



Accelerating Sustainable Composite Manufacturing

Dielectric Sensors and Machine Learning

Alec Redmann, PhD



EXPAND your sense of the possible

NETZSCH
Proven Excellence.

&

The logo for sensXPERT, featuring the text "sens" and "PERT" separated by a large "X" formed by two intersecting diagonal lines.

Parent Company:
NETZSCH

Founded:
1962 (Analyzing and Testing)

Global scientific instrument and thermal analysis leader with 4100+ employees present in 36 countries

Corporate Venture:
NETZSCH Process Intelligence GmbH

Founded:
2019

Technology startup developing intelligent manufacturing solutions

sensXPERT Digital Mold



Technology Overview

1. integrated sensor hardware to measure critical process parameters
2. edge device to evaluate machine and material data for automated process optimization
3. cloud service and customizable dashboards

3

In-Mold Thermal Analysis



Real-Time Material Characterization with Dielectric Sensors

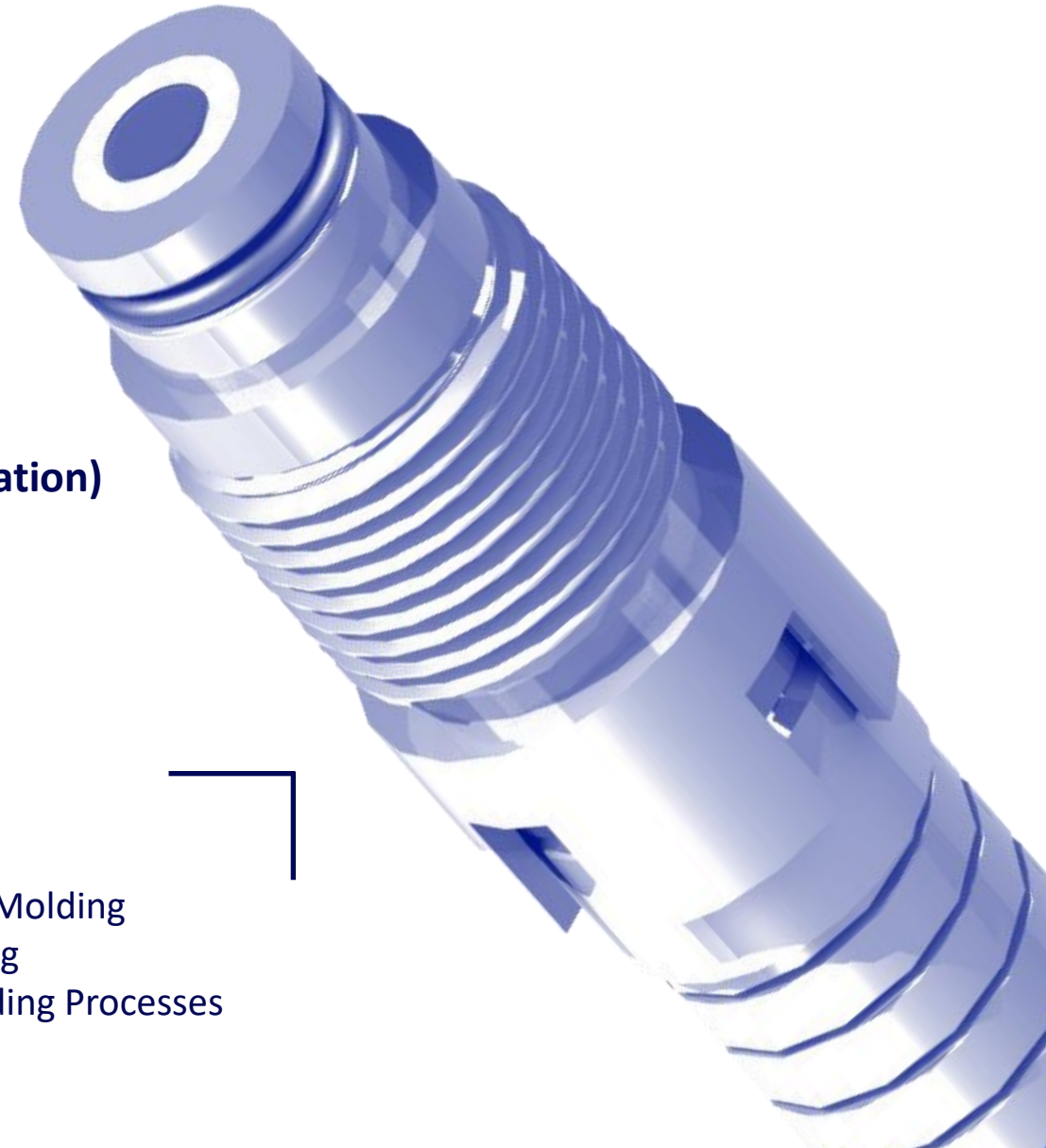
- Measuring material behavior
 - **resin viscosity, degree of cure, glass-transition, material condition (mixing ratio, ageing, shrinkage, contamination)**
- Combined with third-party measurement devices (pressure transducers, thermocouples, and more)

MATERIALS

- Thermosets and thermoplastics
- Fiber reinforced polymers
- Mineral casting

PROCESSES

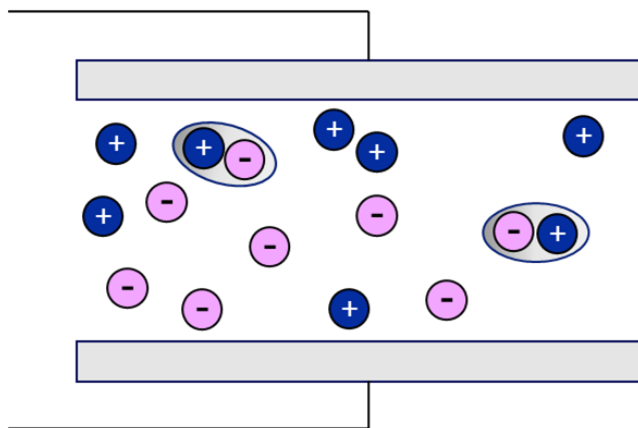
- (Reaction) Injection Molding
- Compression Molding
- Resin Transfer Moulding Processes
- Autoclave Curing



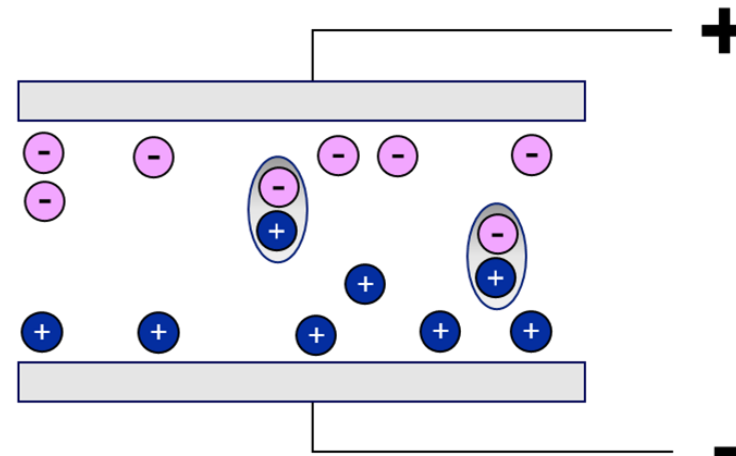
- Observes the behavior of material under the application of an electric field
- Molecules in the material sample have a net electric charge
- Interact with the electric field
- **Ion viscosity** – An analog to mechanical viscosity

