Cohesive Laws for Adhesive Tapes

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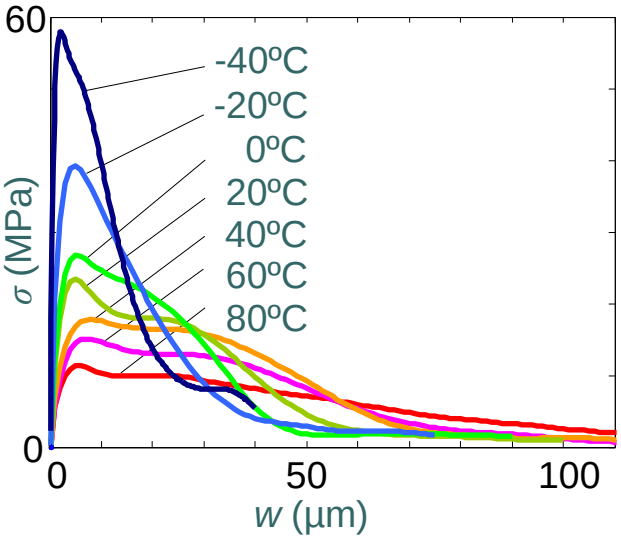
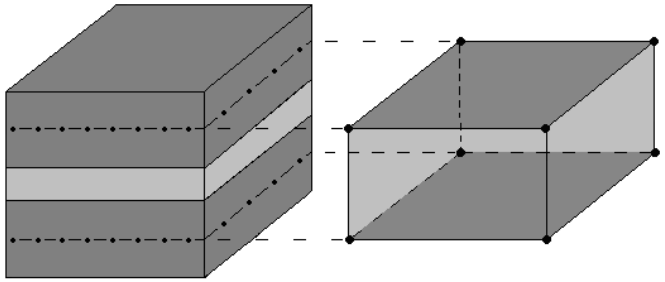
Introduction

1) Experiment

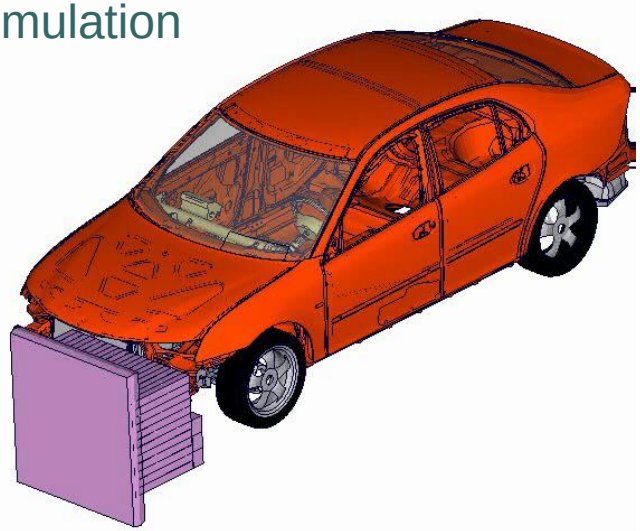
2) Cohesive laws



3) FE-element

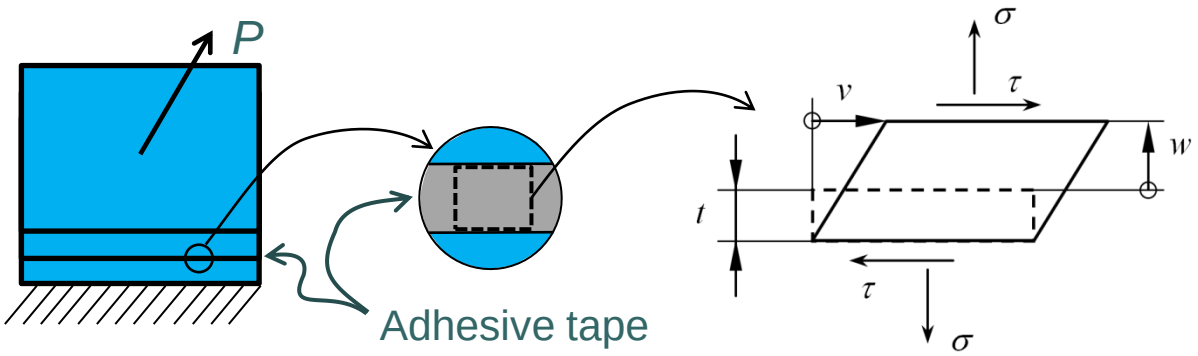


4) Simulation



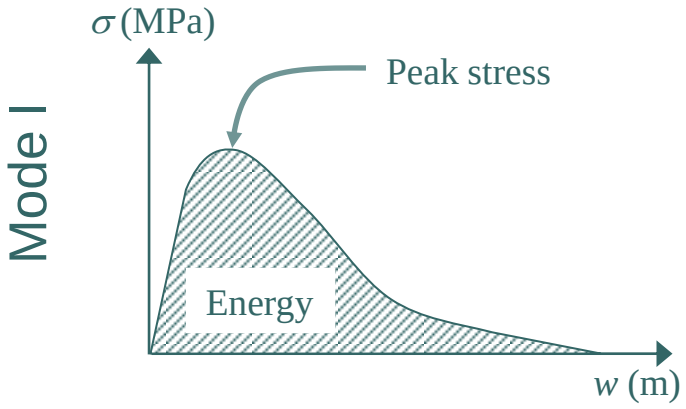
Cohesive law

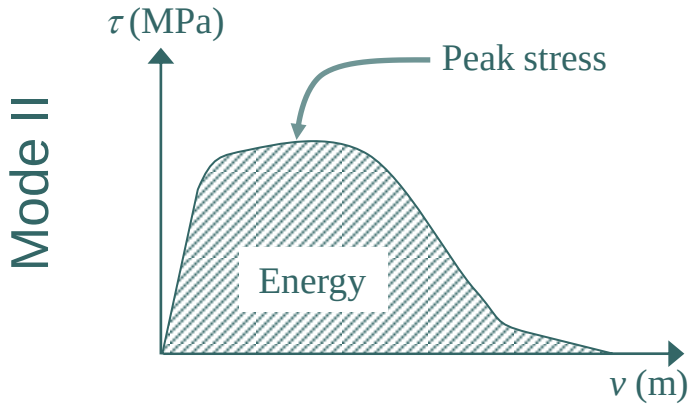
Layer (adhesive tape) exposed to a load – two kind of deformations



