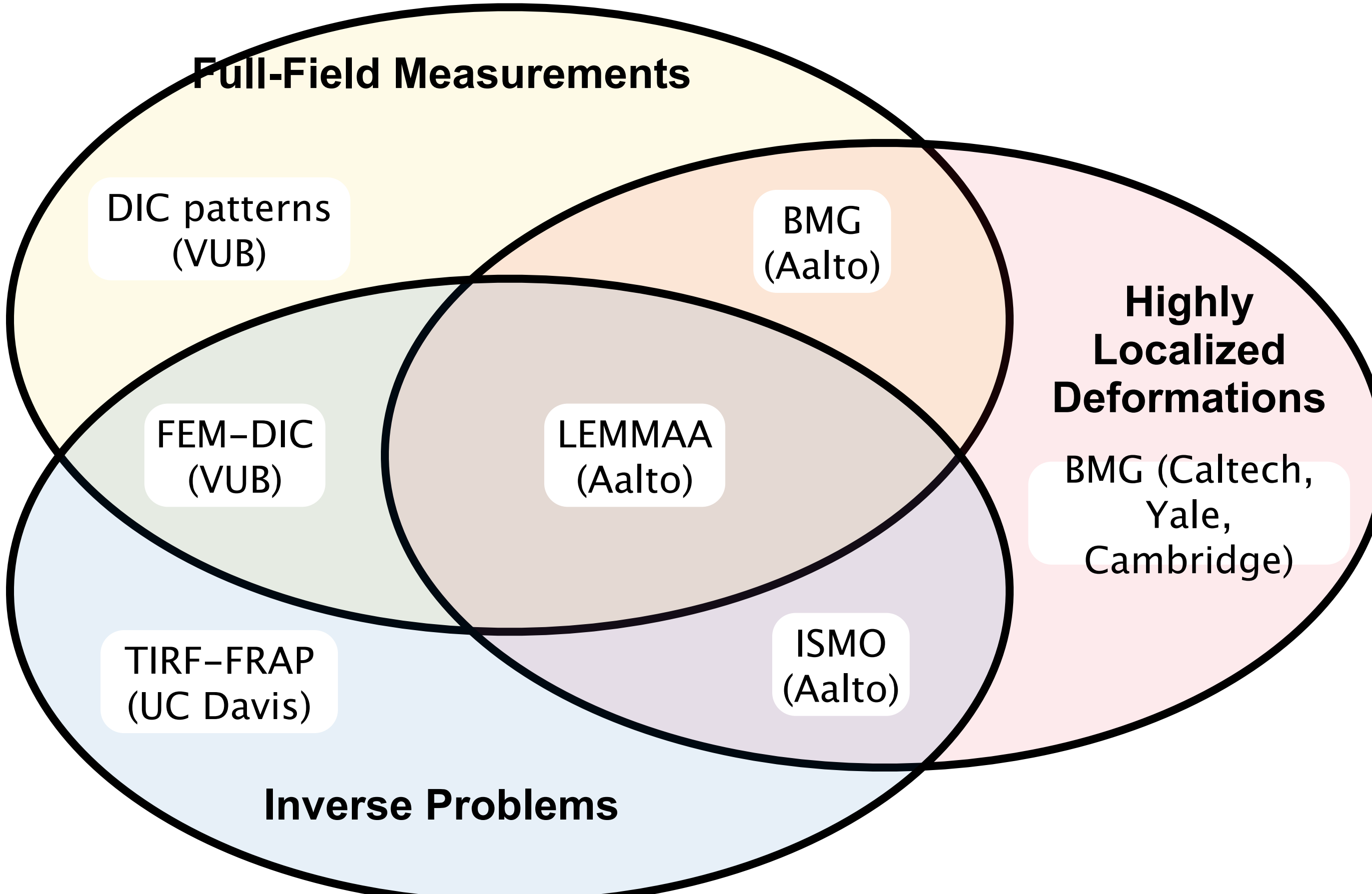
Introductions

- from Belgium originally
  - *Engineering degree in Materials Science*
- Ph.D. in Applied Physics from Caltech
  - *“Crystallization behavior of glass-forming alloys”*
- postdoc in Cambridge
  - *electrochemical de-oxygenation*
- return grant to Belgium
  - *mechanics of materials and constructions*
  - *inverse methods visit TKK institute of mathematics*
- Academy Research Fellow at TKK/Aalto
  - *“Localization Phenomena in Experimental Mechanics Measured using Appropriate Assumptions”*
  - now Associate Prof. in Engineering Materials