Behavior of ions and dipoles inside an external electrical field

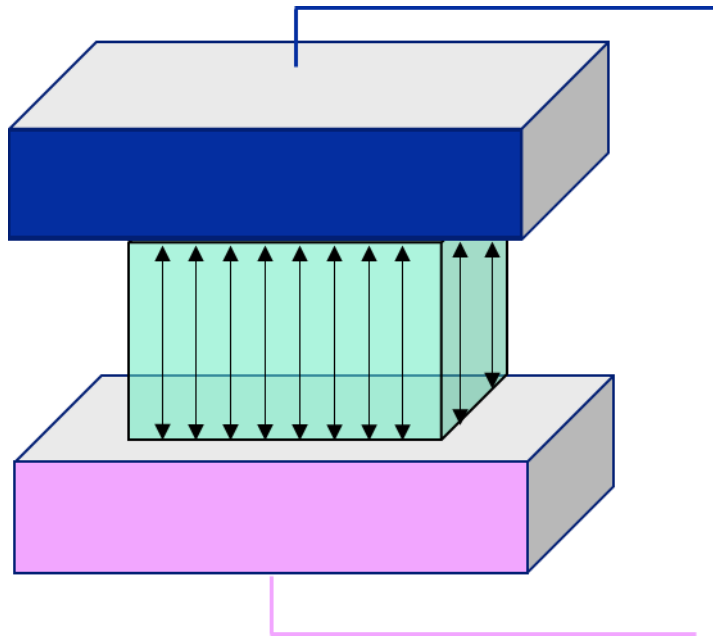
Without external electrical field



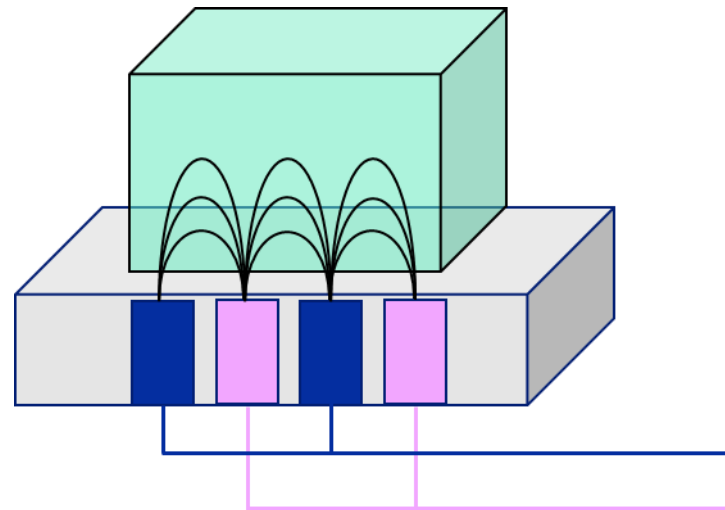
With external electrical field



Traditional parallel plate electrodes



Interdigitated "comb" electrodes



sensXPERT in-mold sensor



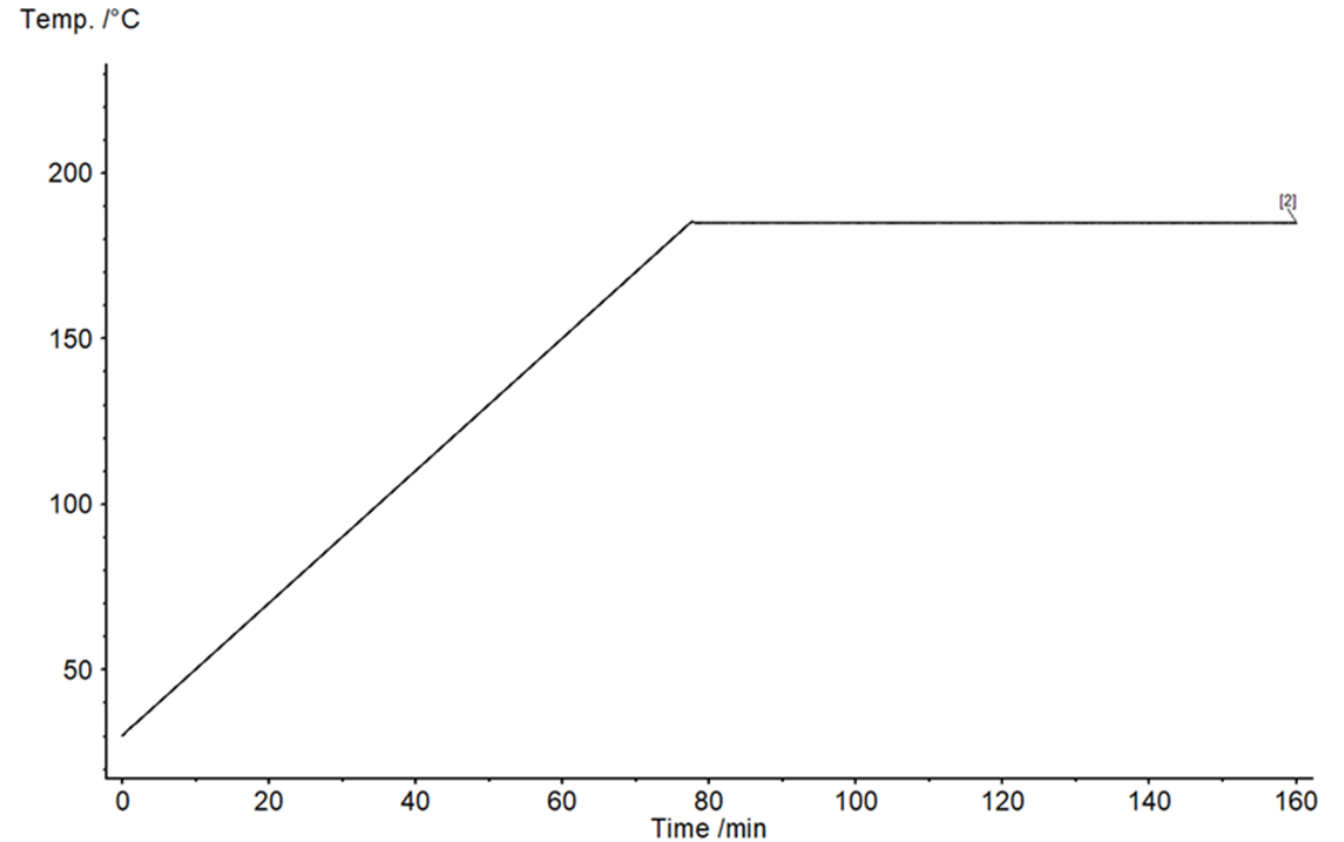
Dielectric Analysis: Ion Viscosity

RTM / Infusion Epoxy

180 °C / 350 °F mono-component epoxy system

Standard process data

- Temperature ramp
- Holding time
- No viscosity or cure information



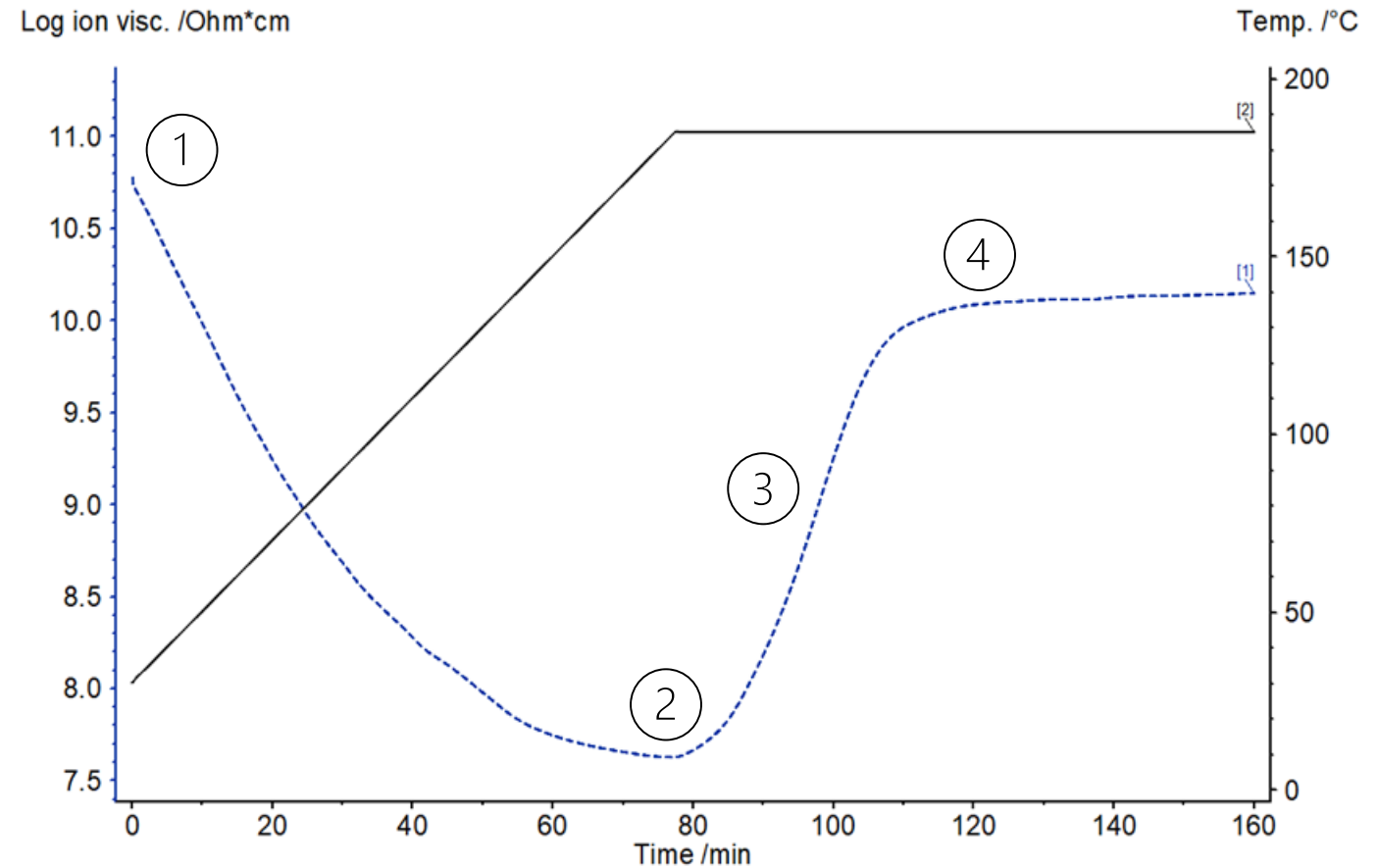
Dielectric Analysis: Ion Viscosity

RTM / Infusion Epoxy

180 °C / 350 °F mono-component epoxy system

sensXPERT process data

- ① Introduction of the material
- ② Minimum resin viscosity
- ③ Progression of cure / gelation
- ④ Completion of cure



