View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by Archive Ouverte en Sciences de l'Information et de la Communication

Open Archive Toulouse Archive Ouverte

OATAO is an open access repository that collects the work of Toulouse researchers and makes it freely available over the web where possible

This is an author's version published in: http://oatao.univ-toulouse.fr/23315

To cite this version:

Ho, Caroline and Tongne, Amèvi and Dalverny, Olivier and Alexis, Joël and Lacroix, Loïc and Dehoux, Anita and Châtel, Sébastien and Faure, Bruce *FE simulation of interfacial delamination between SiO2 thin film and polymeric substrate.* (2017) In: European Congress and Exhibition on Advanced Materials, EuroMat 2017, 17 September 2017 - 22 September 2017 (Thessaloniki, Greece).

Any correspondence concerning this service should be sent to the repository administrator: tech-oatao@listes-diff.inp-toulouse.fr

FE Simulation of Interfacial Delamination between SiO_2 Thin Film and Polymeric Substrate

C. Ho [1-2], A.Tongne [1], O. Dalverny [1], J. Alexis [1], A. Dehoux [2], S. Châtel [2], B. Faure [2]

[1] University of Toulouse; INP / ENIT; LGP – *Tarbes, France*
[2] Essilor International R&D – *Créteil, France*

© ESSILOR 2017 – All rights reserved
Do not disclose, copy or distribute

EUROMAT 2017
EUROPEAN CONGRESS AND EXHIBITION ON ADVANCED MATERIALS AND PROCESSES

General outline

1. Context
2. Experimental study
3. Numerical modeling of the test
4. Numerical simulation results
5. Conclusions and perspectives

© ESSILOR 2017 – All rights reserved
Do not disclose, copy or distribute

General outline

1. Context
2. Experimental study
3. Numerical modeling of the test
4. Numerical simulation results
5. Conclusions and perspectives