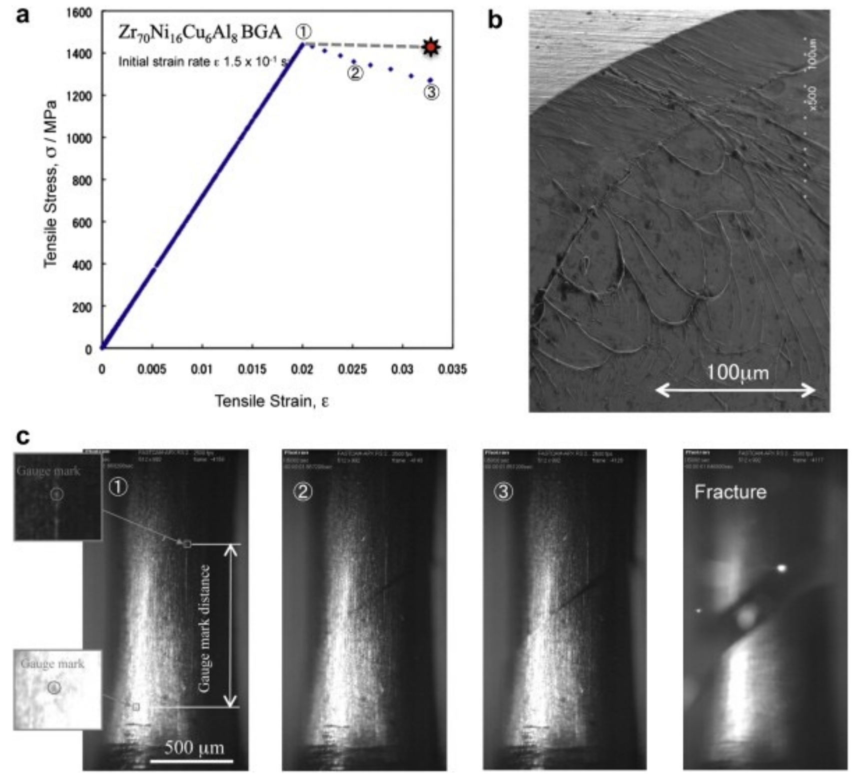
Sven's Research:
Multi-Disciplinary and International



Highly Localized Deformations:
Shear Banding in Bulk Metallic Glasses

BMG's are novel, highly processable materials with ultra-high strength

- net-shape casting or thermoplastic forming
- amorphous atomic structure of liquid retained in solid below glass transition
- microscopically perfect elasto-plastic
- lack of work hardening allows deformation to localize into (~100 nm) narrow bands



experimental challenge to measure highly dynamic highly localized deformation

- universal problem when ultra-high strength reaches theoretical limit
- BMG's as model material for engineering of extrinsic toughening mechanisms in future ultra-high strength materials

Amorphous Metal Alloys

disordered structure

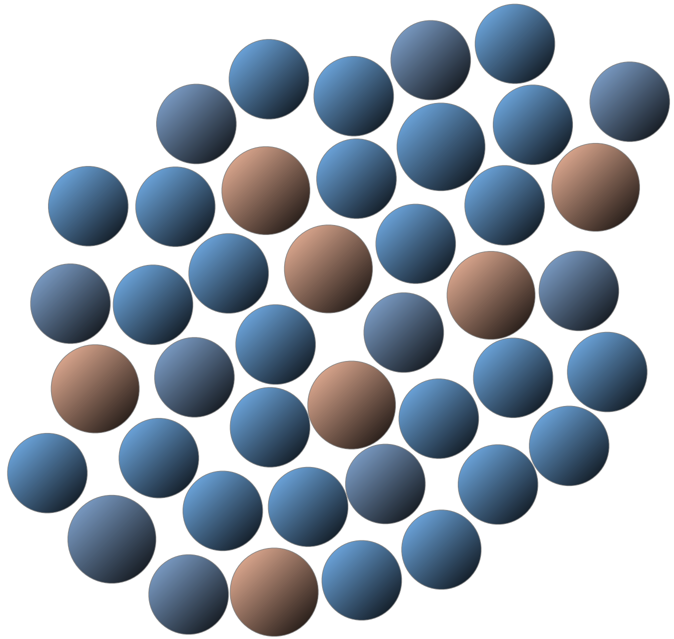
- no long-range order
- equilibrium structure of liquid phase

persists in solid by:

- quenching the liquid
- vapor phase condensation
- electrochemical deposition

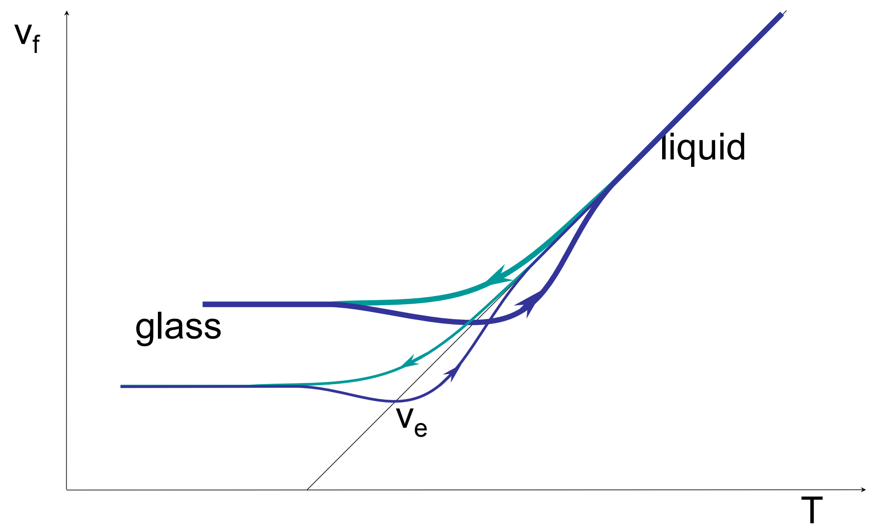
or induced by:

- solid-state amorphization
- mechanical deformation
- ion mixing



Glass Transition

- relaxation time depends on structure
- glass transition depends on cooling rate



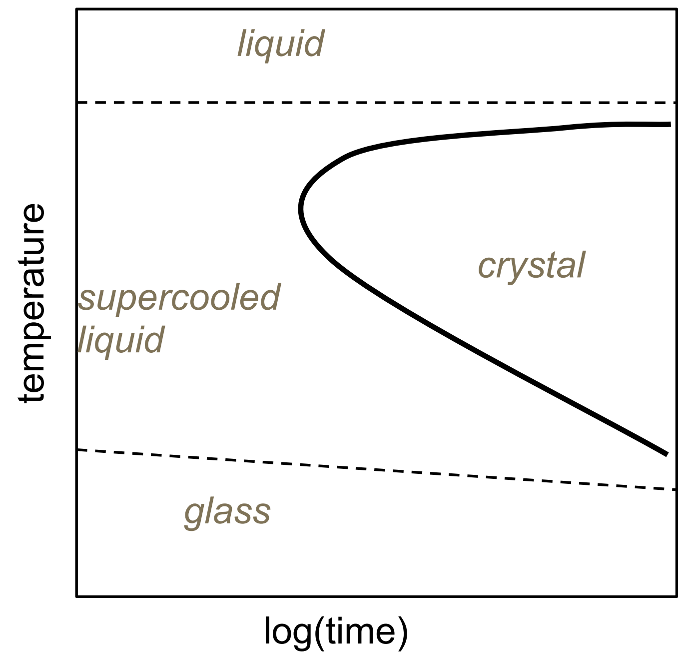
Glass Formation

glass is a liquid cooled below its glass transition

- material behaves as a solid
- atomic structure of liquid is “frozen in”

