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Excimer Laser-Annealing of Amorphous Silicon Layers

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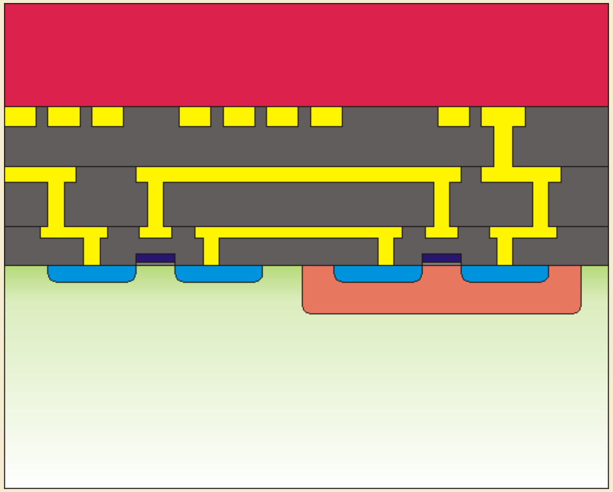
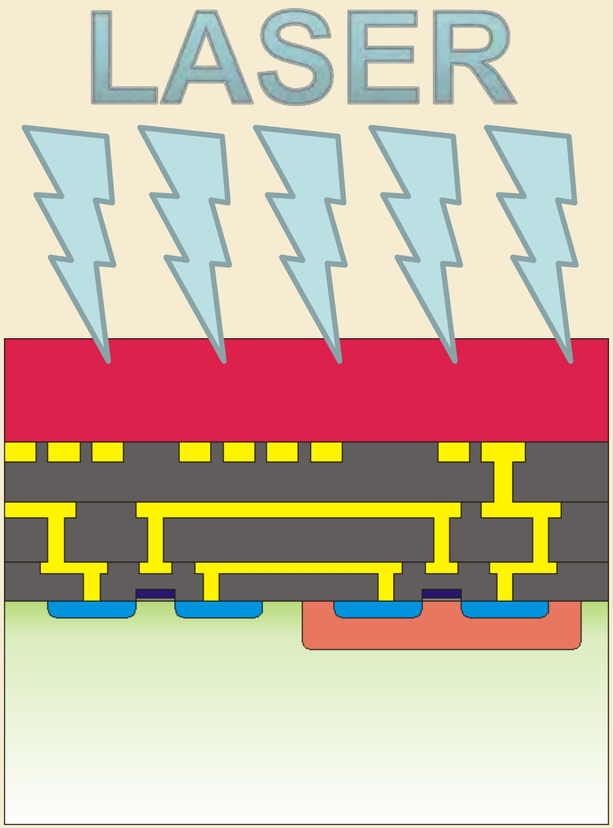
Excerpt from the Proceedings of the 2011 COMSOL Conference in Stuttgart

Motivation



- Modern TFT-Displays and modern MEMS are often based on amorphous silicon
- Almost always temperature-sensitive substrates are used
- Annealing of amorphous semiconductors on temperature-sensitive substrates or CMOS structures is challenging
- Classic annealing techniques (e. g. furnace or IR radiation) require high temperatures
- Substrates or CMOS structures will be damaged
- Need for an annealing technique with very low thermal stress for underlying substrates
- **Known solution: (Excimer-)Laser- Annealing**

Motivation



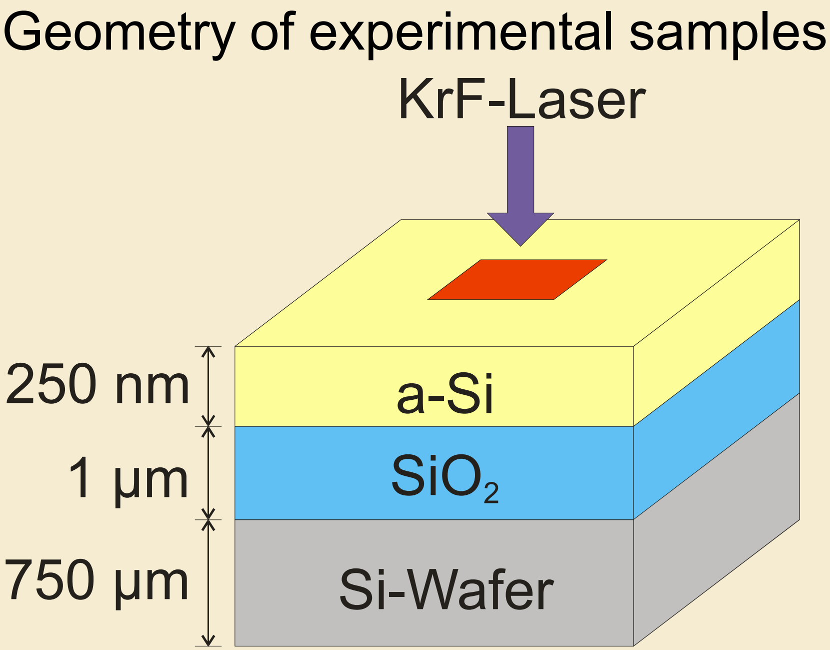
How does Excimer-Laser-Annealing (ELA) work?