Mode I → σ
Mode II → τ
Mixed mode → τ and σ

Cohesive law



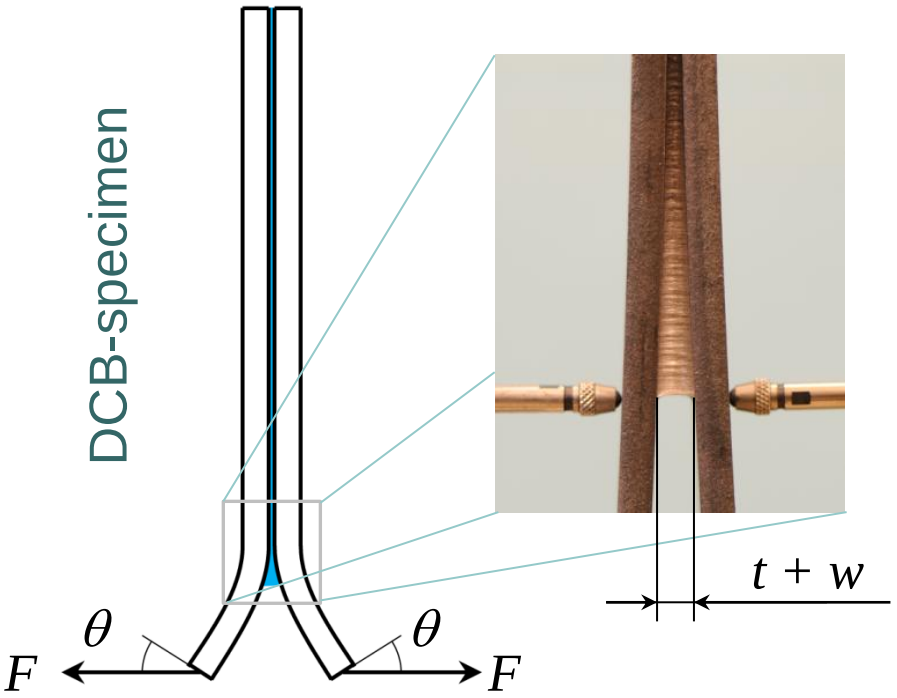


Experimental method

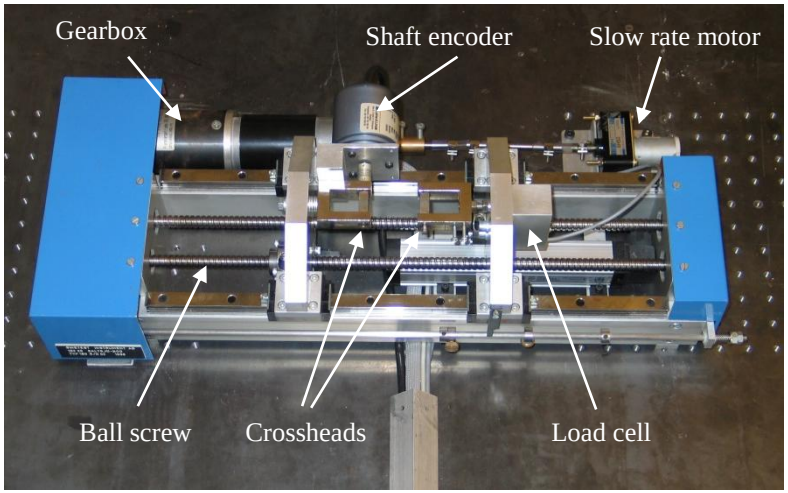
$$J = \frac{2F\sin\theta}{b}$$

$$J = \int \sigma \, dw$$

$$\sigma = \frac{dJ}{dw} = \frac{d}{dw}\left(\frac{2F\sin\theta}{b}\right)$$



Tensile test machine



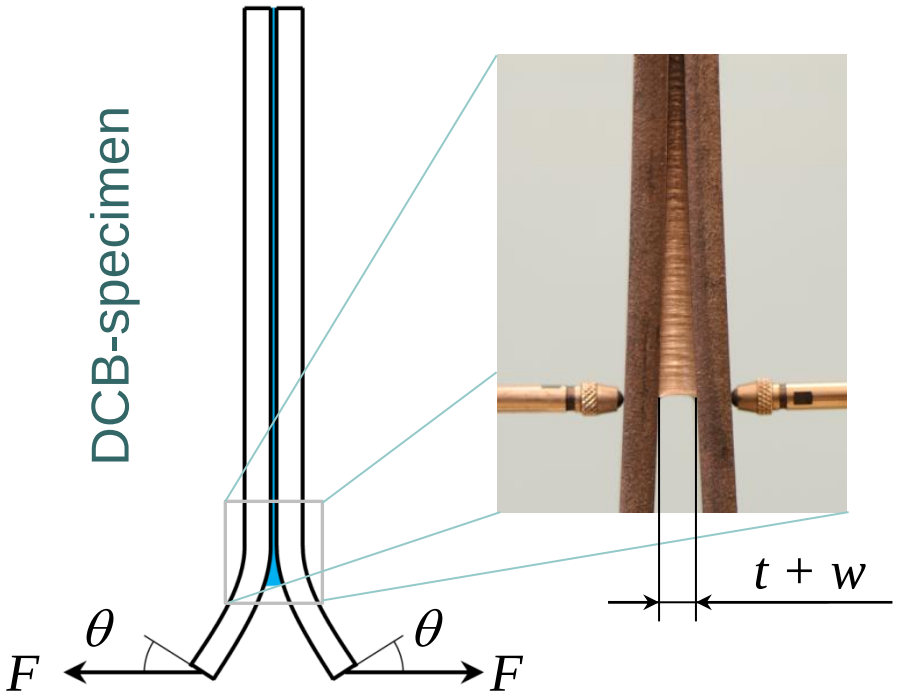
- The elongation, w at the start of the adhesive layer is measured with two LVDTs
- The rotation is measured with a shaft encoder
- Constant loading rate