avoid crystallization

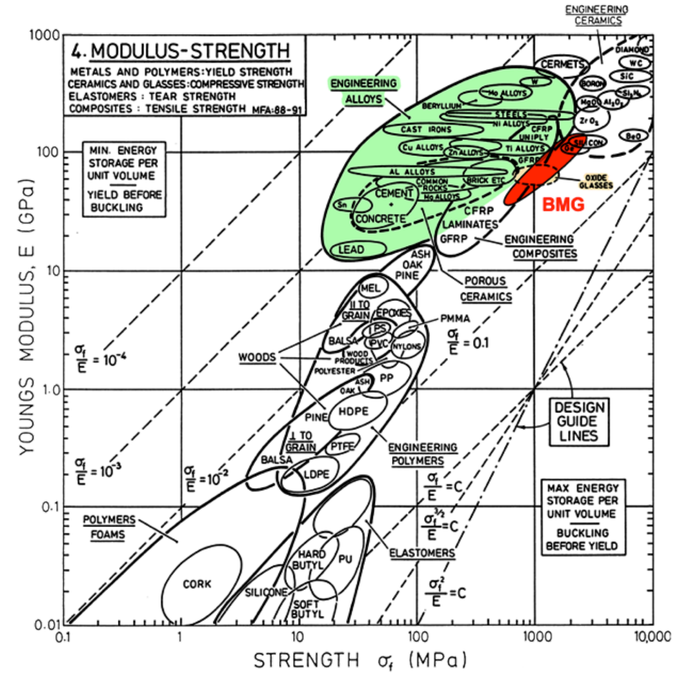
- extremely high cooling rates required for most metals



Mechanical Properties

no dislocations

- high strength
- large elastic strain
- final properties without further heat treatment
- elastic – perfectly plastic
- failure can be catastrophic due to shear localization
- partial crystallization can be used to increase toughness



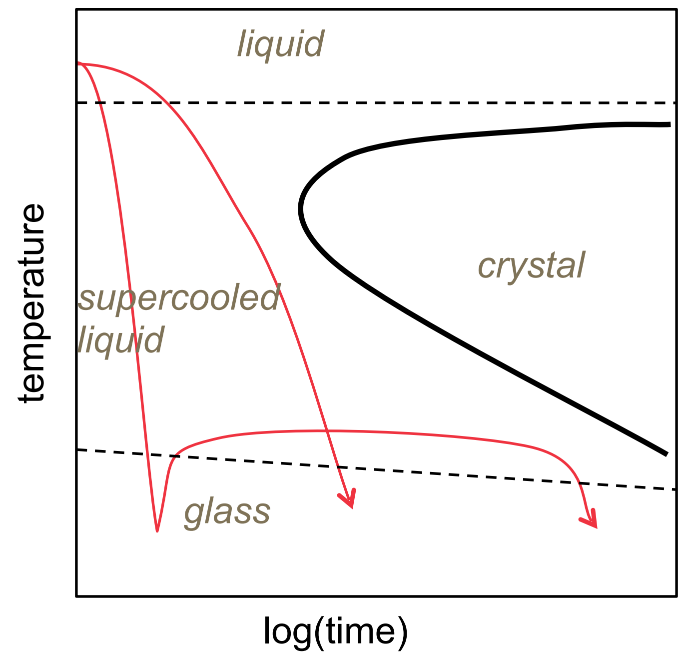
Bulk Metallic Glass Processing

easily shaped in supercooled liquid state

- net-shape forming
- suitable for mass production
- excellent surface finish

die casting

semi-fabricated products



Full-Field Measurements:
Digital Image Correlation

match images of deformed object to reference image of that object

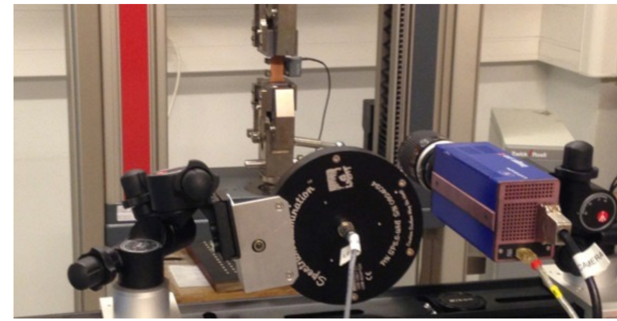
- cross-correlation via FFT
  - *peak amplitude indicates how well it matches*
- Lucas-Kanade
  - *deform reference image with hypothetical displacement fields, then interpolate and calculate sum of squared differences*
- find the displacement field that gives the best match with observed image