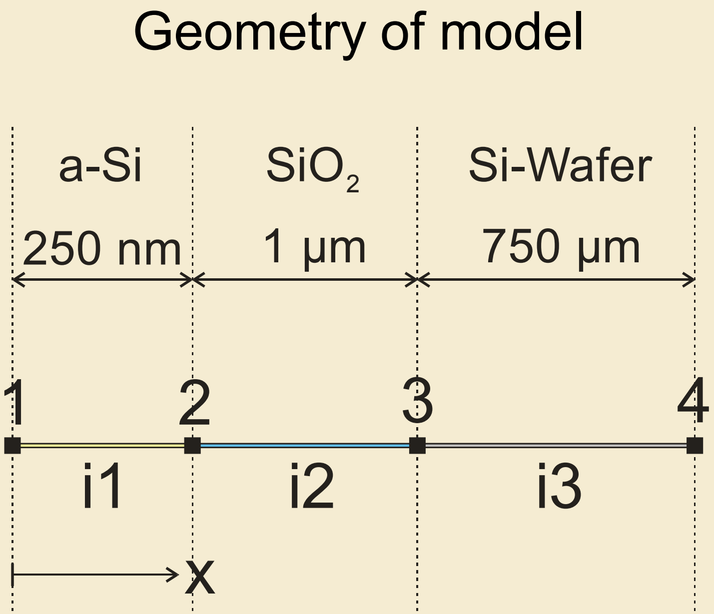
- Samples are irradiated with a laser
- Laser irradiation is absorbed in the samples and transformed into heat
- Short absorption length for UV light allows extreme short and near-surface heating
- Reduced risk of damaging the substrates
- Determination of temperature inside the samples is hardly possible

- **Model of ELA gives detailed information on temperature distribution in the samples**

- **Model prevents from time-consuming and expensive ELA tests**

Model Geometry





- Pulsed KrF-Laser is homogeneous distributed (5 mm x 5 mm)
- Lateral dimensions are greater than vertical ones by orders of magnitude
- **Reduction of ELA to an one-dimensional problem of heat-transfer**