Mode I, Energy Release Rate

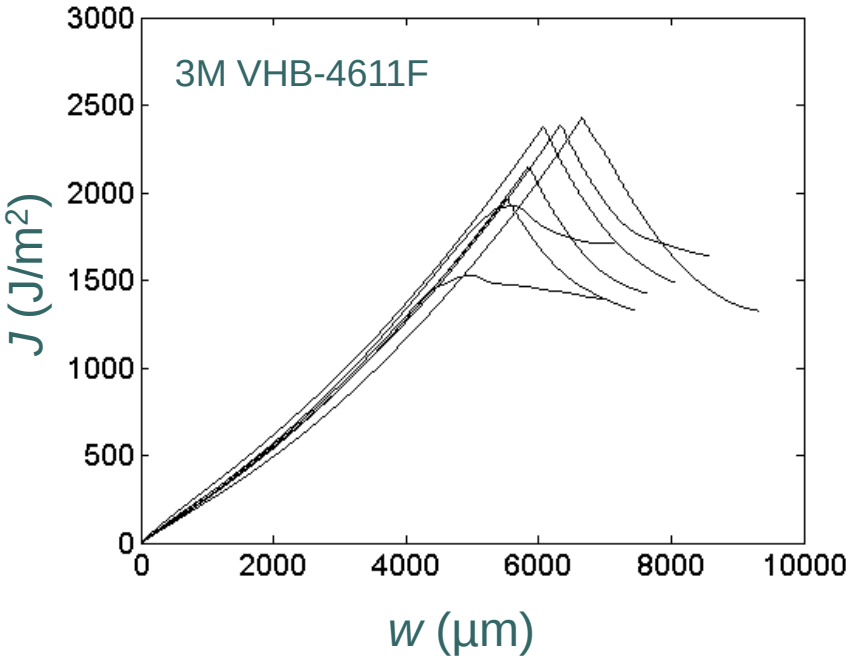
$$J = \frac{2F\sin\theta}{b}$$

$$J = \int \sigma \, dw$$

$$\sigma = \frac{dJ}{dw} = \frac{d}{dw}\left(\frac{2F\sin\theta}{b}\right)$$



Energy release rate – elongation



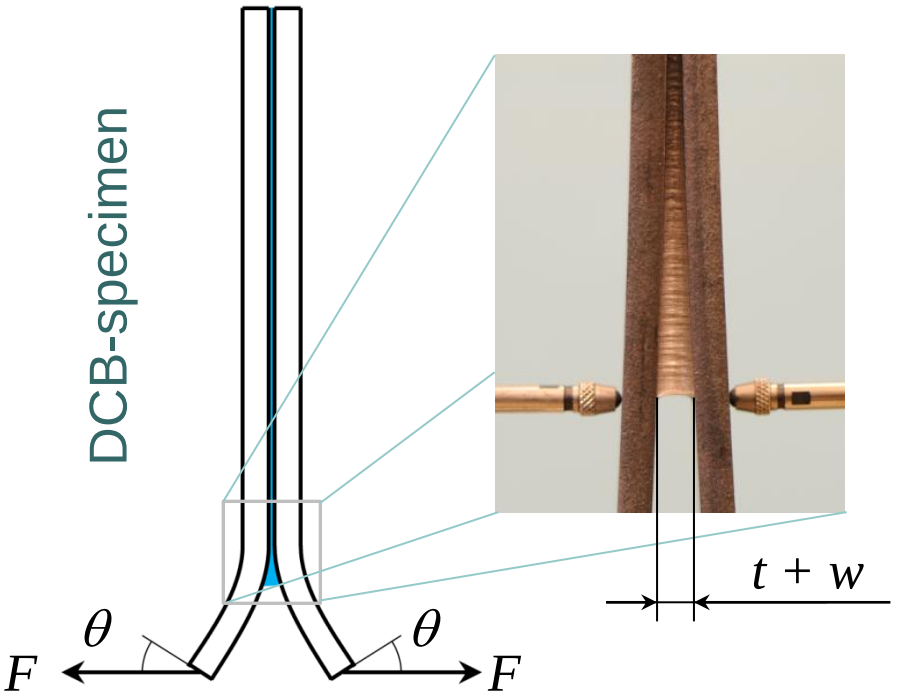
Constant loading rate 30 µm/s

Mode I, Cohesive Law

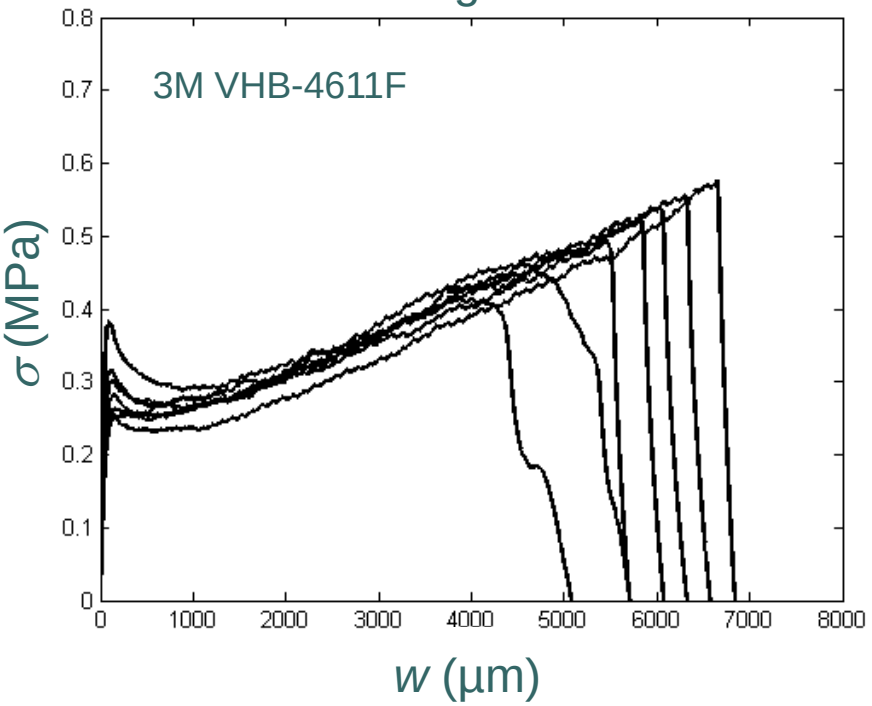
$$J = \frac{2F\sin\theta}{b}$$

$$J = \int \sigma \, dw$$

$$\sigma = \frac{dJ}{dw} = \frac{d}{dw}\left(\frac{2F\sin\theta}{b}\right)$$