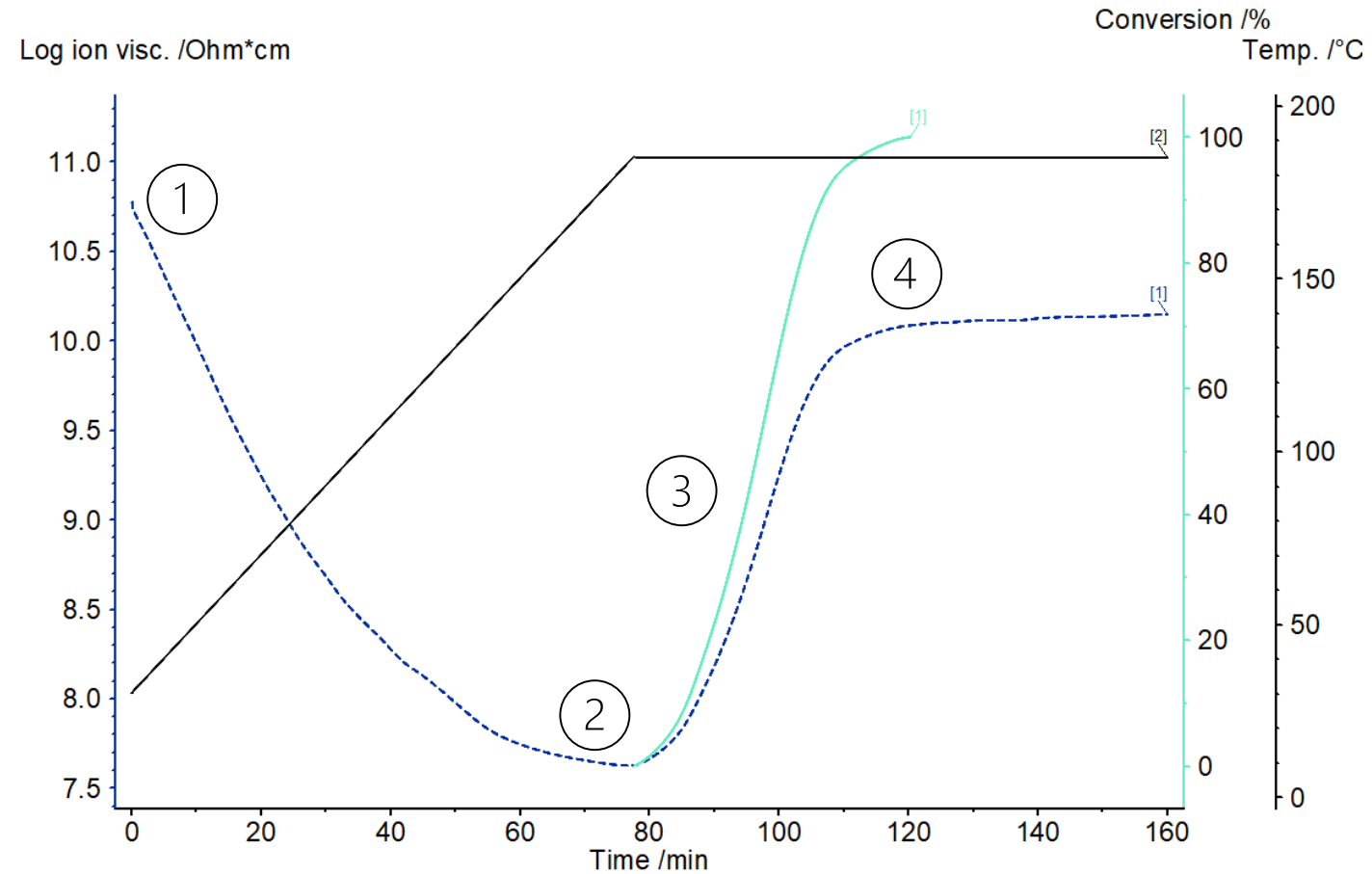
Dielectric Analysis: Ion Viscosity

RTM / Infusion Epoxy

180 °C / 350 °F mono-component epoxy system

sensXPERT process data

- ① Introduction of the material
- ② Minimum resin viscosity
- ③ Progression of cure / gelation
- ④ Completion of cure



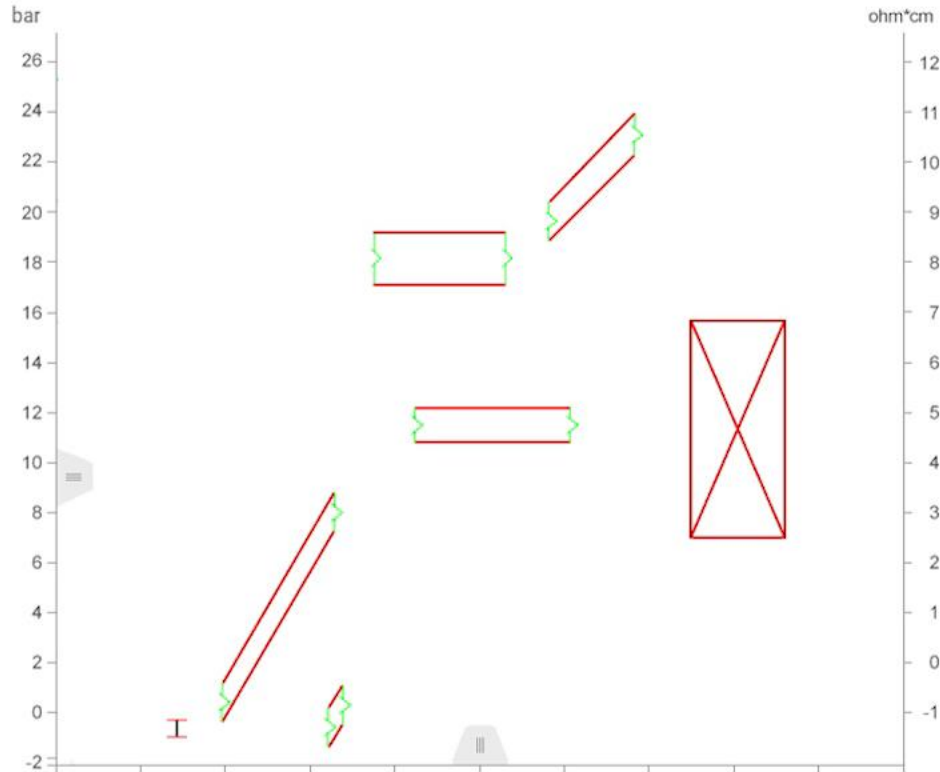
Dielectric Analysis: Ion Viscosity

65 52 [1 0] Production [Composite hood]

Cycle Viewer Reference Cycles

Analysis > Cycle > Cycle Viewer

Cycle 65



PROCESS STATUS - OK
EVACUATION:
INJECTION:
COMPRESSION:
HOLDING:
GELPOINT:
CURING:

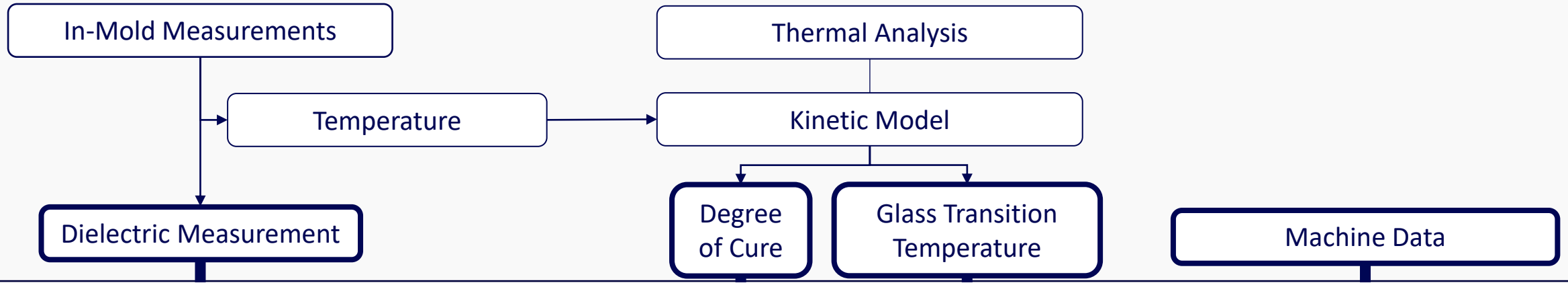


Process Predictions and Optimization

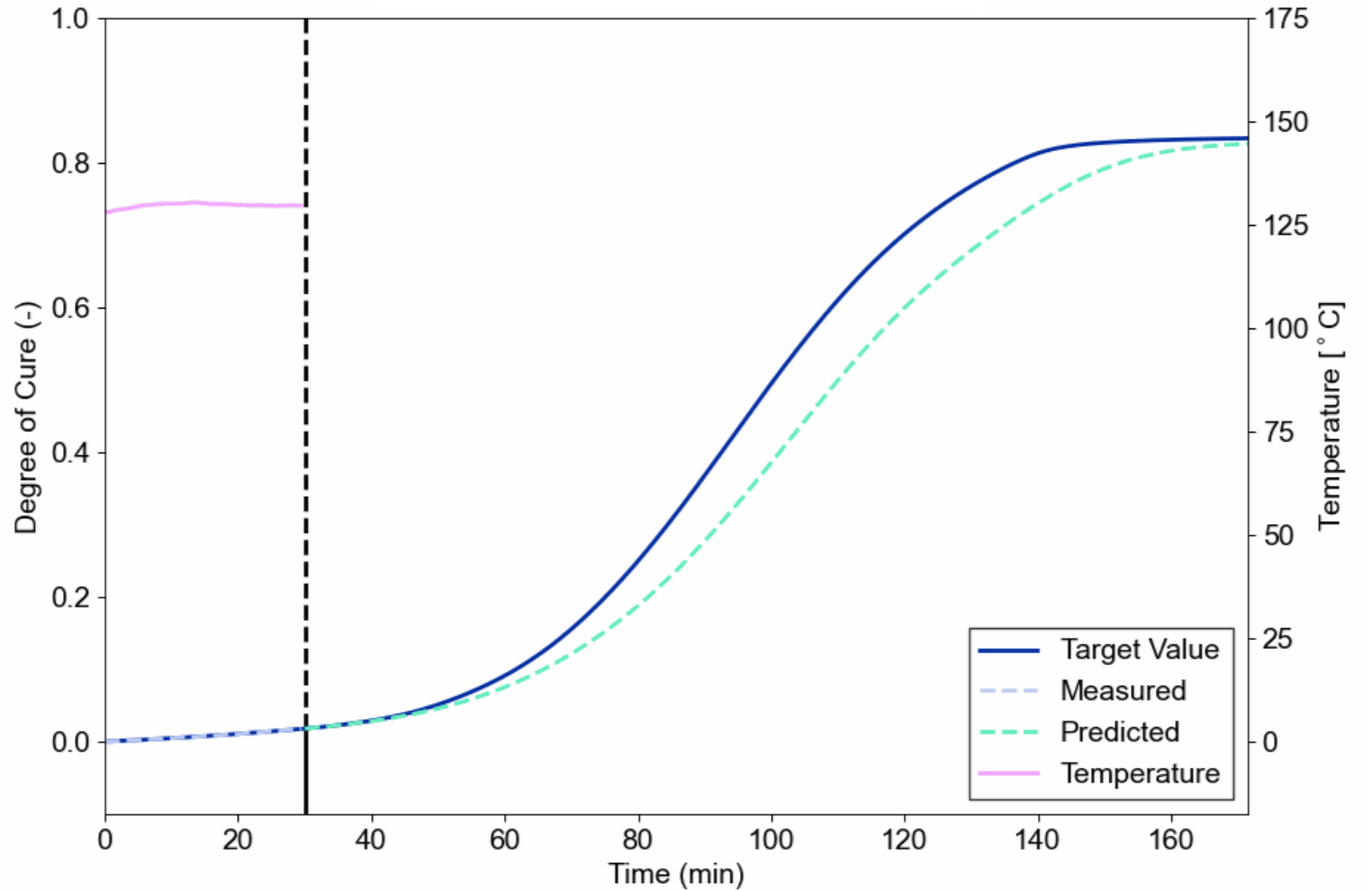


Machine Learning and Process Optimization

Data Preprocessing

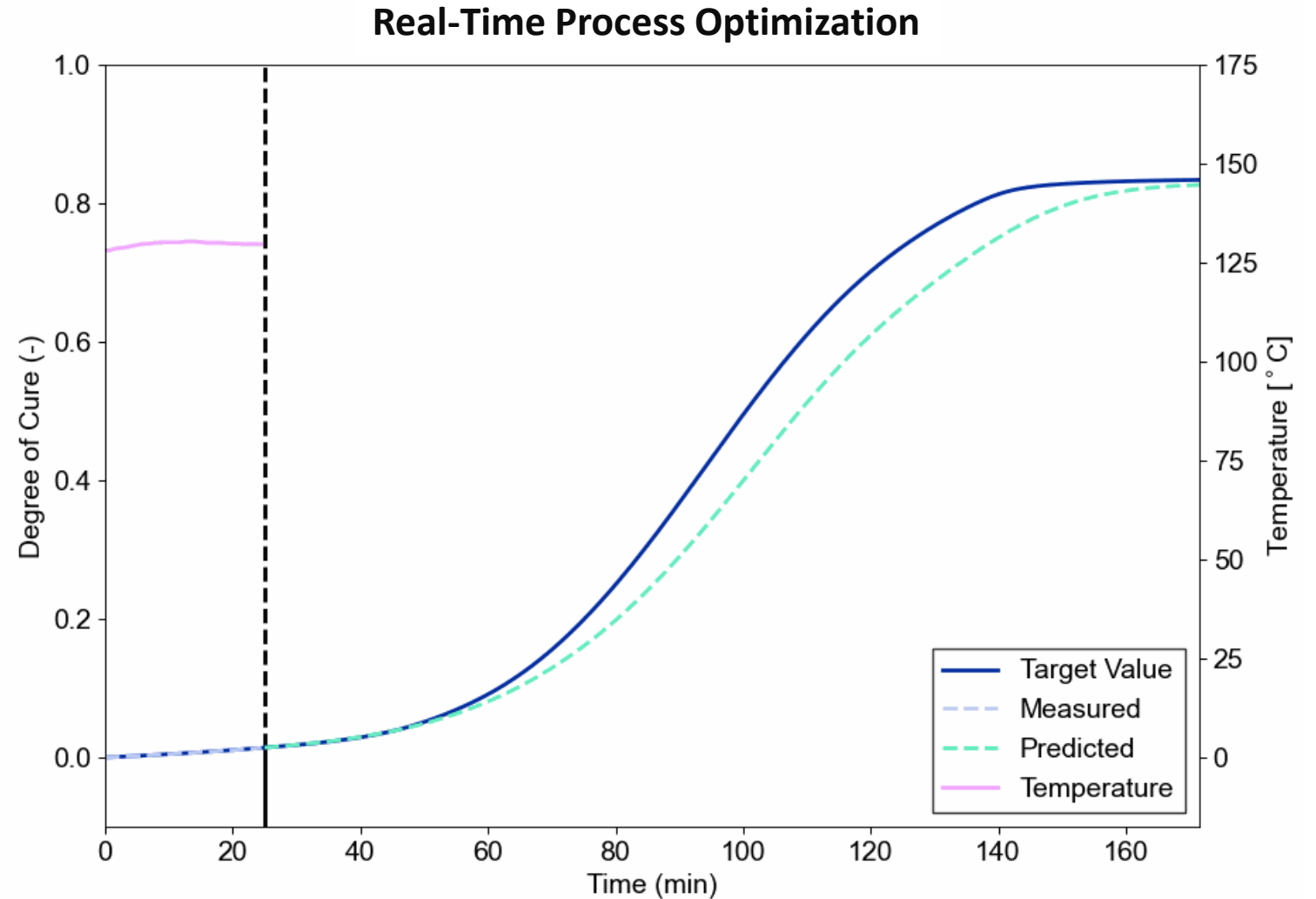


Real-Time Process Optimization



A data driven solution.

- AI model calculates and predicts material properties
- Dynamically control and adapt the process to ensure constant quality



Process Monitoring and Customized Dashboards



Tailgate Z15

- Transfer Molding
- Compression Molding
- Injection Molding

Engine Cover sensX

- Transfer Molding
- Injection Molding

Bumber Bar U76

- Compression Molding

Data History

Settings

Logout

Tailgate Z15

Transfer Molding: Epoxy Resin

Sensor Status: Connected Last Data Sync: 12.02.22 | 07:12:32 Automatic Refresh: ON | OFF

★ Favorite Parameters All Parameters

Parameter Visualisation

Material temperature before serv...
Residual time of material inside cavit...
Mold Temperature
Height of venting

Part 264
Residual time of mat.: 274.5 s
[Show more details](#)

Parameter Categories

- Primary Machine Data
- Secondary Machine Data
- Sensor Data

Status	Parameter	Latest Value	Average Value	Favorite	Show in Graph
	Material temperature before serving the cavity	110 °C	121 °C	★	<input checked="" type="checkbox"/>
	Residual time of material inside cavity before serving cavity	2 s	4 s	★	<input checked="" type="checkbox"/>
	Mold Closing Speed	44 mm/s	12 mm/s	★	<input type="checkbox"/>
	Mold Temperature	90 °C	98 °C	★	<input checked="" type="checkbox"/>

- Process transparency
- 24/7 access on any device
- Customizable dashboards
- OpenAPI: flexible data handling



Part 174

Measurement Details



Meta Data

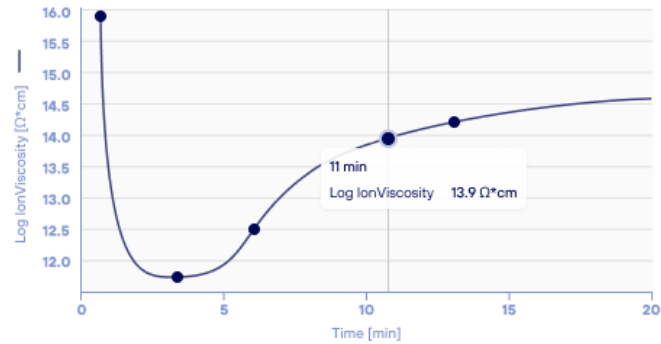
Channel 1

Channel 2

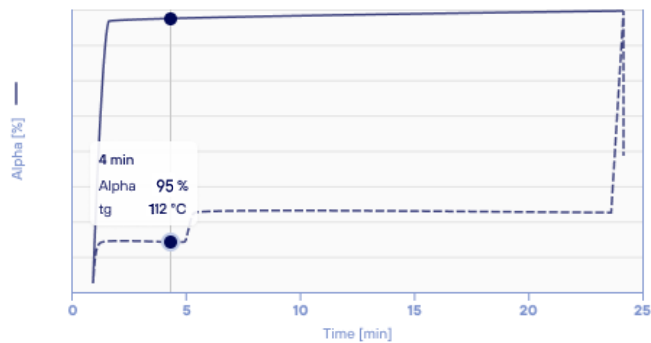
Calculated/Predicted Data

Data Type	Value
CP1 time	0.84 min
CP2 time	3.56 min
CP3 time	6.12 min
CP4 time	13.38 min
Ending alpha	95.05 %
Ending tg	124.88 °C
Ending time	13.38 min

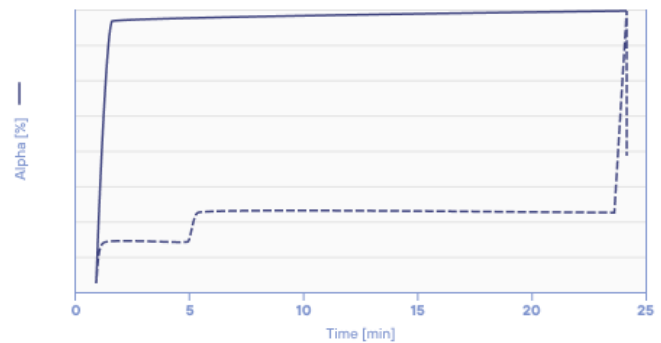
Master Curve (Channel 2)



First Prediction (Channel 2)



Last Prediction (Channel 2)