Realisation in COMSOL Multiphysics

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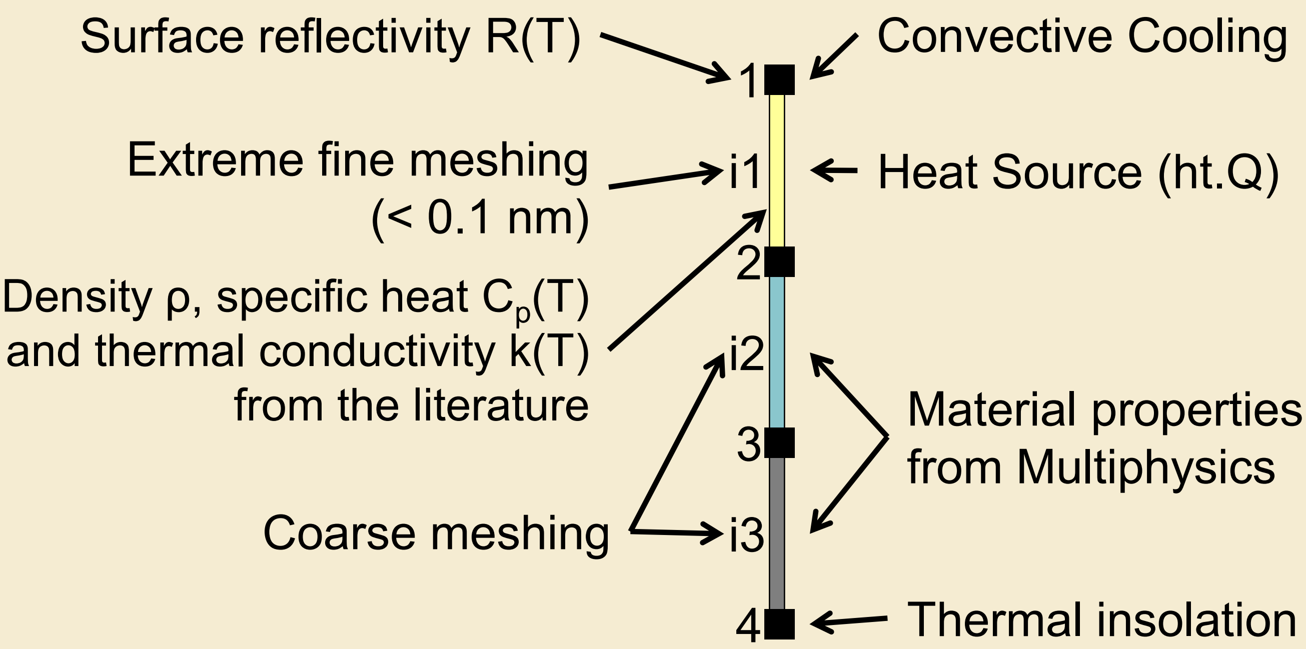
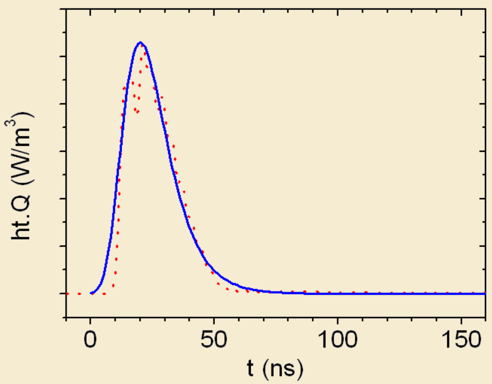
- Physic module used: Heat Transfer in Solids (ht)





- Time-dependent study (time steps t_{step} = 100 ps)
- Modelling phase change by adding latent heat L_m to $C_p(T)$
- **Verification of model by comparing calculated values with experimental ones**

Results of Interest

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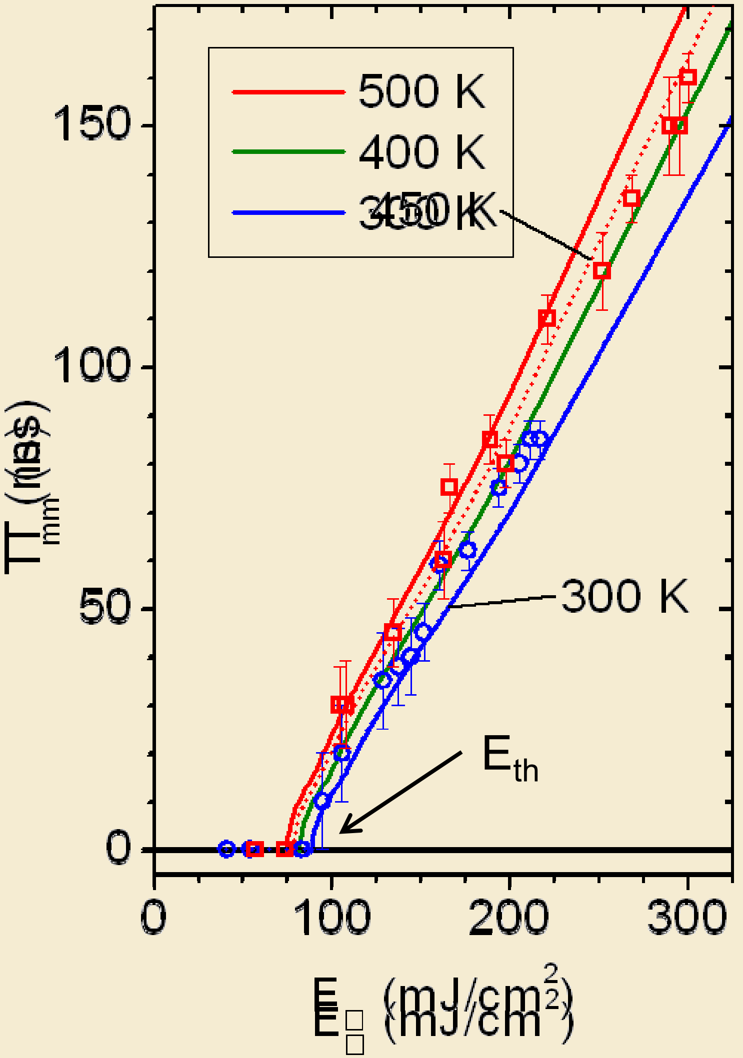
Parameter	Simulation	Experiment	Verification	Theoretical Prediction
melt duration	✓	✓	✓	✓
melt threshold	✓	✓	✓	✓
onset time to melt	✓	✓	✓	✓
melt depth	✓	✓	✓	✓
thermal stress	✓	✗	✗	✓