© ESSILOR 2017 – All rights reserved
Do not disclose, copy or distribute

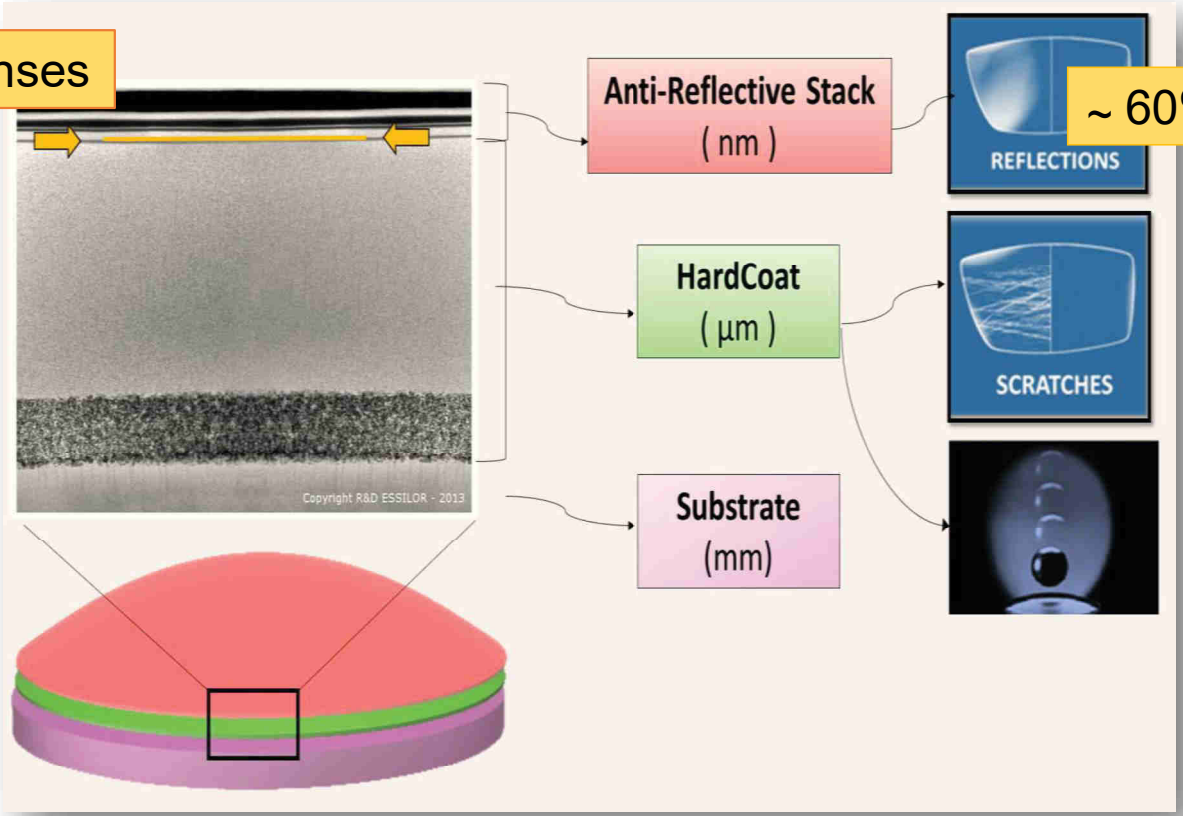
Context

70% of French population uses vision correction products

« Les Français et l'optique », Institut Ipsos (2012)

~ 10% contact lenses

~ 60% eyeglasses

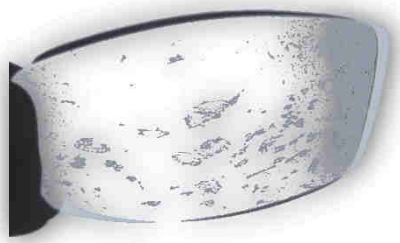


→ Ophtalmic lens is a complex system (structure and materials)

© ESSILOR 2017 – All rights reserved
Do not disclose, copy or distribute

Challenge

- Insufficient adhesion between layers can lead to delamination



Delamination after Process Modification

→ Important margin of safety prior to product launch

Need of a better understanding of mechanisms of adhesion

Simplification of the system: Study of Adhesion of SiO_2 thin film on Hardcoat

© ESSILOR 2017 – All rights reserved
Do not disclose, copy or distribute

ESSILOR RESEARCH & DEVELOPMENT

General outline

1. Context
2. Experimental study
3. Numerical modeling of the test
4. Numerical simulation results
5. Conclusions and perspectives

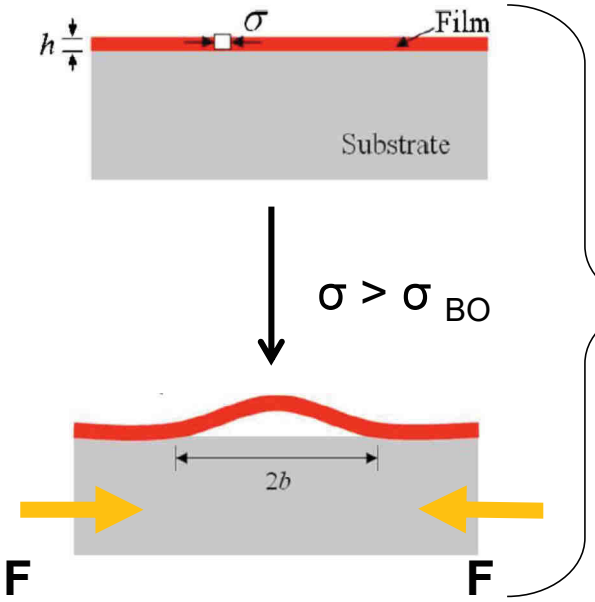
© ESSILOR 2017 – All rights reserved
Do not disclose, copy or distribute