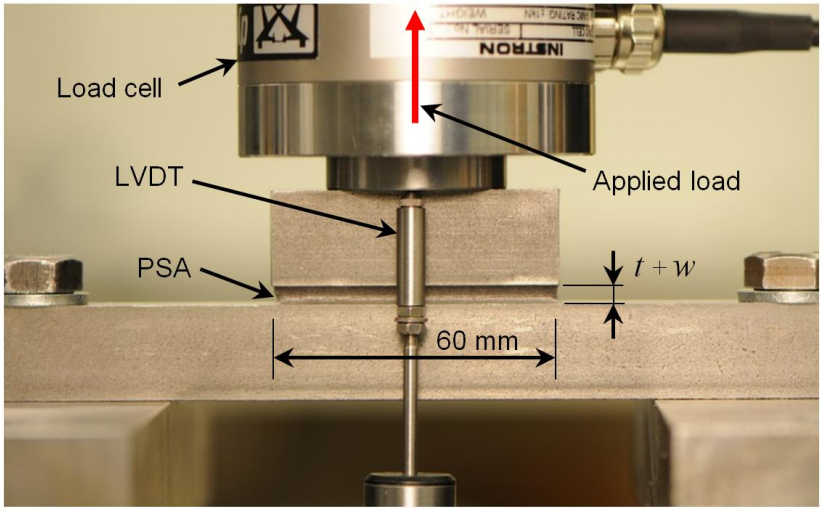


Stress – elongation relation

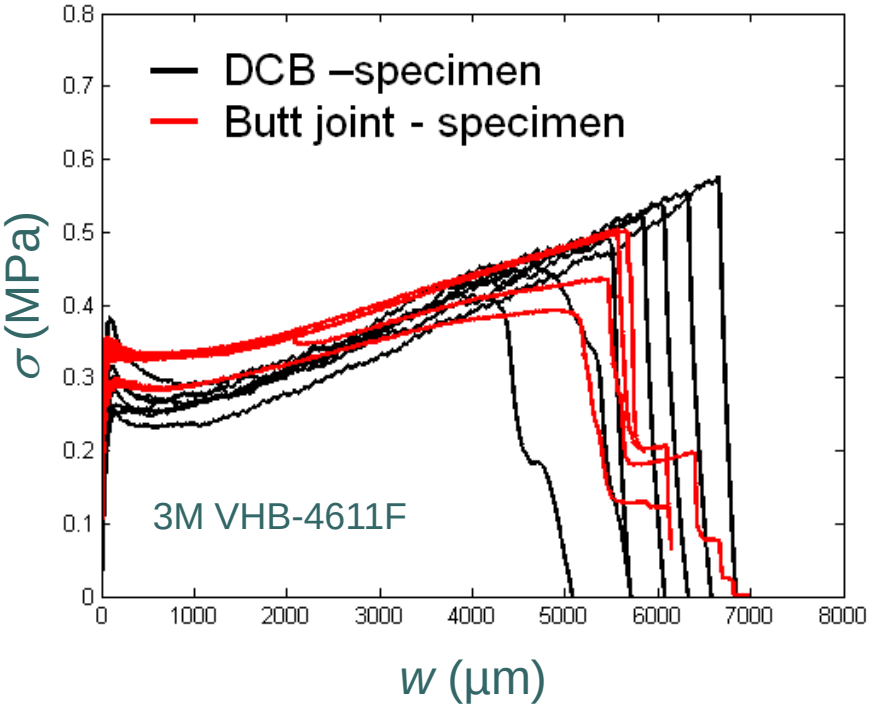


Butt-joint

$$\sigma = \frac{F}{A}$$



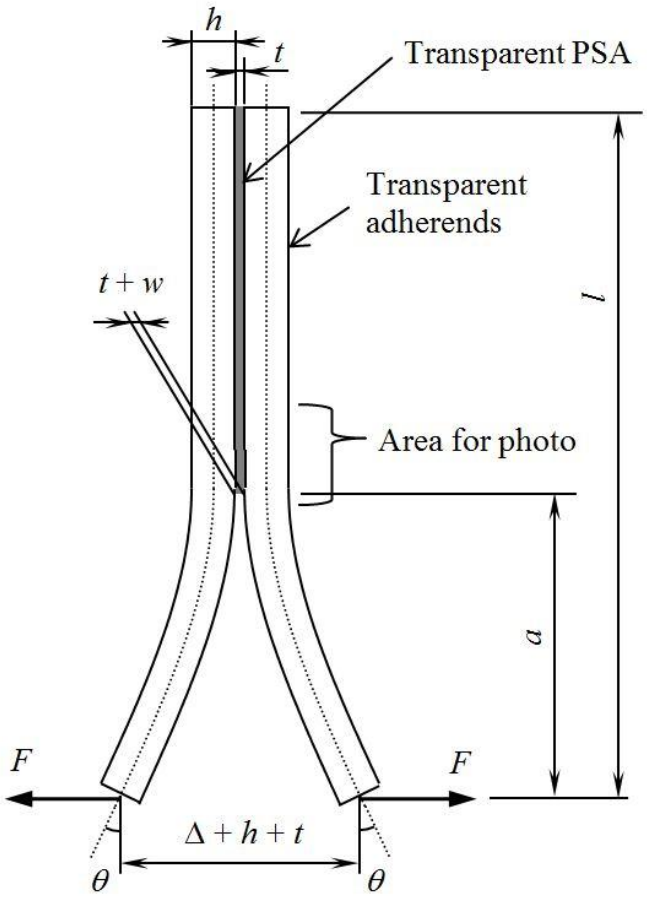
Stress – elongation relation



- Constant loading rate 10 µm/s

- Similar result
- Two peak stresses

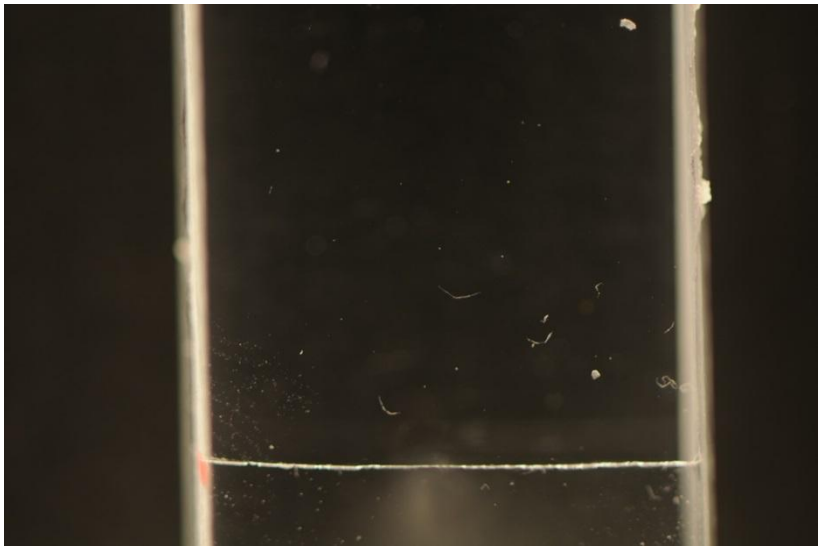
Mode I – Transparent



- Adherends made of *PMMA*
- Transparent tape (3M-4905F)
- Enables the study of crack initiation and growth
- Crack growth is photographed during the experiment