Melt Duration



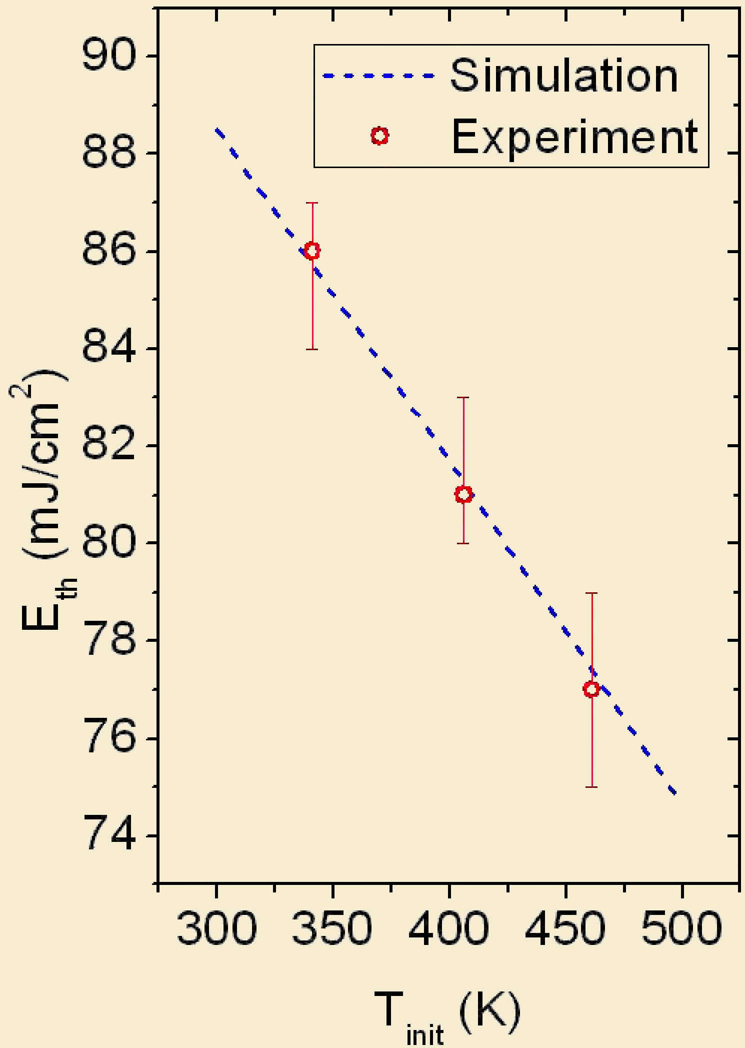
Results:

- Linear increase of T_m with $E_{\square}$
- Obvious melt threshold E_{th}
- **Behaviour as expected!**

Verification:

- Calculated values and experimental ones are in good agreement
- Especially values for E_{th}
- **Calculated values are reliable!**