Experimental study

Adhesion Characterization by compression test

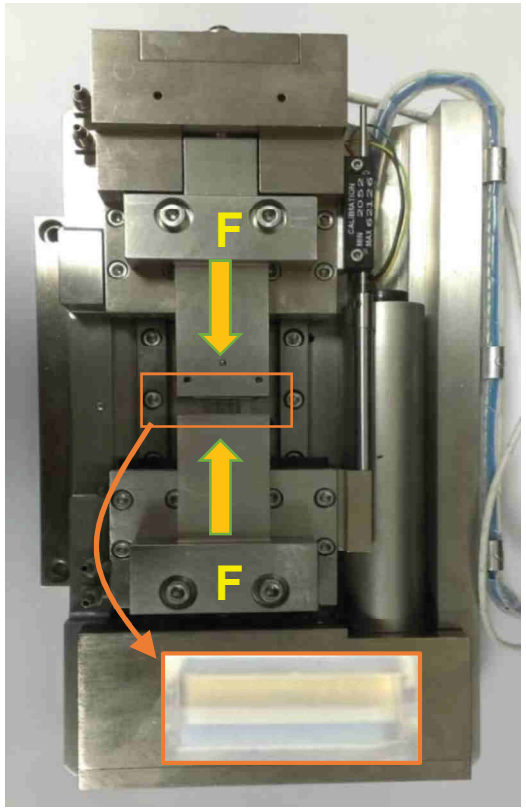
➢ Buckling by compression test

➢ Experimental Set-up



Hutchinson & Suo analytical model

T(ψ), Energy Release Rate

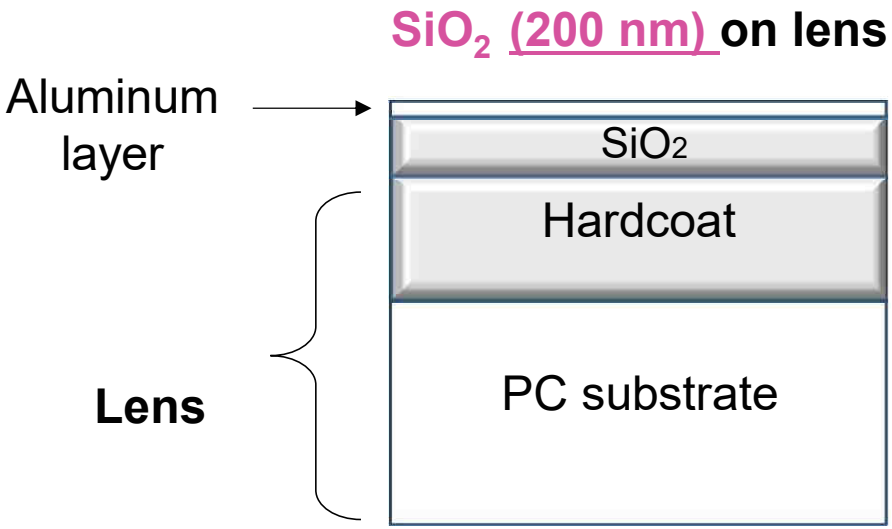


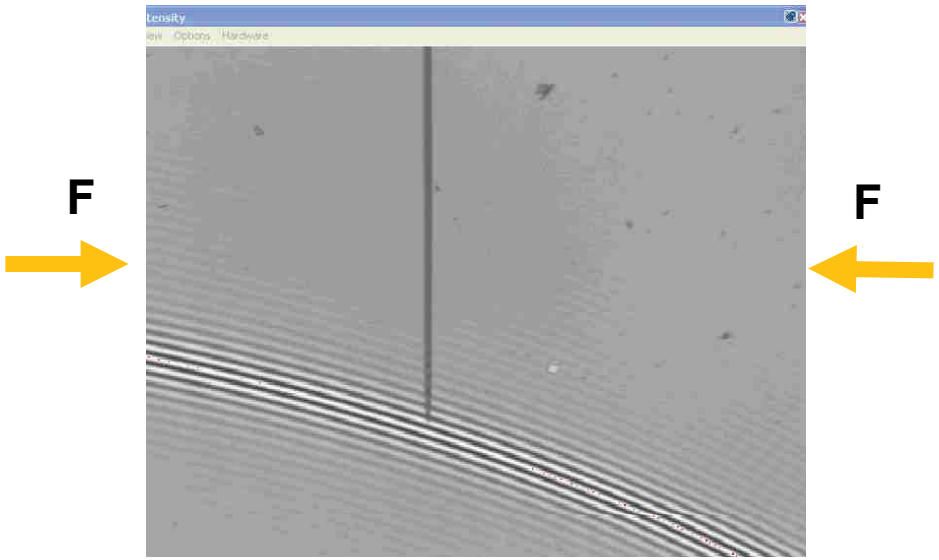
© ESSILOR 2017 – All rights reserved
Do not disclose, copy or distribute