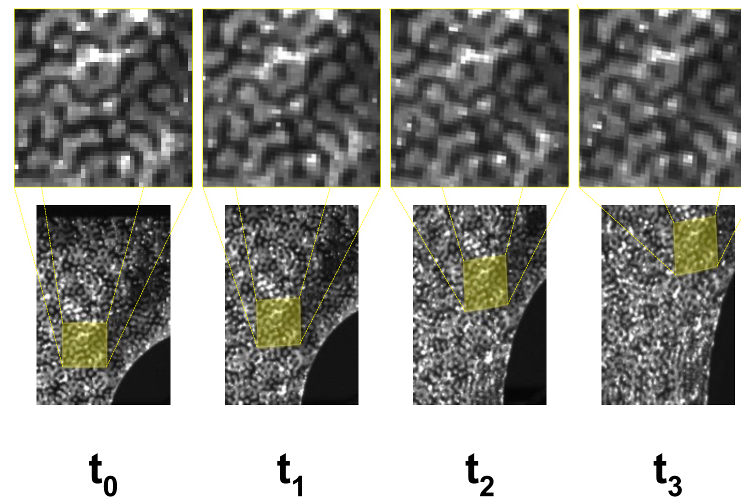
advantages:

- instantaneous non-contact optical full-field measurement
- leverage advances in digital cameras and computers
- sub-pixel resolution (due to peak fitting or interpolation)
- 3D displacements from stereo image pairs

issues:

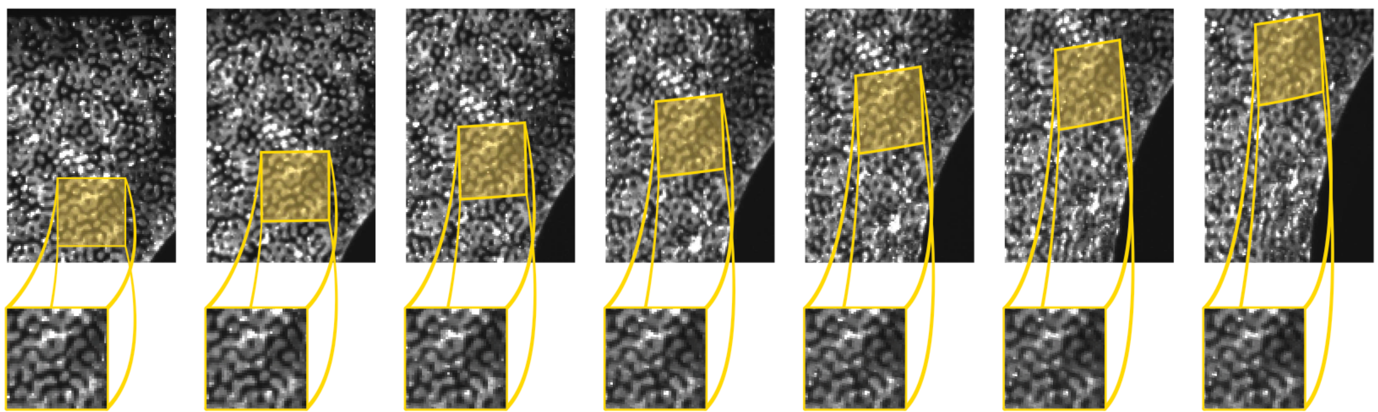
- calibrating camera geometry and distortions
- contrast and feature spacing in image
- implicit assumptions in algorithm and in discretization method of fields
  - *e.g., cracks and shear bands replaced by unrealistically high but smooth localized strain*



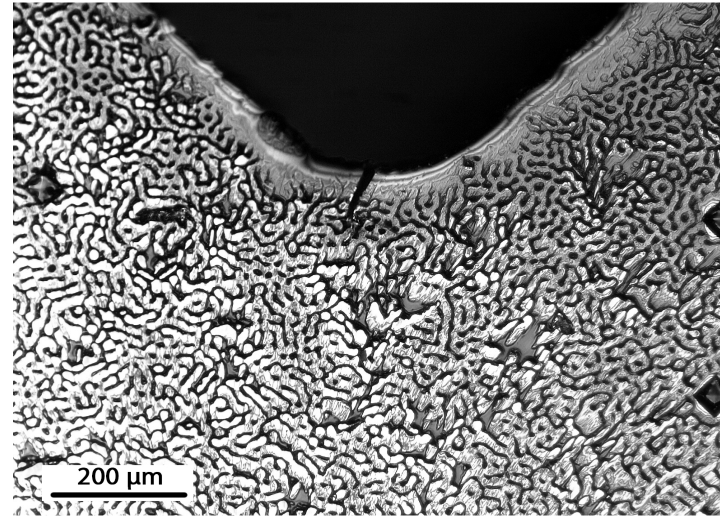


Digital Image Correlation
principle

Find displacement fields that map sequence of images of un-deformed material onto observed sequence of images of deformed material