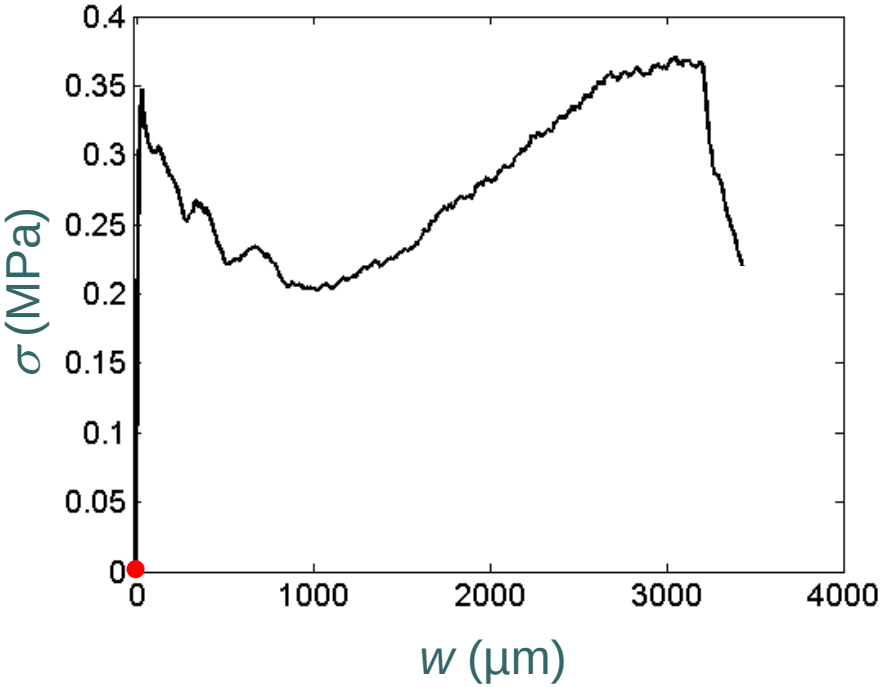
Mode I - PMMA

Fracture process



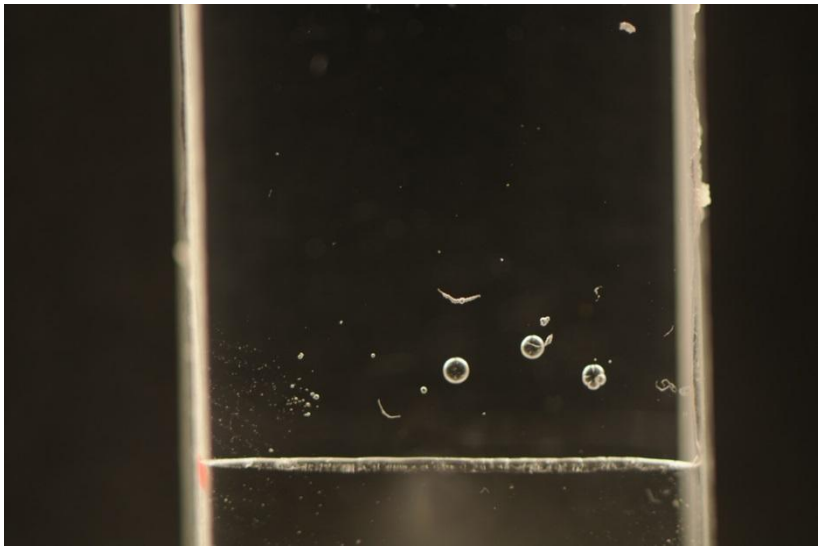
w = 0 µm

Stress – elongation relation



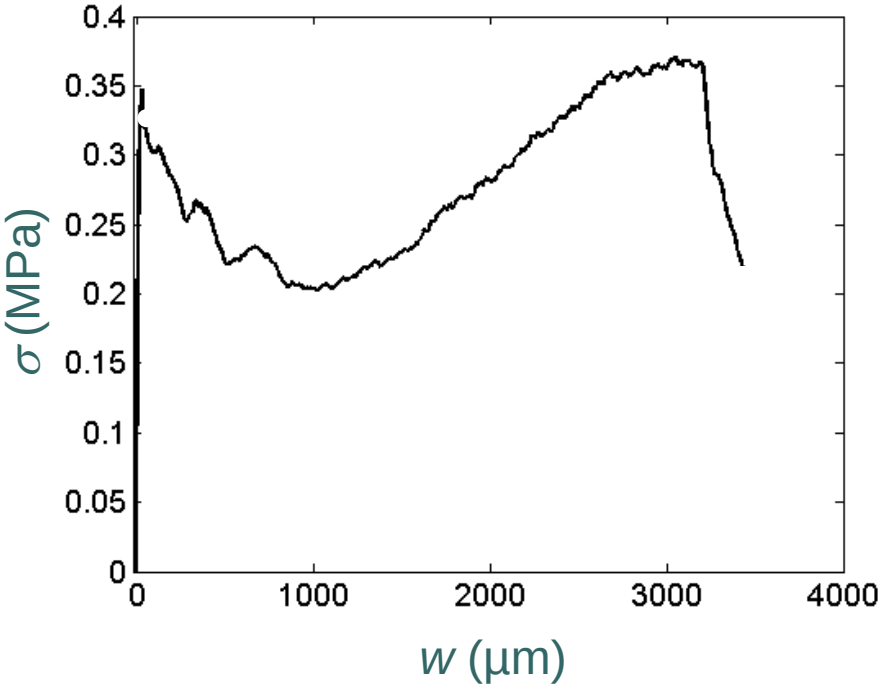
Mode I - PMMA

Fracture process



w = 50 µm

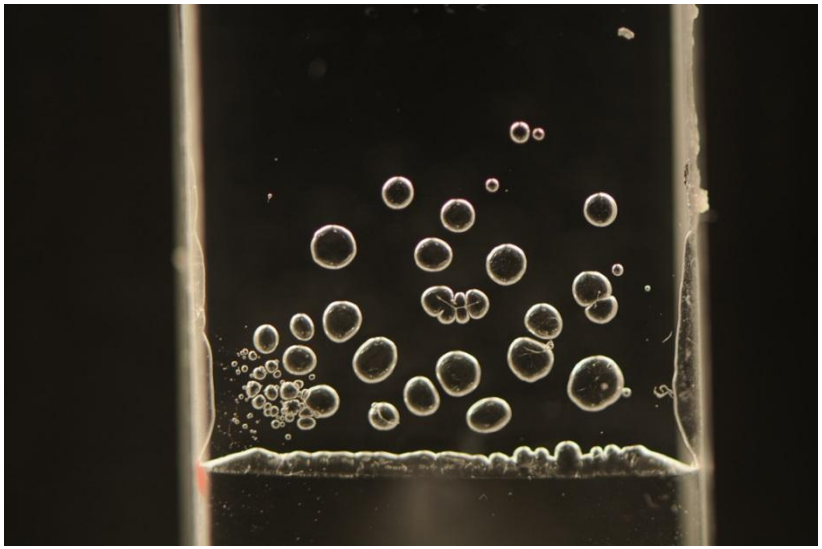
Stress – elongation relation



Creation of small cavities – stress starts to decrease

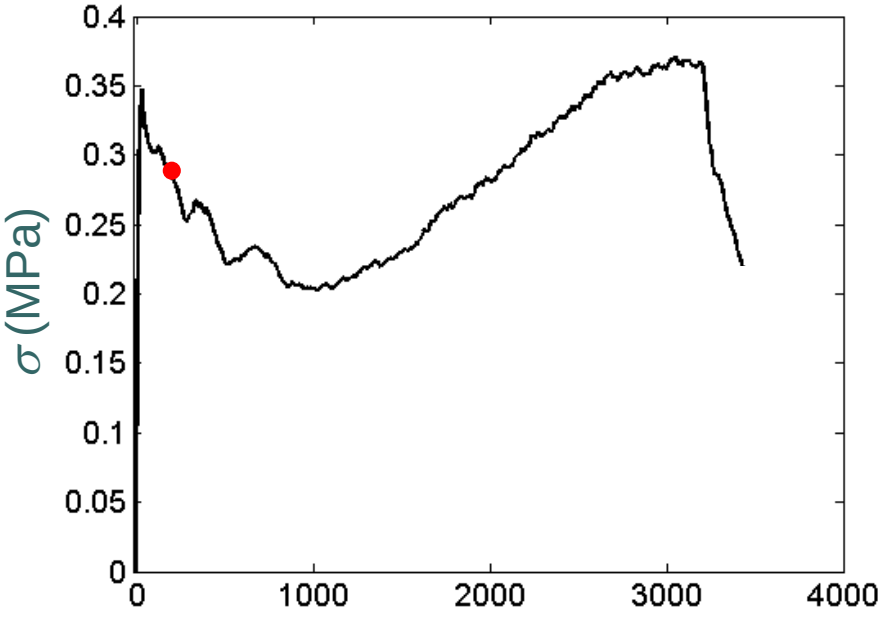
Mode I - PMMA

Fracture process



w = 250 µm

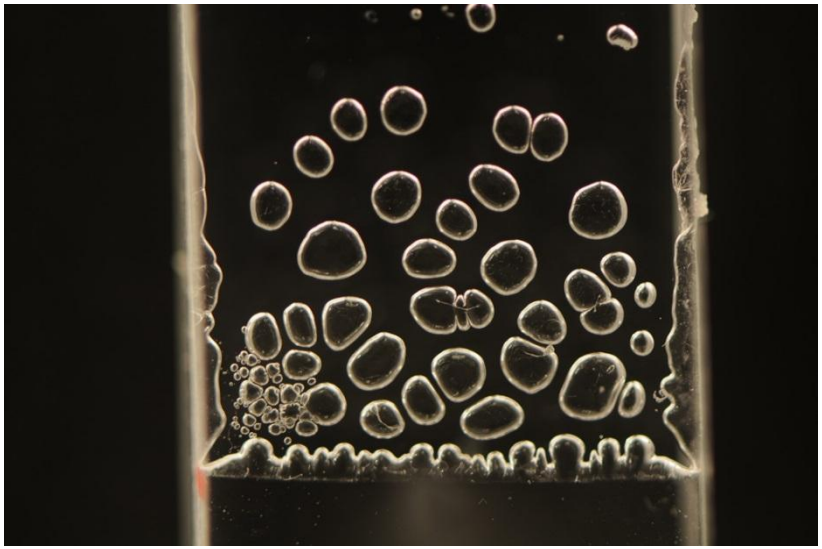
Stress – elongation relation



Number of and the size of the cavities is growing

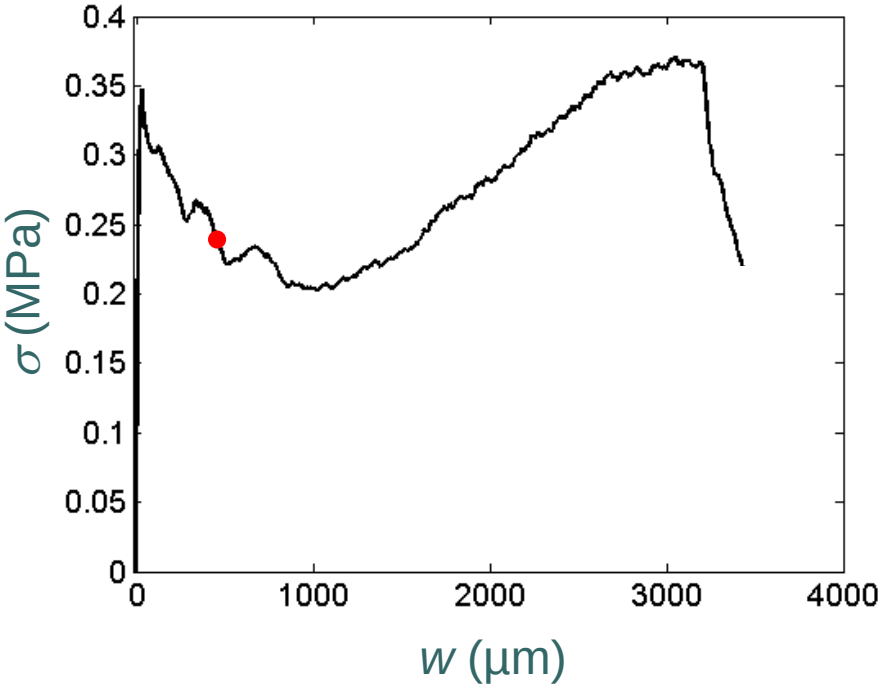
Mode I - PMMA

Fracture process