Tailgate Z15

Transfer Molding

Compression Molding

Injection Molding

Engine Cover sensX

Transfer Molding

Injection Molding

Bumber Bar U76

Compression Molding

Data History

Settings

Logout

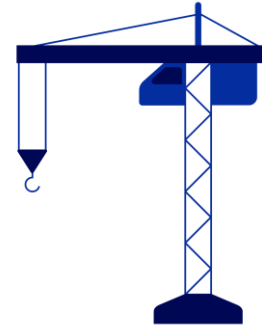
INDUSTRIES WE WORK WITH



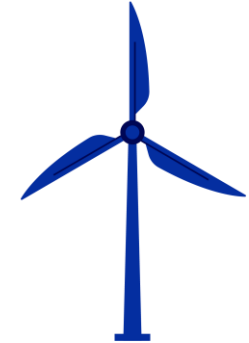
Automotive



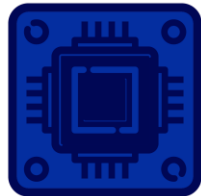
Aerospace



Building & Construction



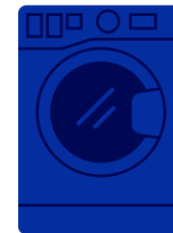
Renewable Energy



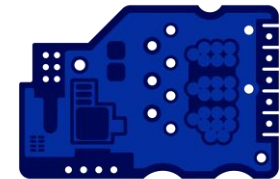
Electrical Applications



Military Defense



Consumer Goods



Electronics Encapsulation

Electronics Encapsulation

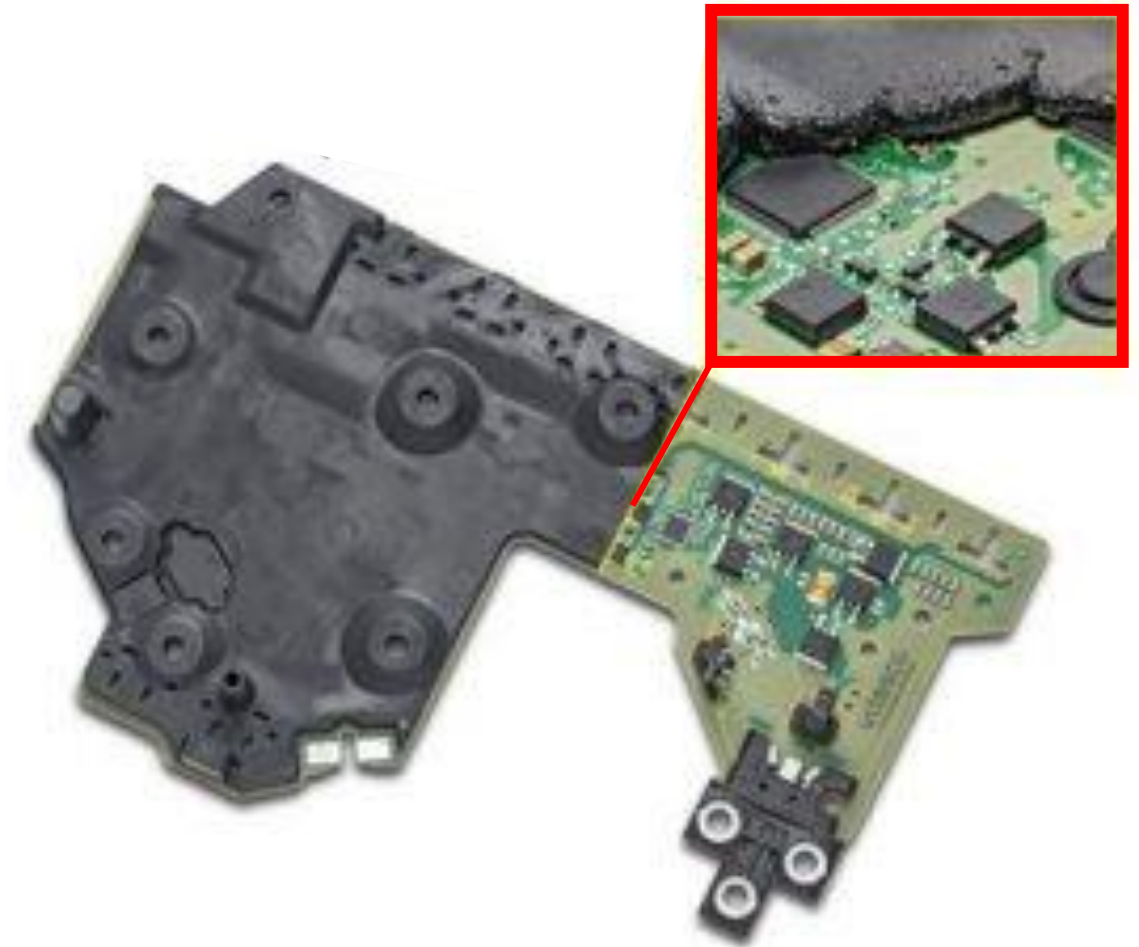
Use Case

Component: High-power electronics circuit board

Material: Epoxy molding compound

Quality criterion: Degree of cure > 90%

Target cycle time: 3 minutes



sensXPERT USE CASE: OPTIMIZING ELECTRONICS ENCAPSULATION FOR E-MOBILITY

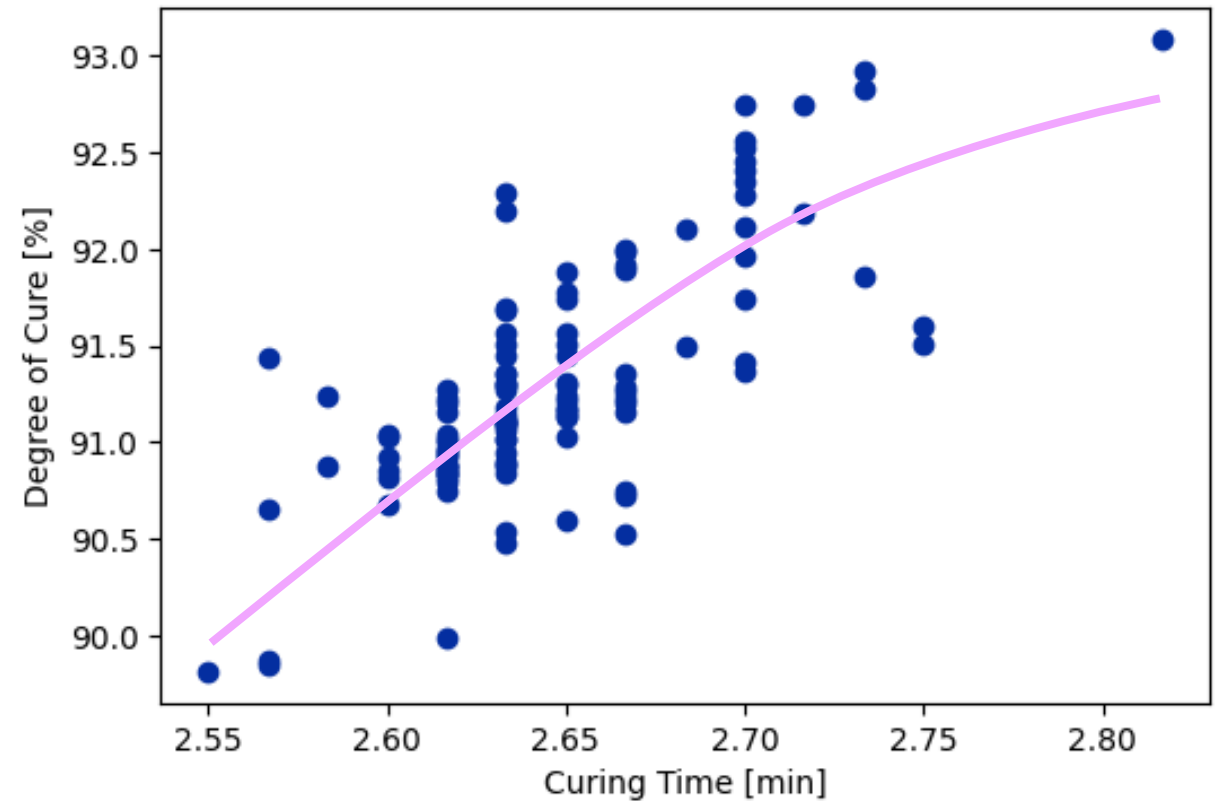


Component: High-power electronics circuit board

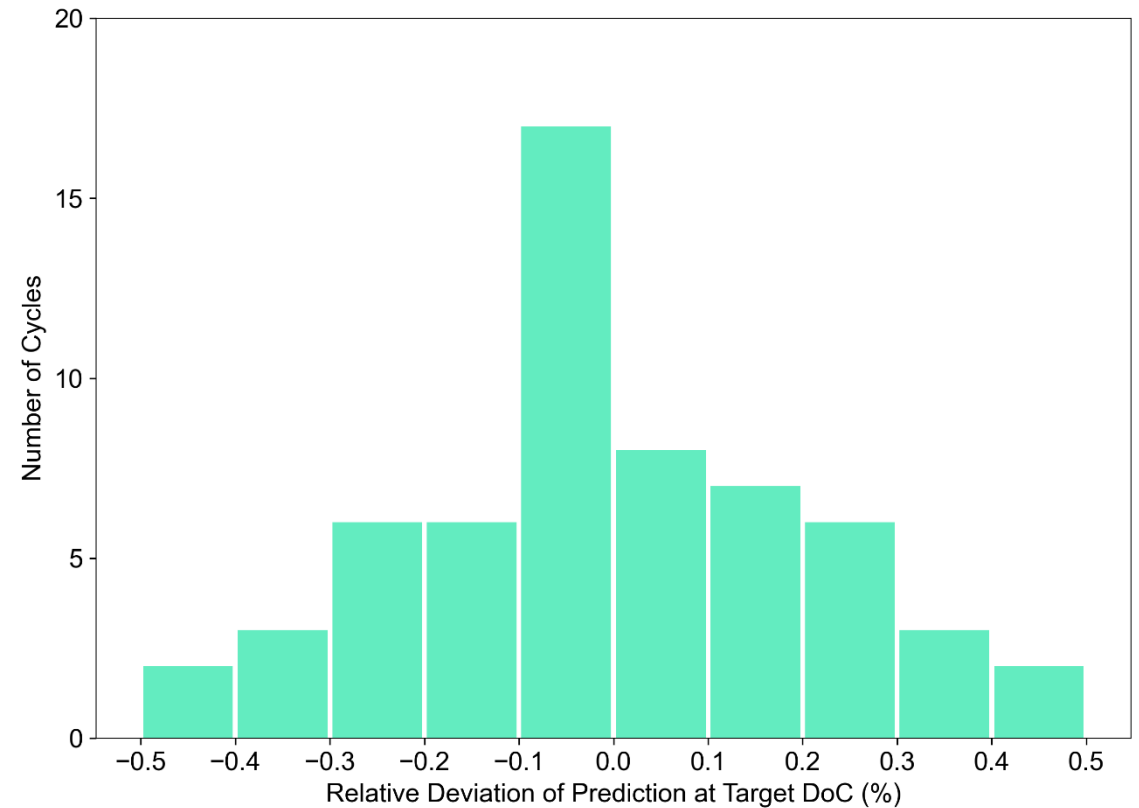
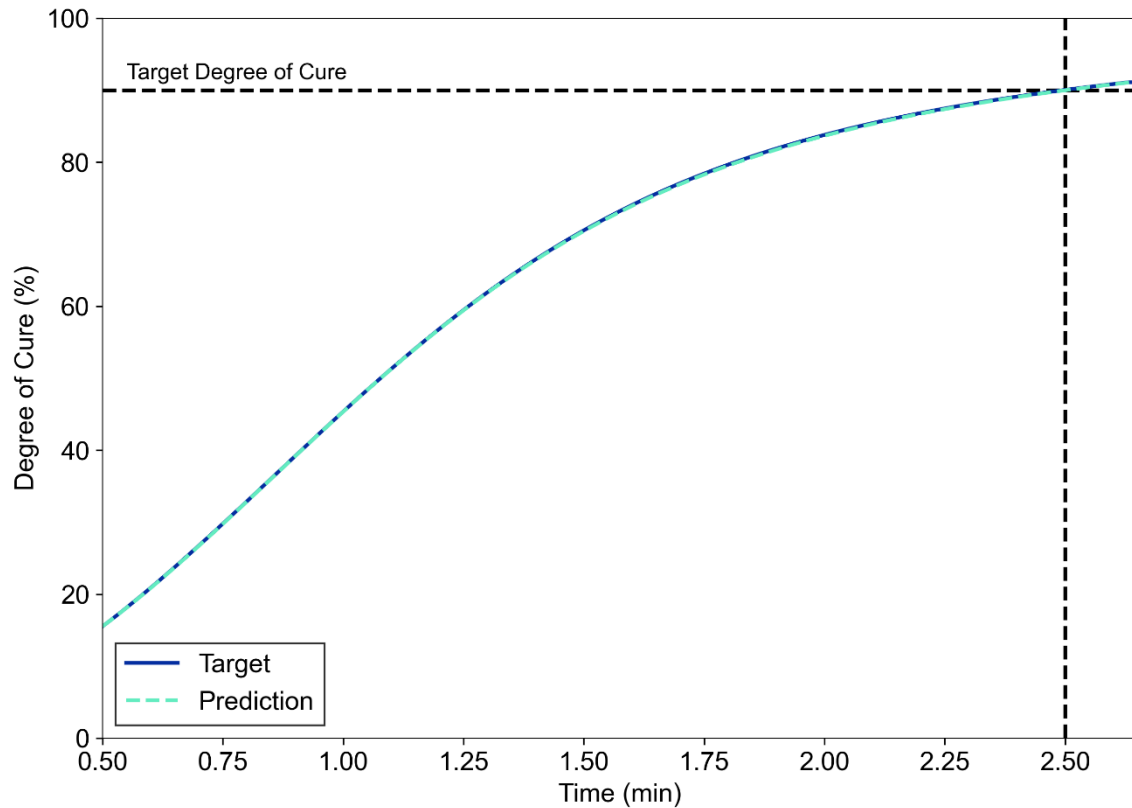
Material: Epoxy molding compound