Micro-mechanics of fatigue
in polycrystalline metal

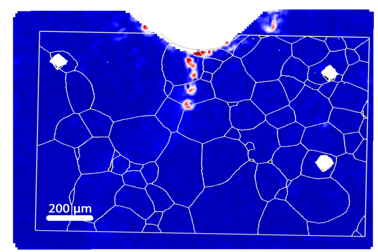


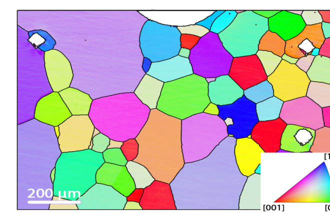
Full-field measurements

- Resolve displacement, strain, and strain rate inside grains
- Electron BackScatter Diffraction characterizes grain structure
- Non-contact measurement during fatigue test at typical rates (few Hz)

Limitations

- Surface measurements
- Optical imaging ≳ 1µm
- Sub-µm resolution much slower



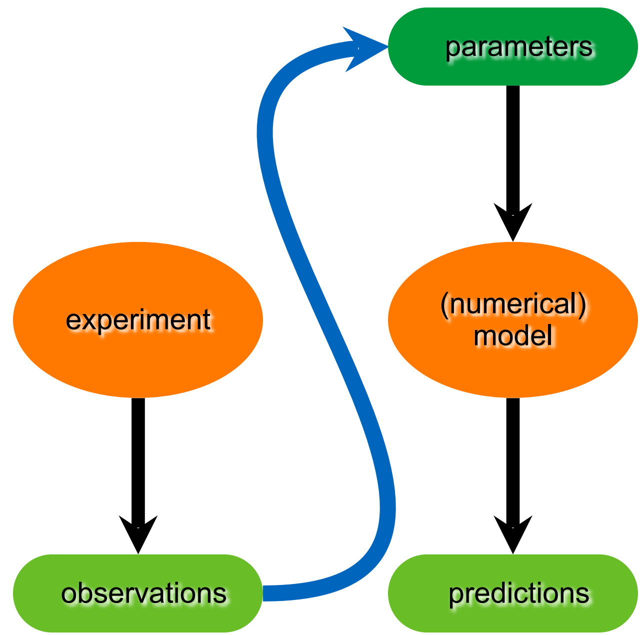


E. Malitckii, H. Remes, & al. *Acta Mater.*, 144, p. 51-59, 2018. DOI 10.1016/j.actamat.2017.10.038

Inverse Problems:
Mixed Numerical Experimental Techniques

determine model parameters from observed data

- forward problem predicts observations for given model parameters
  - *iterative solution to find model parameters that agree with observations*
- inverse problem is often ill-posed
  - *regularisation, preferably using a priori knowledge about actual experiment*

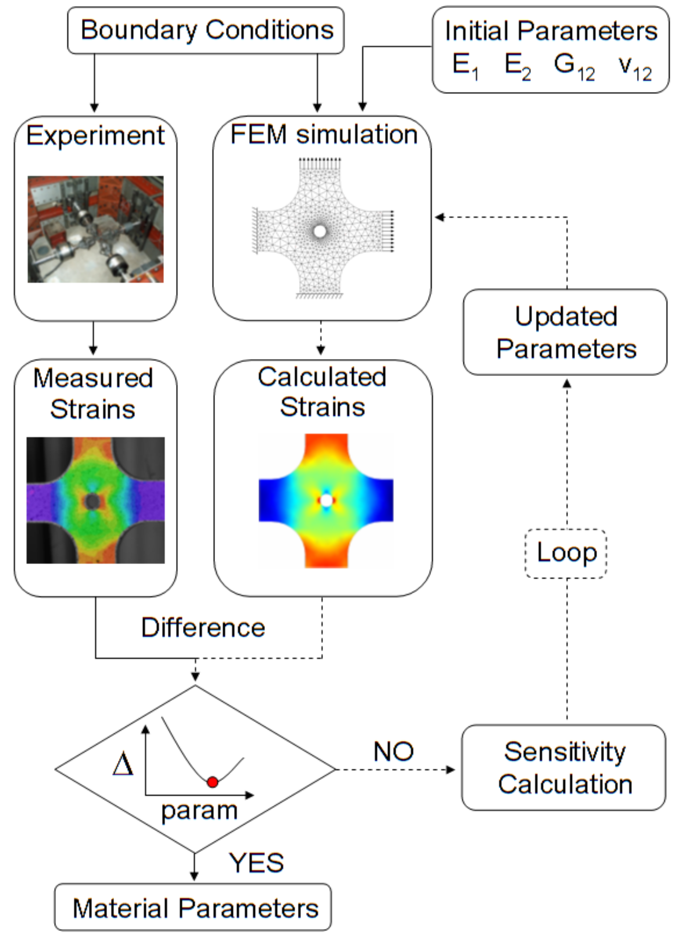


Inverse Problems
in Experimental Mechanics

parameter identification
- over-determined
- ill-posed only with non-linearities

full-field measurements
- under-determined
- excessive regularization causes artifacts