ESSILOR RESEARCH & DEVELOPMENT

Experimental results

- Configurations of samples
- Video of buckling





© ESSILOR 2017 – All rights reserved
Do not disclose, copy or distribute

ESSILOR
RESEARCH & DEVELOPMENT

General outline

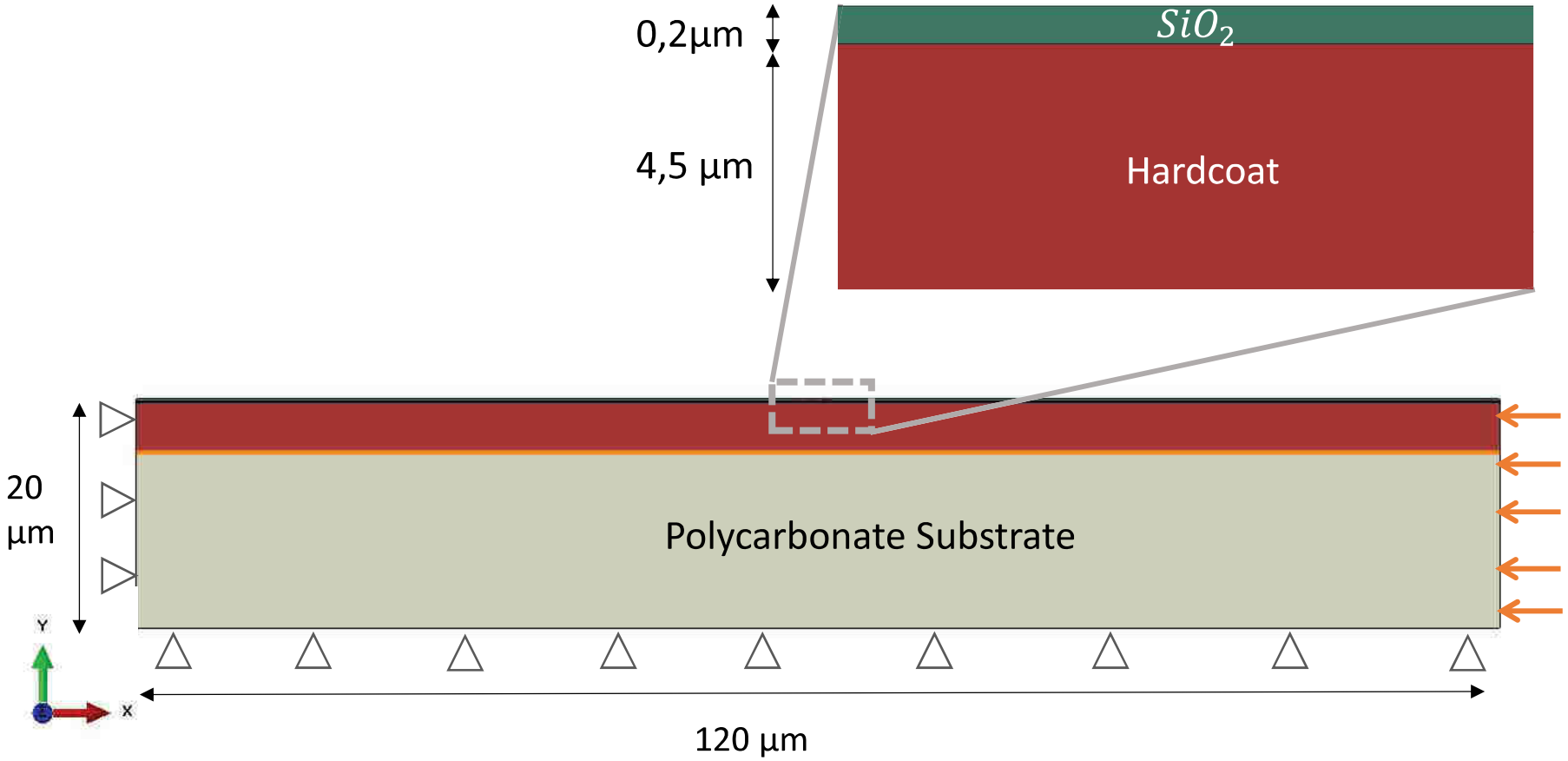
1. Context
2. Experimental study
3. Numerical modeling of the test
4. Numerical simulation results
5. Conclusions and perspectives