Quality criterion: Degree of cure > 90%

Target cycle time: 3 minutes



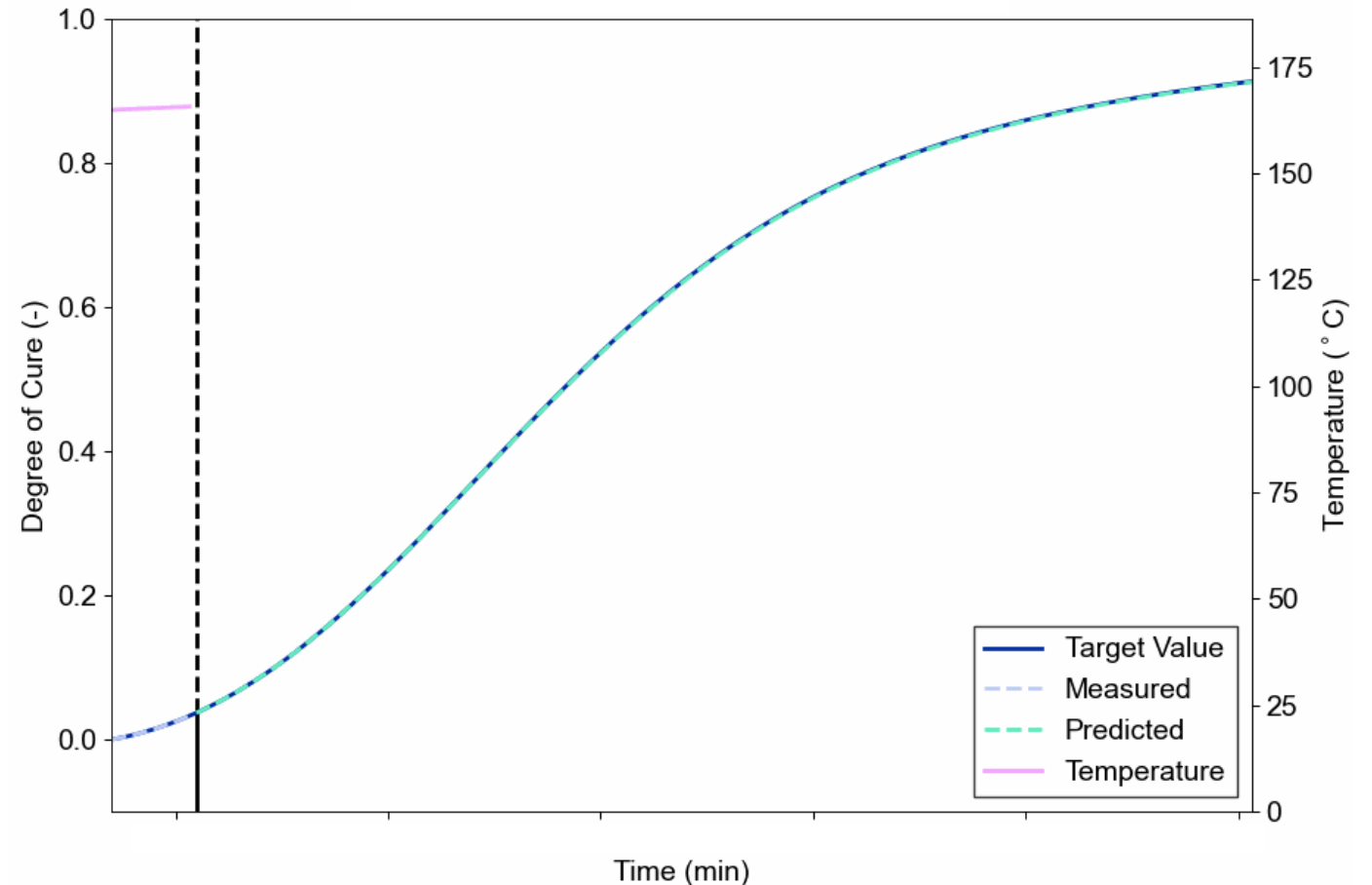
Degree of Cure Predictions After 30 s



Dynamic Process Optimization

- Actively control process to reduce cure deviation by **50%**
- Up to **10%** reduction in cycle time
- Improved automation

Real-Time Process Optimization



CosiMo

Composites for Sustainable Mobility

- Thermoplastic RTM
- Digitized composites processing
- Sensor-based quality control

Use Case

sensXPERT Use Case:

T-RTM FOR AUTOMOTIVE COMPOSITE BATTERY ENCLOSURE

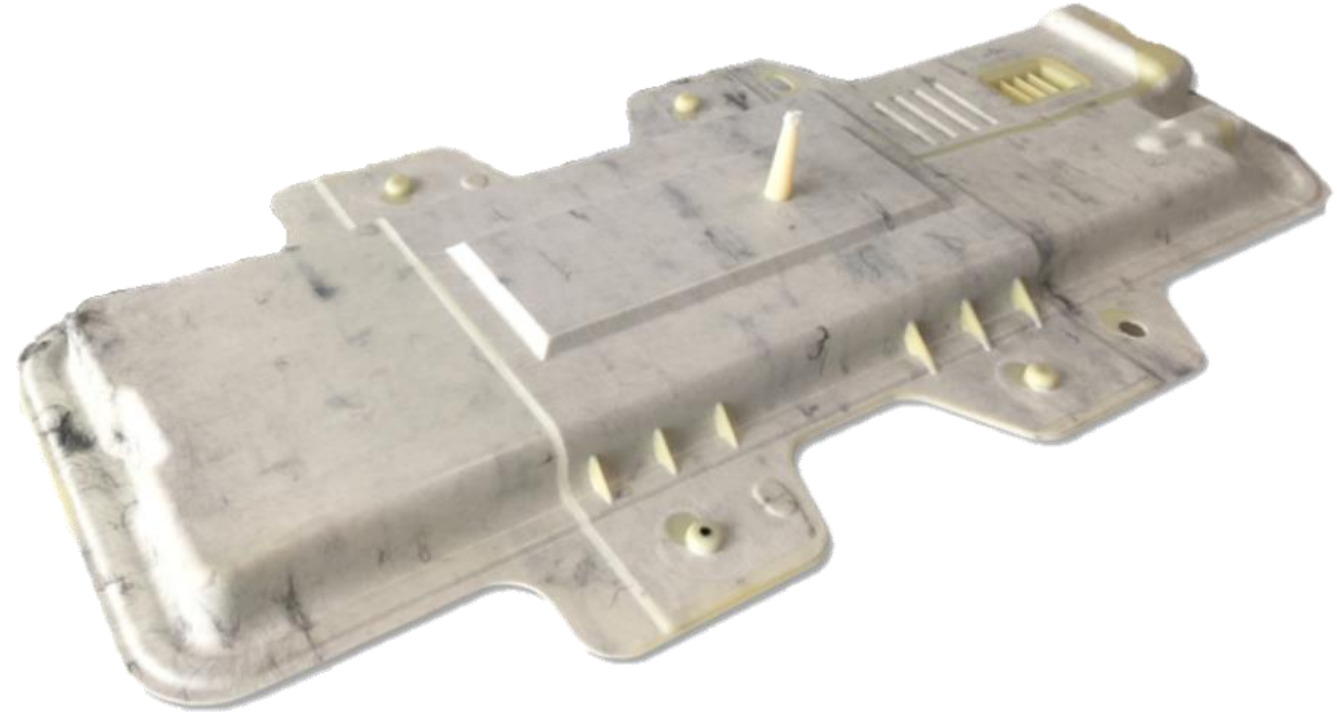


Component: Automotive composite battery enclosure

Material: Polyamide 6, glass fiber, carbon fiber

Quality criterion: Degree of polymerization > 90%

Target cycle time: 10 minutes



Component: Automotive composite battery enclosure

Material: Polyamide 6, glass fiber, carbon fiber

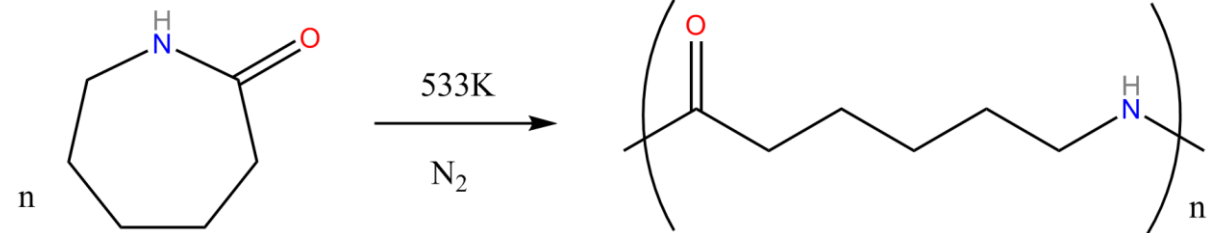
Quality criterion: Degree of polymerization > 90%