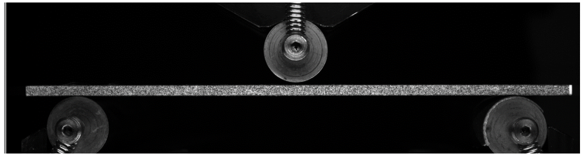
forward problems solved by finite element models
- computationally intensive
- shape functions act as regularization
- finer mesh requires more computation and gives less regularization

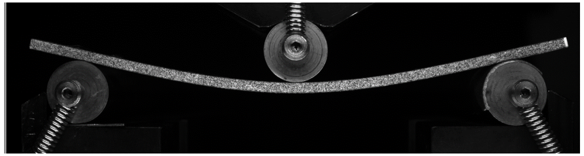


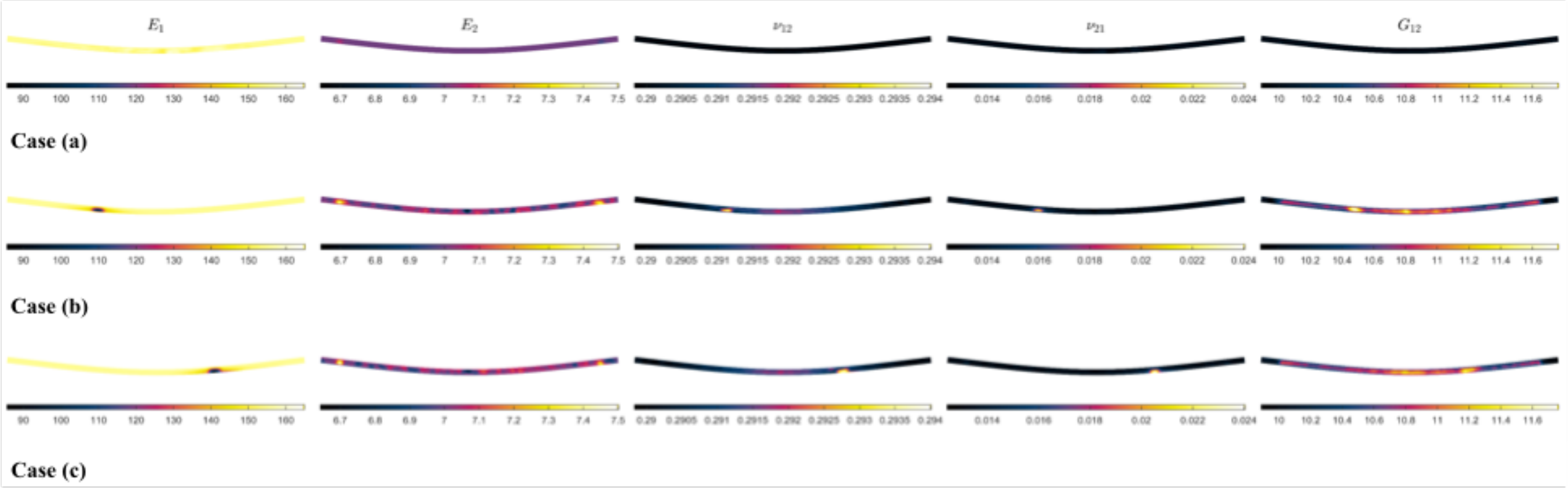
DIC-QSEI

Quasi-Static Elasticity Imaging

- Undeformed CFRP beam
- Deformed CFRP beam







Smyl et al., Inverse Problems (2018) DOI:10.1088/1361-6420/aae793

Roundtable Introductions

I introduced myself

Who are you?

- Which degree programme
- Previous classes in engineering materials
- Prospective employment or research interests

What is your proposed topic?

- Why that topic
- How does it relate to other work