© ESSILOR 2017 – All rights reserved
Do not disclose, copy or distribute

Numerical modeling of the test

Description of Numerical model

Geometry | Boundary conditions



© ESSILOR 2017 – All rights reserved
Do not disclose, copy or distribute

ESSILOR RESEARCH & DEVELOPMENT

Numerical modeling of the test

Description of Numerical model

Physical model

- **Solving the momentum equation : Instability caused by buckling**
- **Interface degradation using damage model**

© ESSILOR 2017 – All rights reserved
Do not disclose, copy or distribute

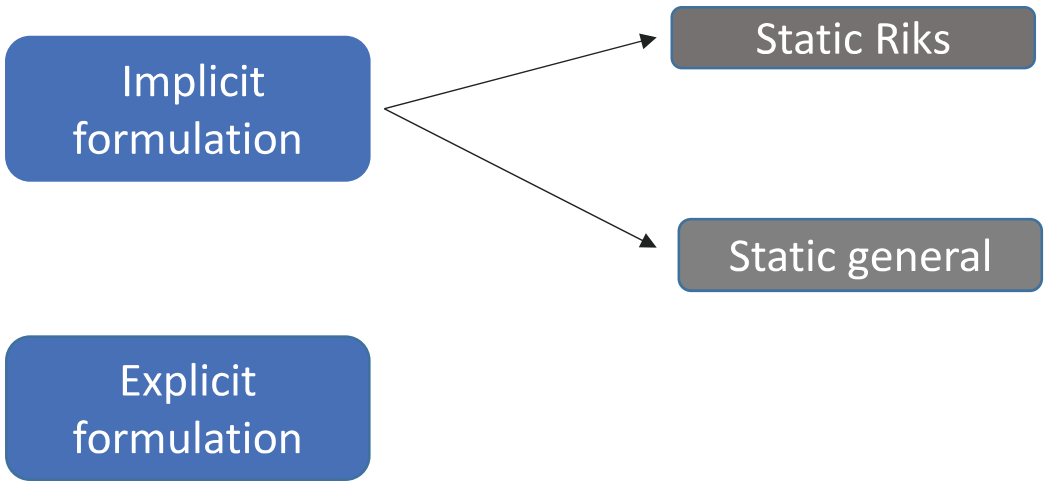
ESSILOR
RESEARCH & DEVELOPMENT

Numerical modeling of the test

Description of Numerical model

Physical model

- **Solving the momentum equation : Instability caused by buckling**



© ESSILOR 2017 – All rights reserved
Do not disclose, copy or distribute

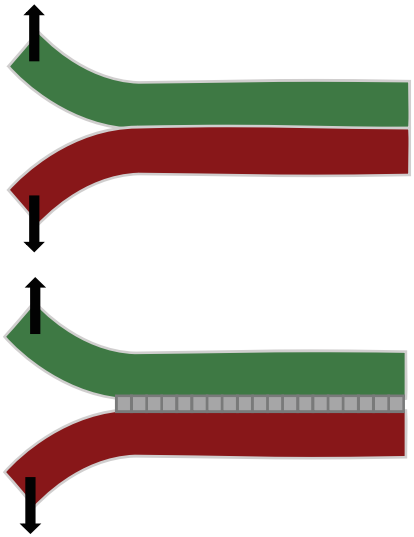
ESSILOR RESEARCH & DEVELOPMENT

Numerical modeling of the test

Description of Numerical model

Physical model

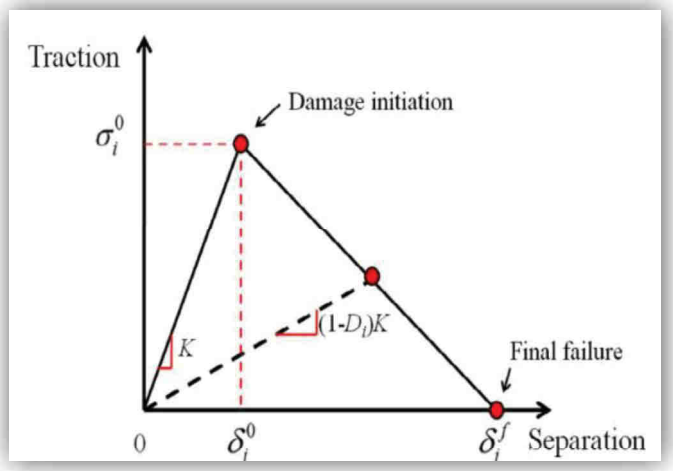
- Solving the momentum equation: Instability caused by buckling
- **Interface degradation using damage model**



Cohesive surface

Cohesive element

Traction – Separation Law



© ESSILOR 2017 – All rights reserved
Do not disclose, copy or distribute

ESSILOR RESEARCH & DEVELOPMENT

Numerical modeling of the test

Description of Numerical model

Materials Properties

SiO_2 thin film	**E, ν**
Hardcoat	**E, ν**

Interfacial Properties

Cohesive Behavior	K_I $K_{II} = K_{III}$
Tangential Behavior	Frictionless
Damage Initiation	$\sigma_I = \sigma_{II} = \sigma_{III}$
Damage Evolution	Total Displacement
Damage Stabilization	Viscous Stabilization

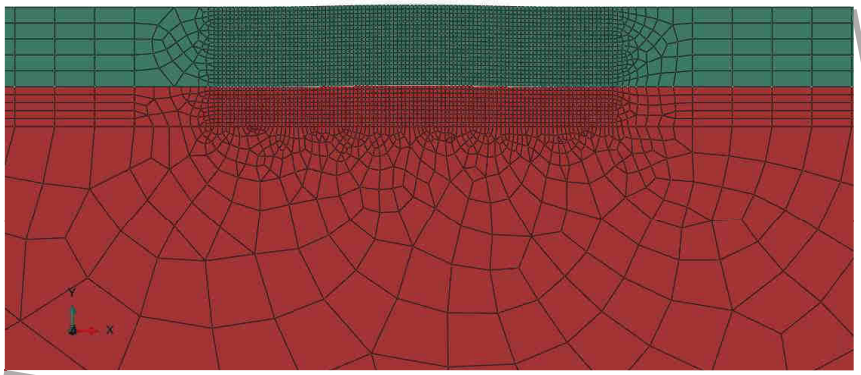
© ESSILOR 2017 – All rights reserved
Do not disclose, copy or distribute