Target cycle time: 10 minutes

Thermoplastic Resin Transfer Molding In-Situ Polymerization

ϵ -Caprolactam

Polyamide 6



source: wikipedia.org

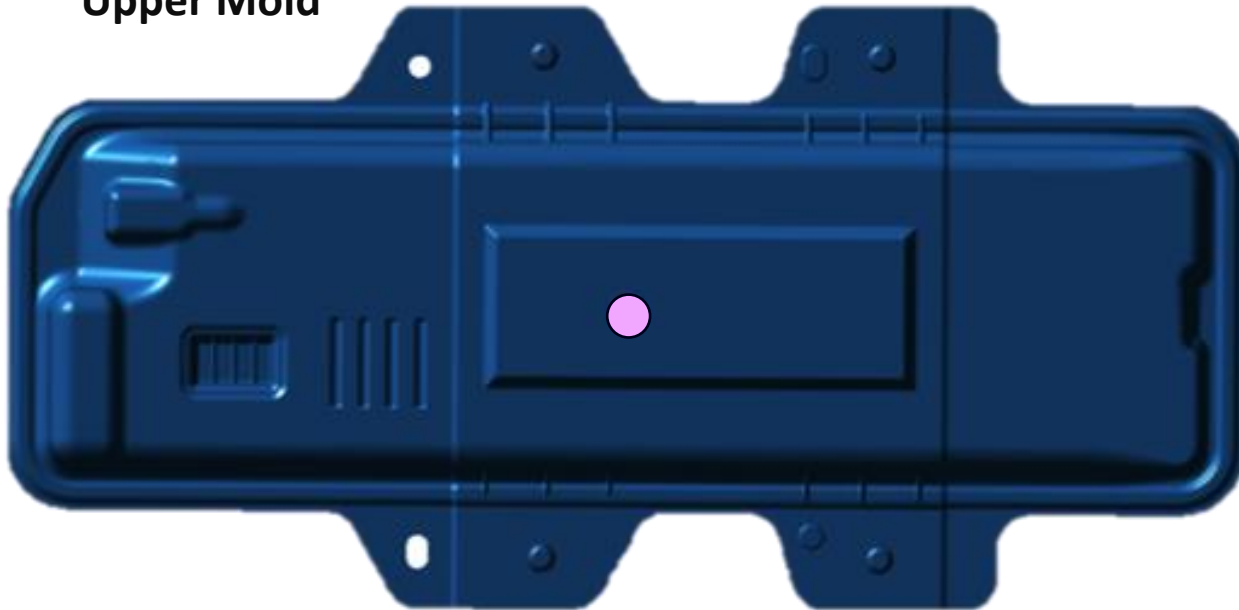
sensXPERT Use Case:

T-RTM FOR AUTOMOTIVE COMPOSITE BATTERY ENCLOSURE

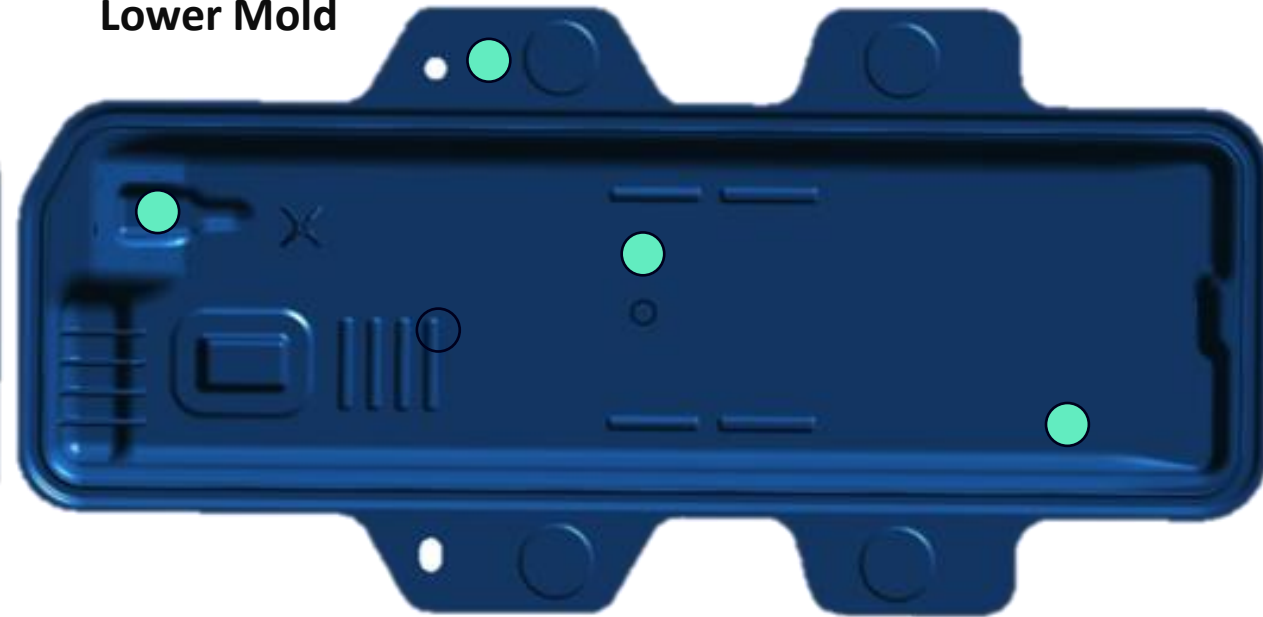


-  sensXPERT DEA Sensor
-  sprue

Upper Mold



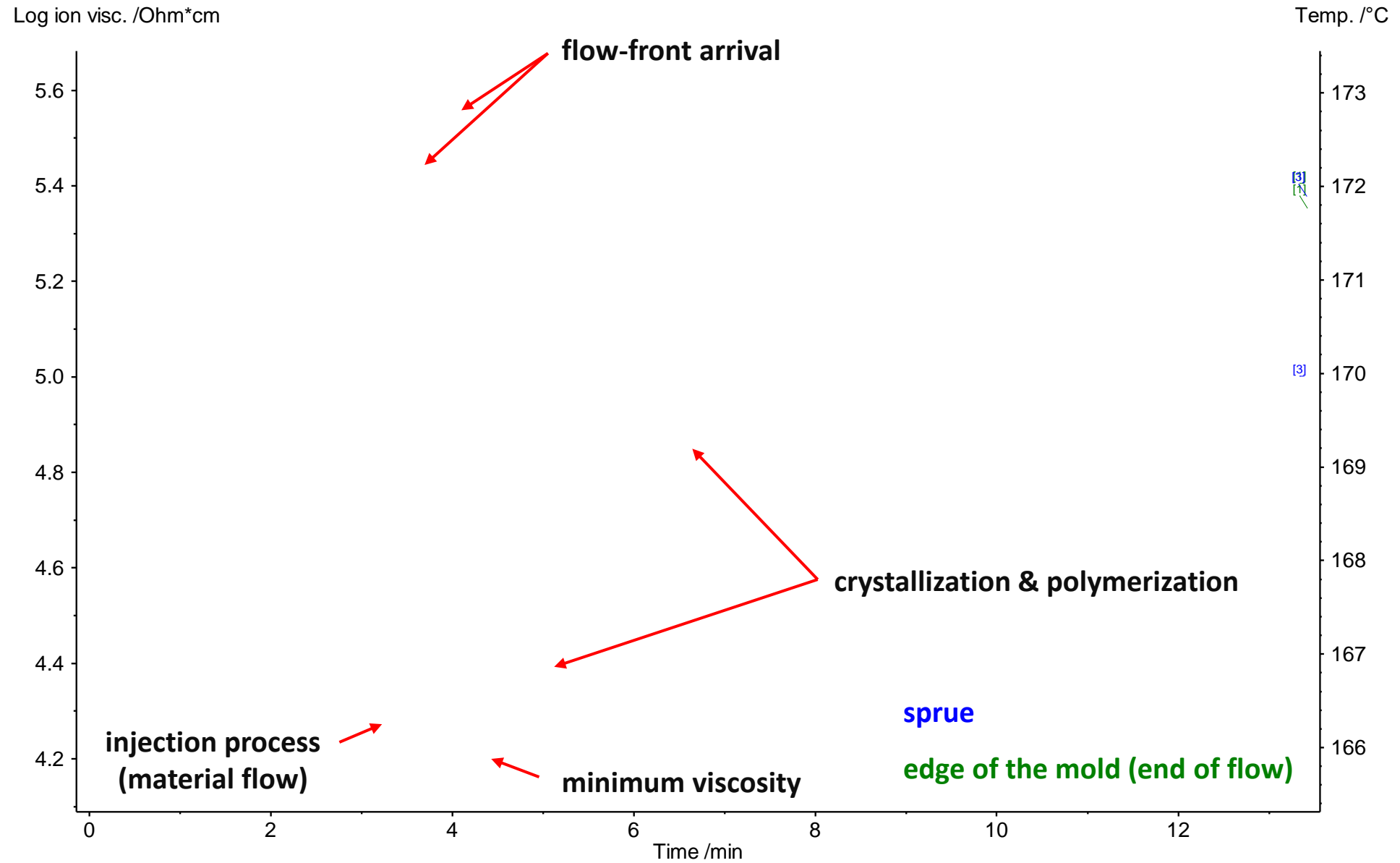
Lower Mold





sens X PERT®

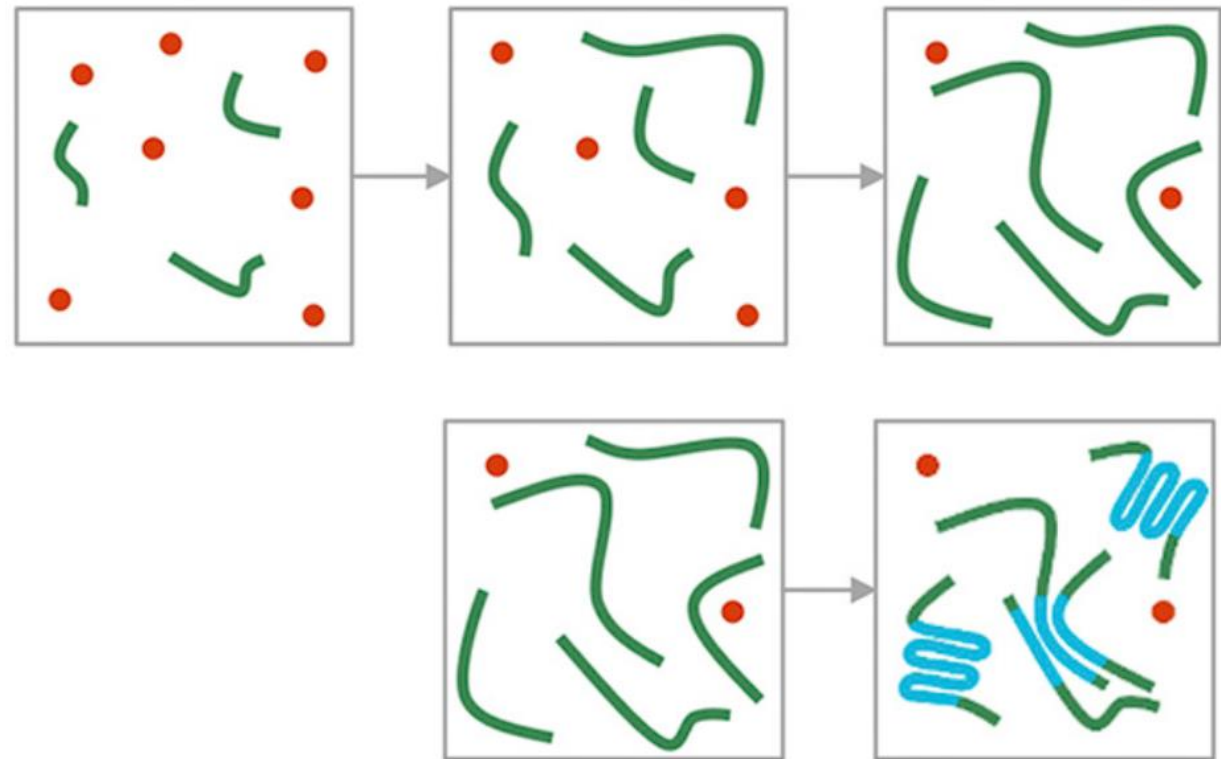
EXPAND your sense of the possible

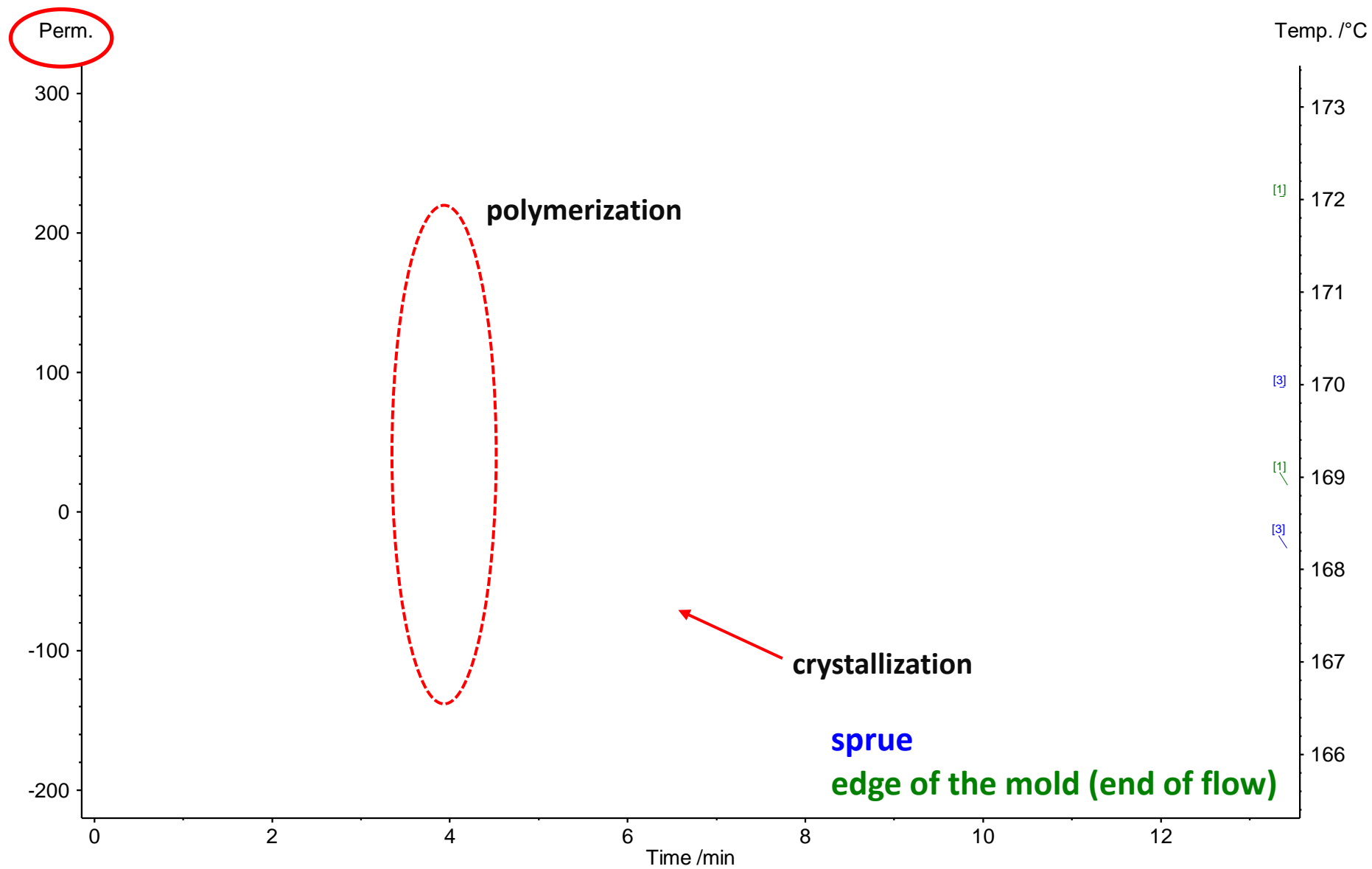


Polymerization & Crystallization

1 **Polymerization**
formation of unoriented polymer chains

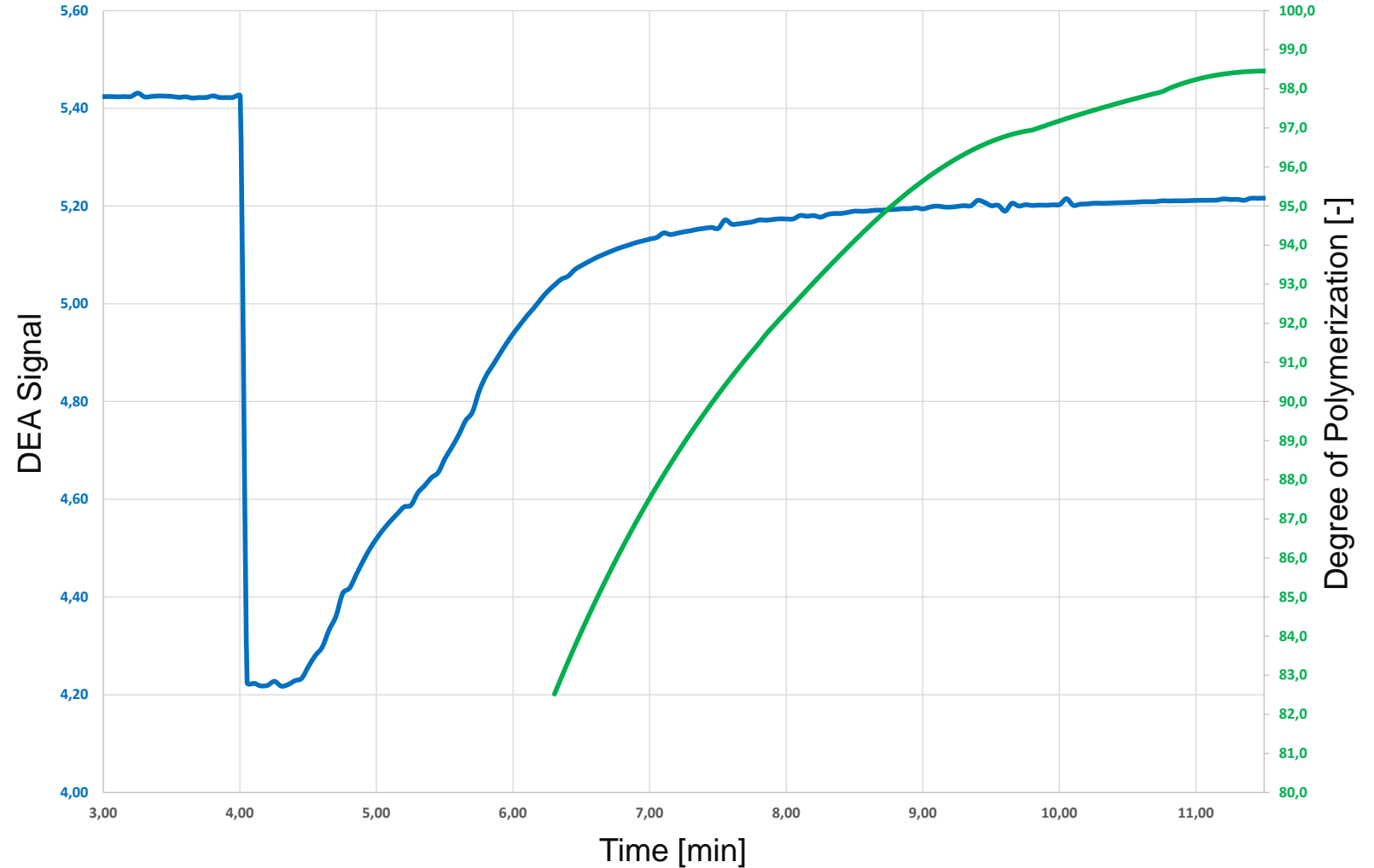
2 **Crystallization**
parallel orientation of lamellae





Real-Time Process Transparency.

- Actively control and measure degree of polymerization
- Eliminate scrap from premature demolding
- Reduce cycle time



RESULTS OF sensXPERT®



Up to

50%

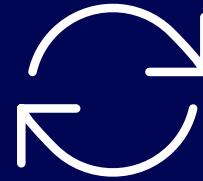
of existing scrap
reduction



Up to

23%

energy savings



Up to

30%

cycle time
reduction



Up to

15 days p.a.

installation
& downtime
reduction

Alec Redmann

m: +1 781 528 5411

e: alec.redmann@netzsch.com

www.sensxpert.com