w = 500 µm

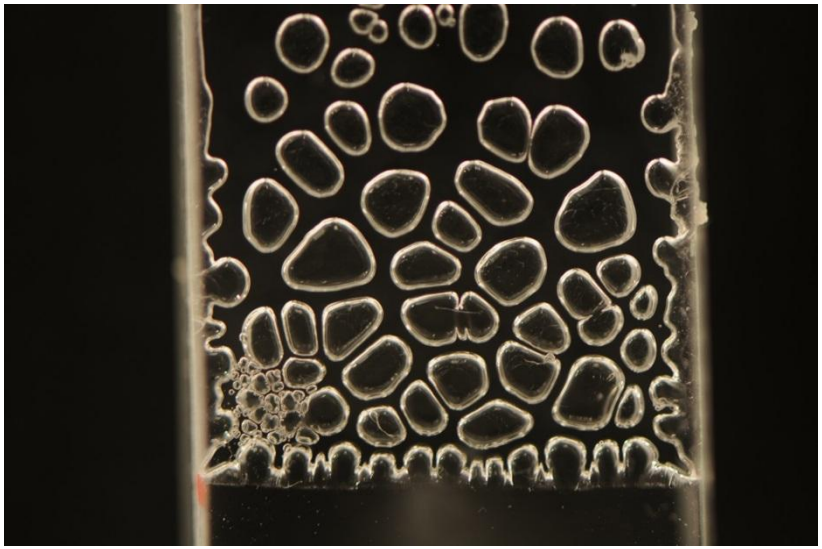
Stress – elongation relation



Number of and the size of the cavities is growing

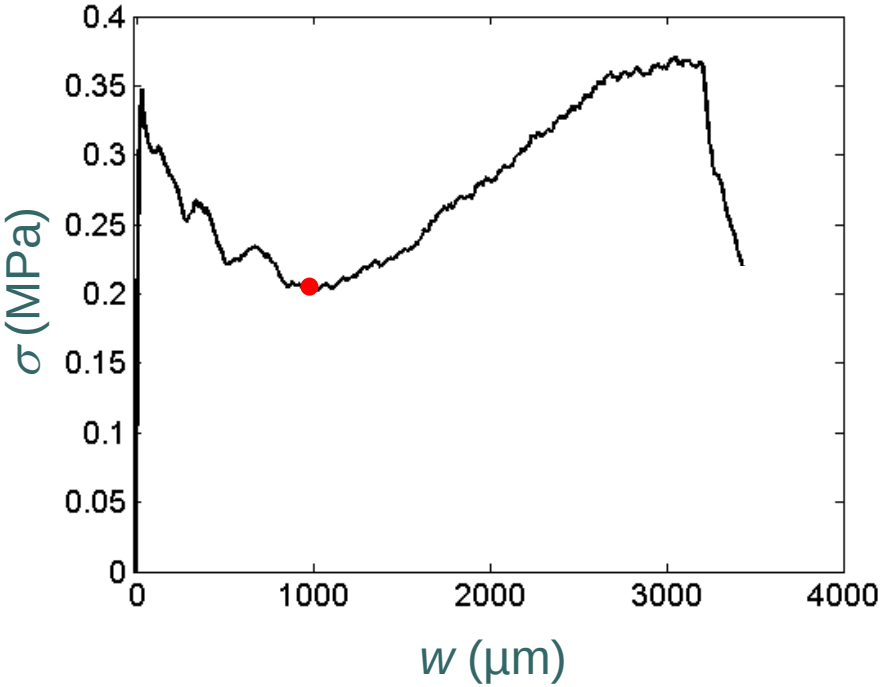
Mode I - PMMA

Fracture process



w = 1000 µm

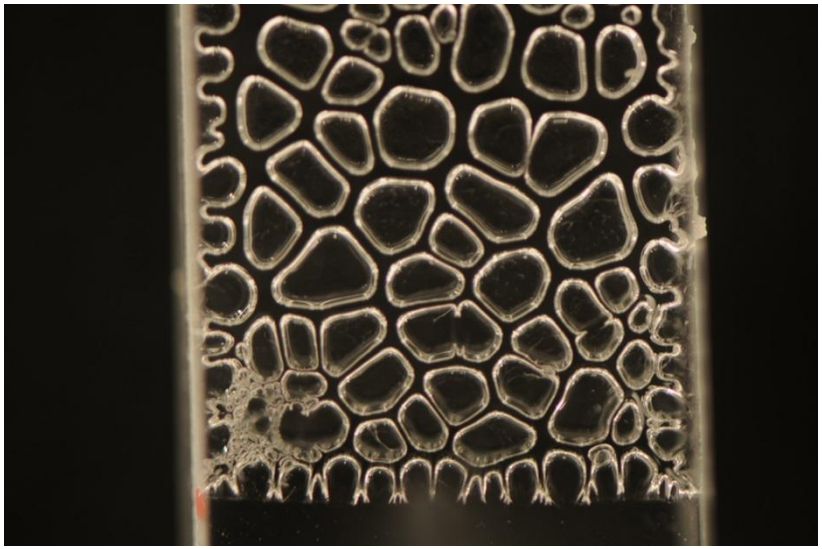
Stress – elongation relation



Cavities is covering the entire width of the specimen

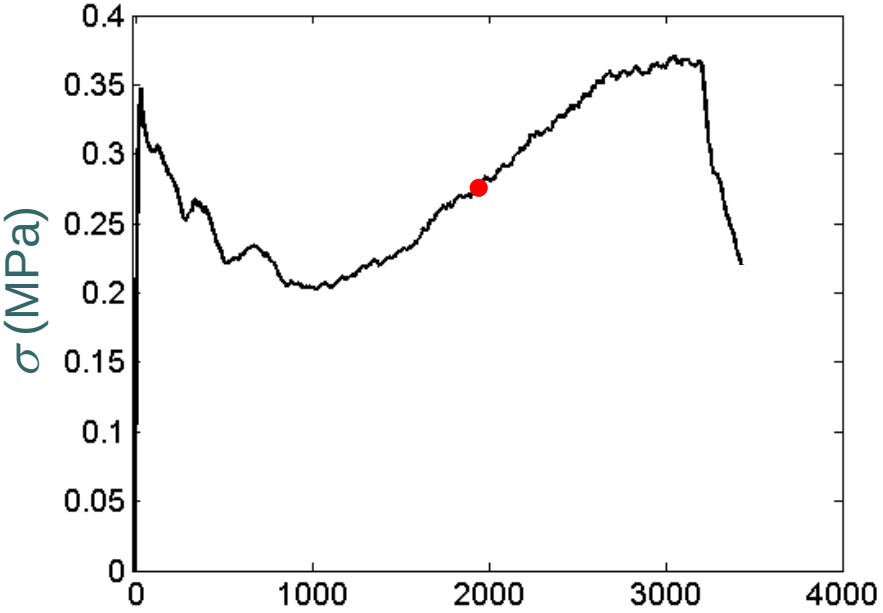
Mode I - PMMA

Fracture process



w = 2000 µm

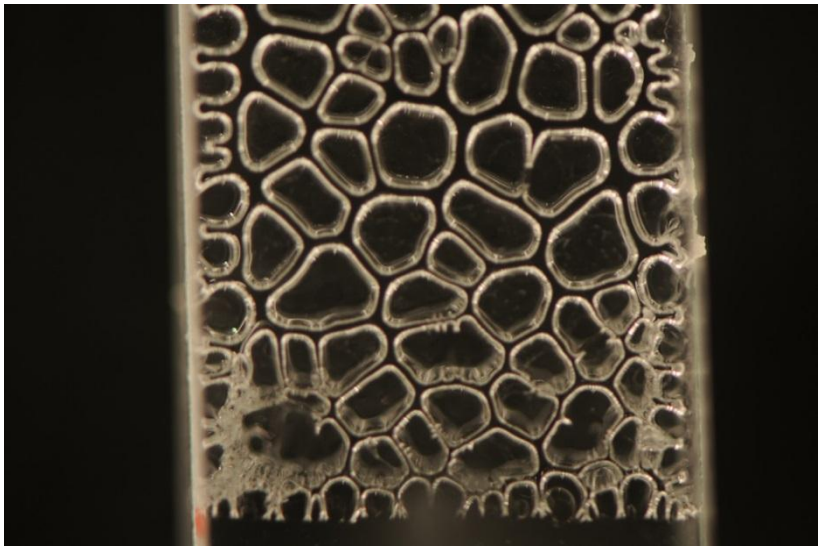
Stress – elongation relation



The growth of the cavities is limited - The stress is increasing

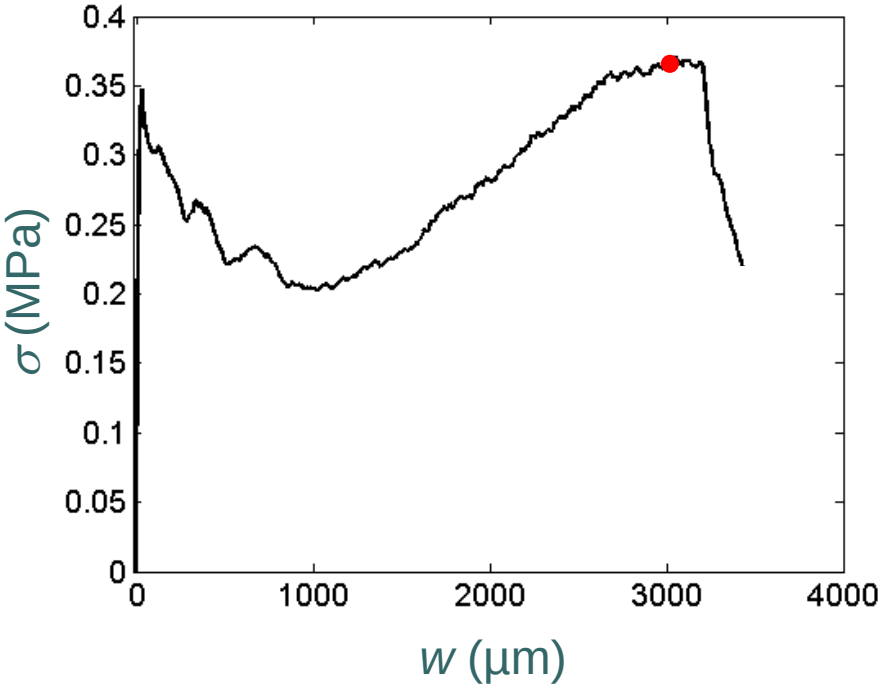
Mode I - PMMA

Fracture process



w = 3000 µm