ESSILOR RESEARCH & DEVELOPMENT

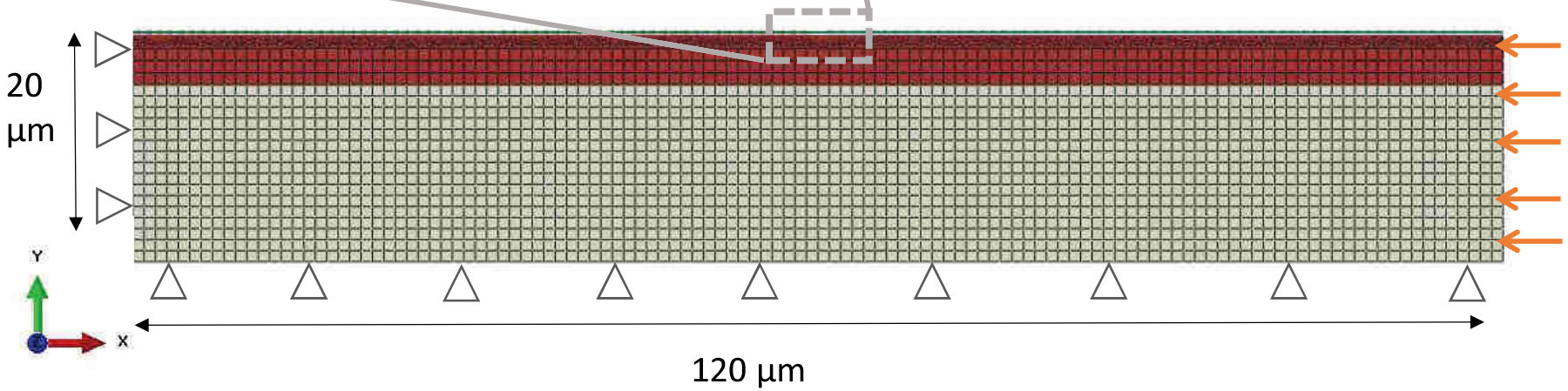
Numerical modeling of the test

Geometry | Boundary conditions | Mesh

- **Homogeneous meshing** near the interface
- **Element Type** : CPS4, CPS3
- **Element Size**
  - → Defect : x = 10 nm ; y = 0,1 nm
  - → SiO_2 layer : x = 100 nm ; y = 40 nm
  - → First 100 nm of Hardcoat
    x = 100 nm ; y = 20 nm



SiO_2 200 nm



© ESSILOR 2017 – All rights reserved
Do not disclose, copy or distribute

ESSILOR
RESEARCH & DEVELOPMENT

General outline

1. Context
2. Experimental study
3. Numerical modeling of the test
4. Numerical simulation results
5. Conclusions and perspectives