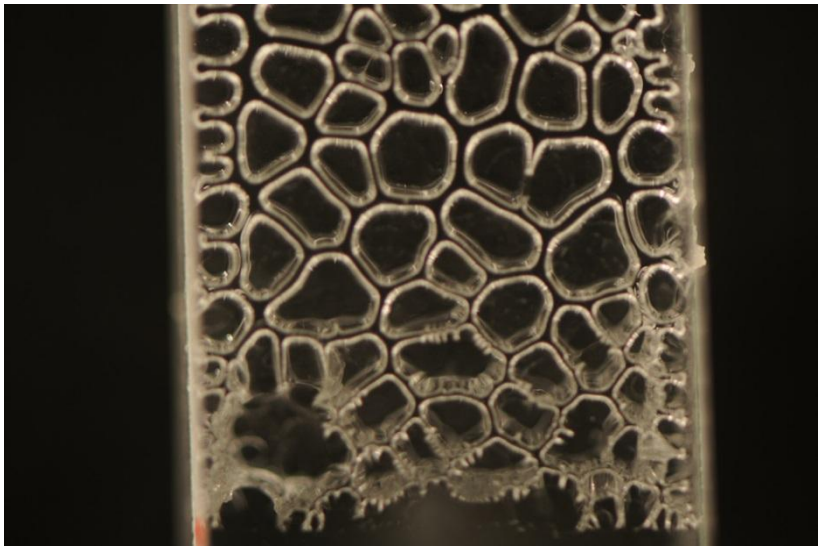
Stress – elongation relation



Cavities start to grow together

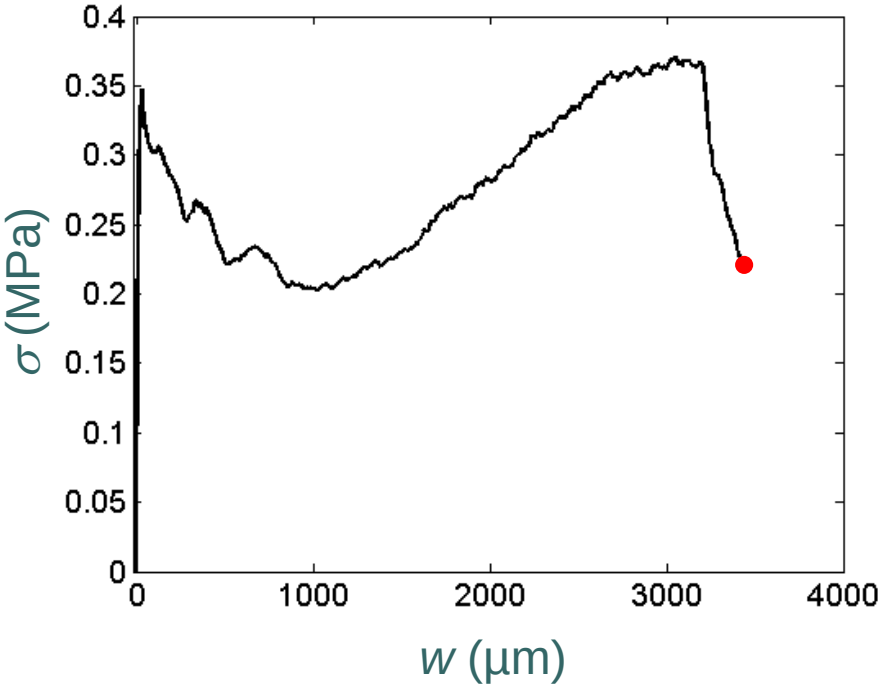
Mode I - PMMA

Fracture process



w = 3500 µm

Stress – elongation relation



Macroscopic crack is created

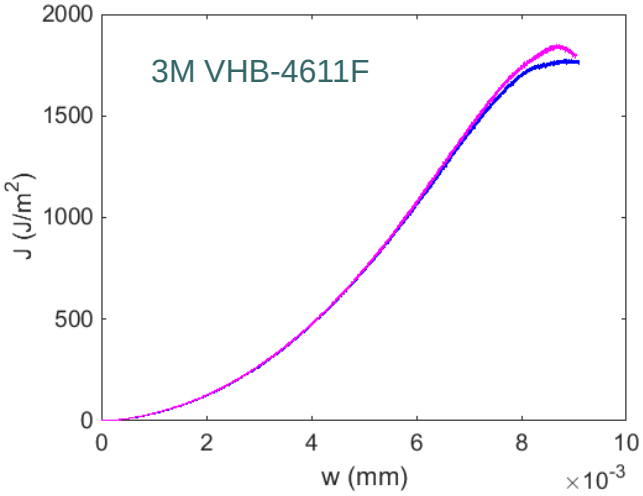
Mode II, Energy Release Rate

$$J = \frac{2F\sin\theta}{b}$$

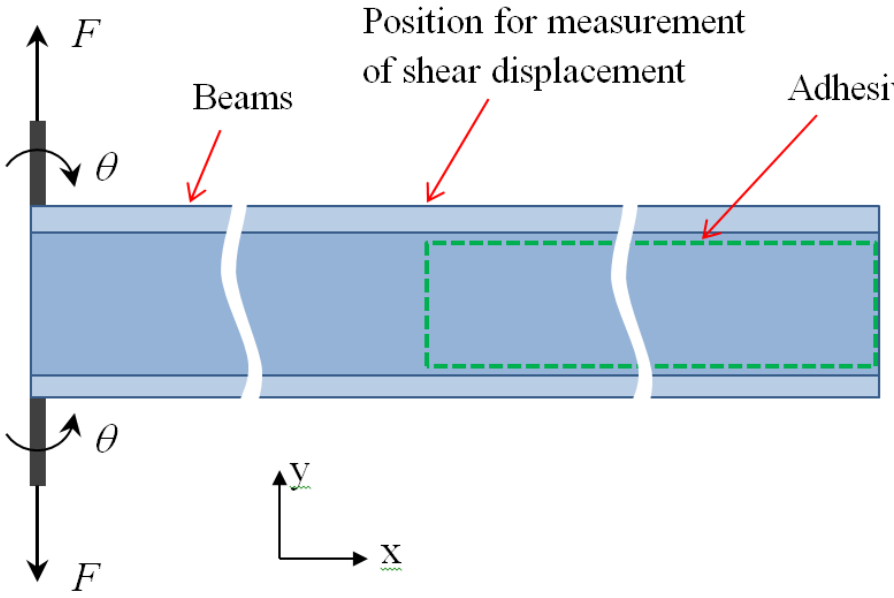
$$J = \int \sigma \, dw$$

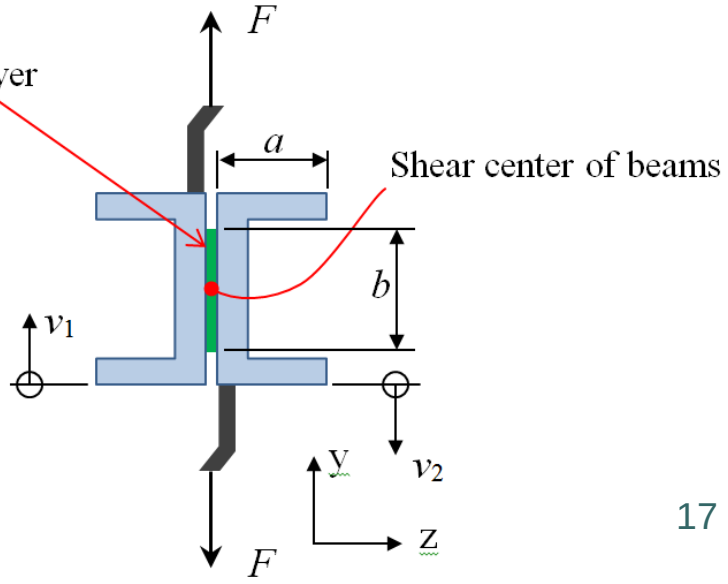
$$\sigma = \frac{dJ}{dw} = \frac{d}{dw}\left(\frac{2F\sin\theta}{b}\right)$$

$$w = v_1 - v_2$$



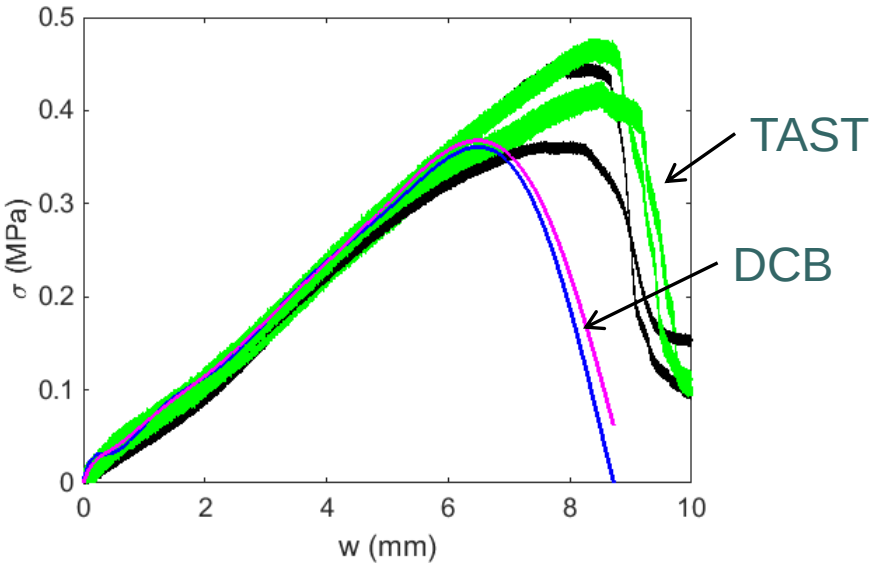
DCB-specimen



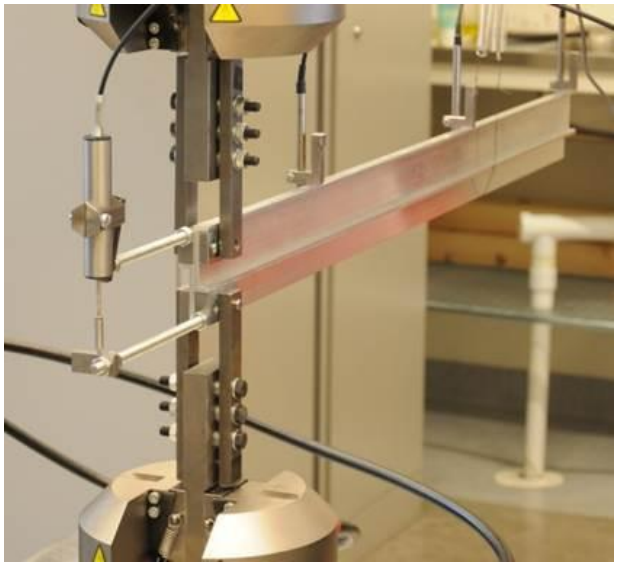