© ESSILOR 2017 – All rights reserved
Do not disclose, copy or distribute

Numerical simulation results

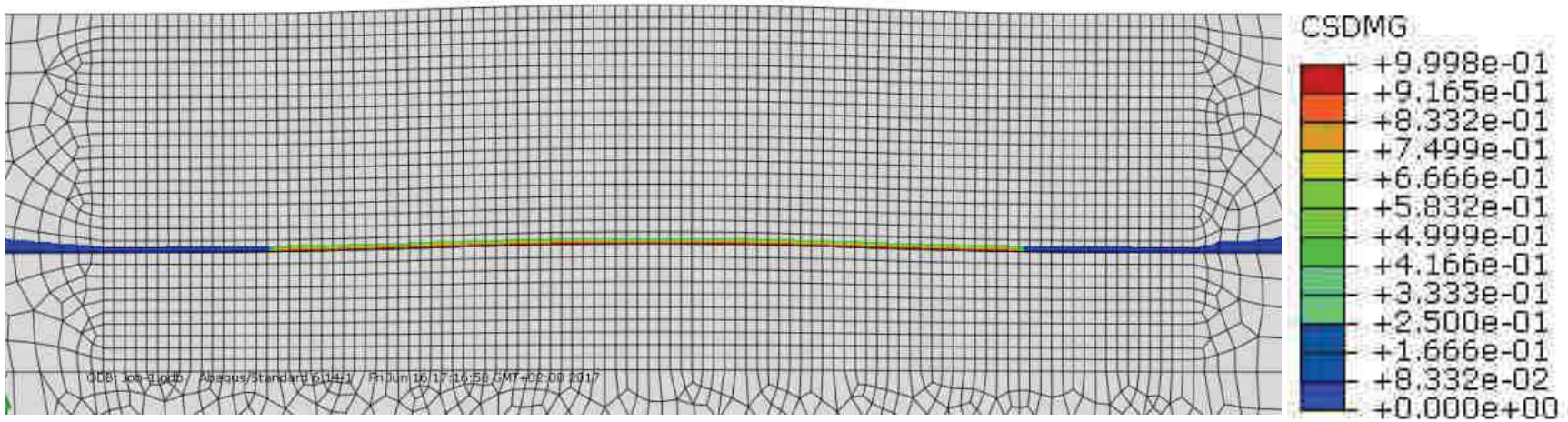
- Video of simulated buckling

© ESSILOR 2017 – All rights reserved
Do not disclose, copy or distribute

ESSILOR
RESEARCH & DEVELOPMENT

Numerical simulation results

- Interface damage variable CSDMG



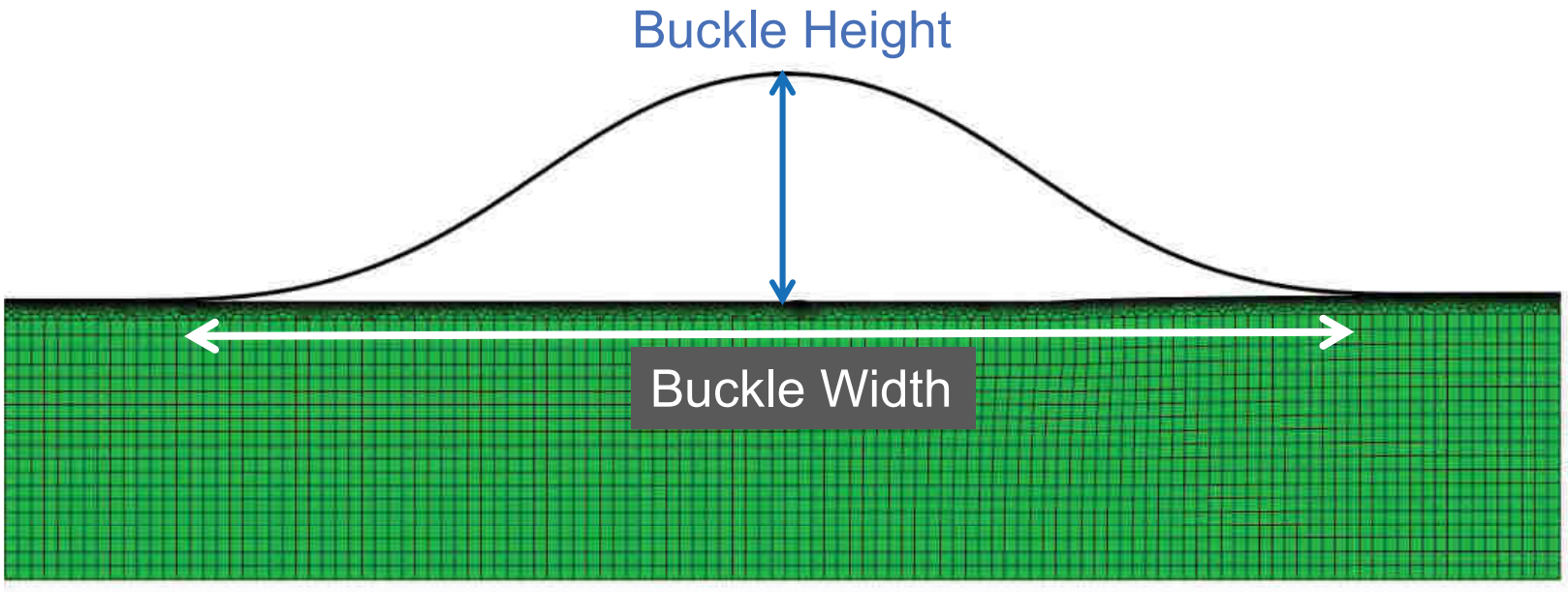
➢ <u>Initiation Strain</u>

Experimental : 3,8 % strain
Numerical : 3,9 % strain

© ESSILOR 2017 – All rights reserved
Do not disclose, copy or distribute

ESSILOR
RESEARCH & DEVELOPMENT

Numerical simulation results



➢ <u>Buckle Height</u> Experimental : 6 µm Numerical : 15 µm	➢ <u>Buckle Width</u> Experimental : 51 µm Numerical : 73 µm

© ESSILOR 2017 – All rights reserved
Do not disclose, copy or distribute

ESSILOR
RESEARCH & DEVELOPMENT

General outline

1. Context
2. Experimental study
3. Numerical modelling of the test
4. Numerical simulation results
5. Conclusions and perspectives

© ESSILOR 2017 – All rights reserved
Do not disclose, copy or distribute

Conclusions and Perspectives

➢ Conclusions

- Model using static calculation with cohesive surface
  → Buckling obtained with numerical model
- Good match of Initiation strain with experimental results
- Buckle dimensions to be improved upon

➢ Perspectives

- Parametric study
- Analysis of energy dissipated

© ESSILOR 2017 – All rights reserved
Do not disclose, copy or distribute

Acknowlegments

Essilor International
Innovation and Technology Center

ANRT
Research and Technology National Association

Thank you for your attention

© ESSILOR 2017 – All rights reserved
Do not disclose, copy or distribute