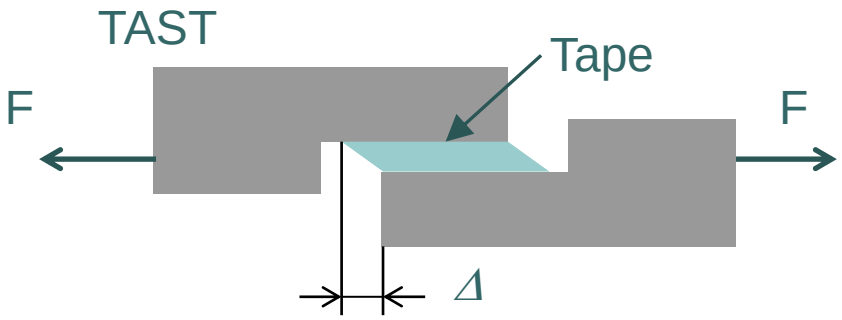
Mode II, Cohesive Law

Cohesive law



DCB experiment for shear

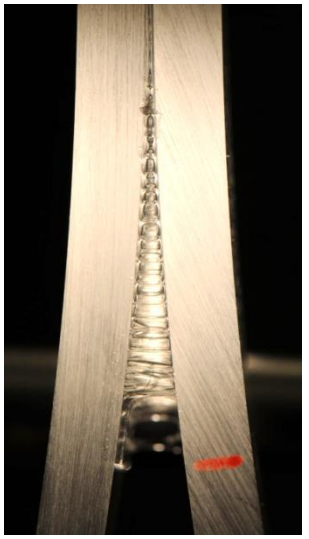




Behaviour for shear is not influenced by cavities

Result and Conclusions

- Adhesive tapes has a low maximum stress but an impressive fracture energy
- Similar result is obtained by use of different methods/geometries
  DCB-specimen – Butt joint - TAST
- The cohesive law for *Mode I* is influenced by the creation, growth and coalescence of cavities
- The cohesive law for *Mode II* is almost bi-linear.



3M VHB-4611F	Mode I	Mode II
Fracture energy	2100 J/m^2	2000 J/m^2
Peak stress	0.5 MPa	0.4 MPa