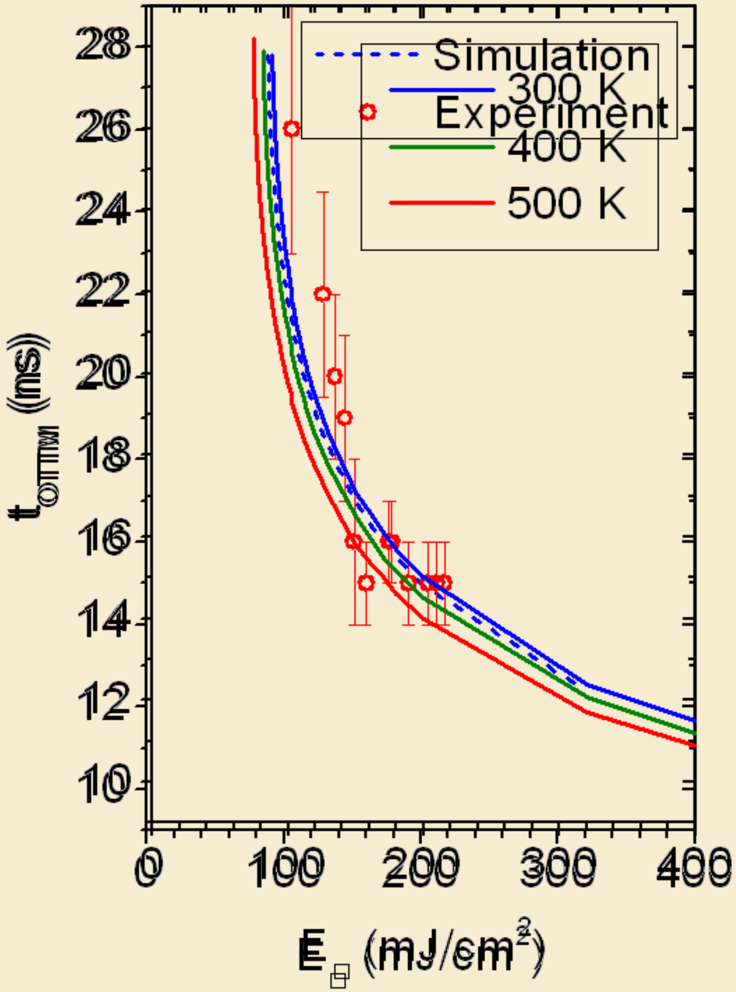
Melt Threshold



Results & Verification:

- As seen before E_{th} is temperature-dependent
- Linear decrease of E_{th} with rising T
- Calculated values and experimental ones are in excellent agreement
- **Behaviour as expected!**
- **Calculated values are reliable!**

Onset Time To Melt



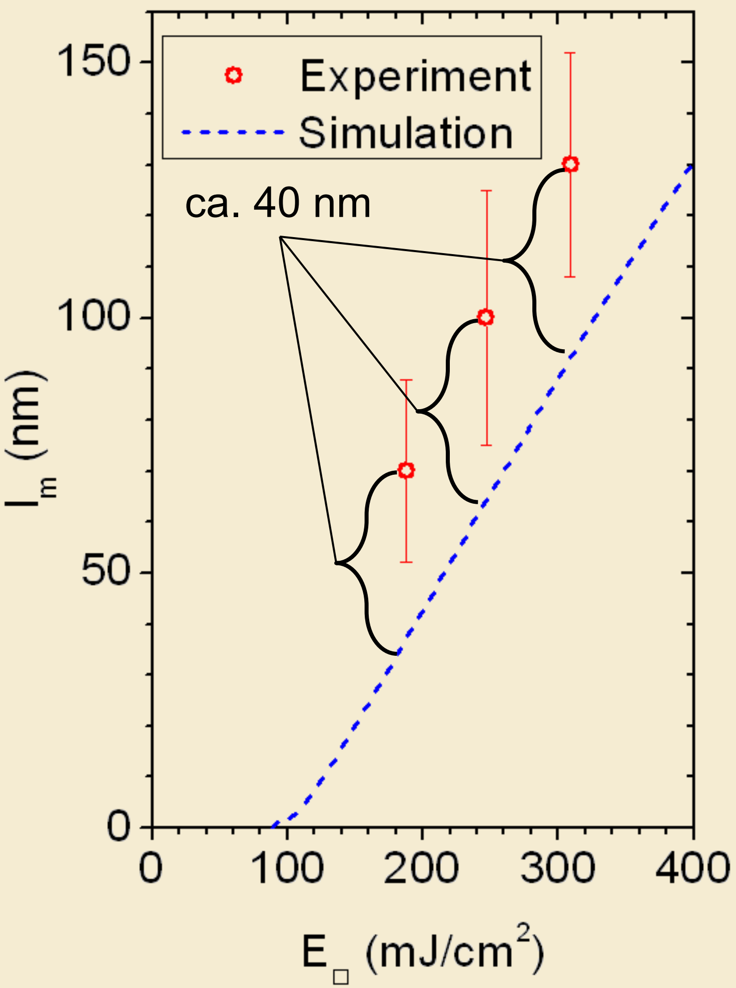
Results:

- Decrease of t_{OTTM} with increasing E□
- t_{OTTM} levels to a value of a few nanosenconds with great values of E□
- **Behaviour as expected!**

Verification:

- Calculated values and experimental ones are in good agreement
- **Calculated values are reliable!**

Melt Depth



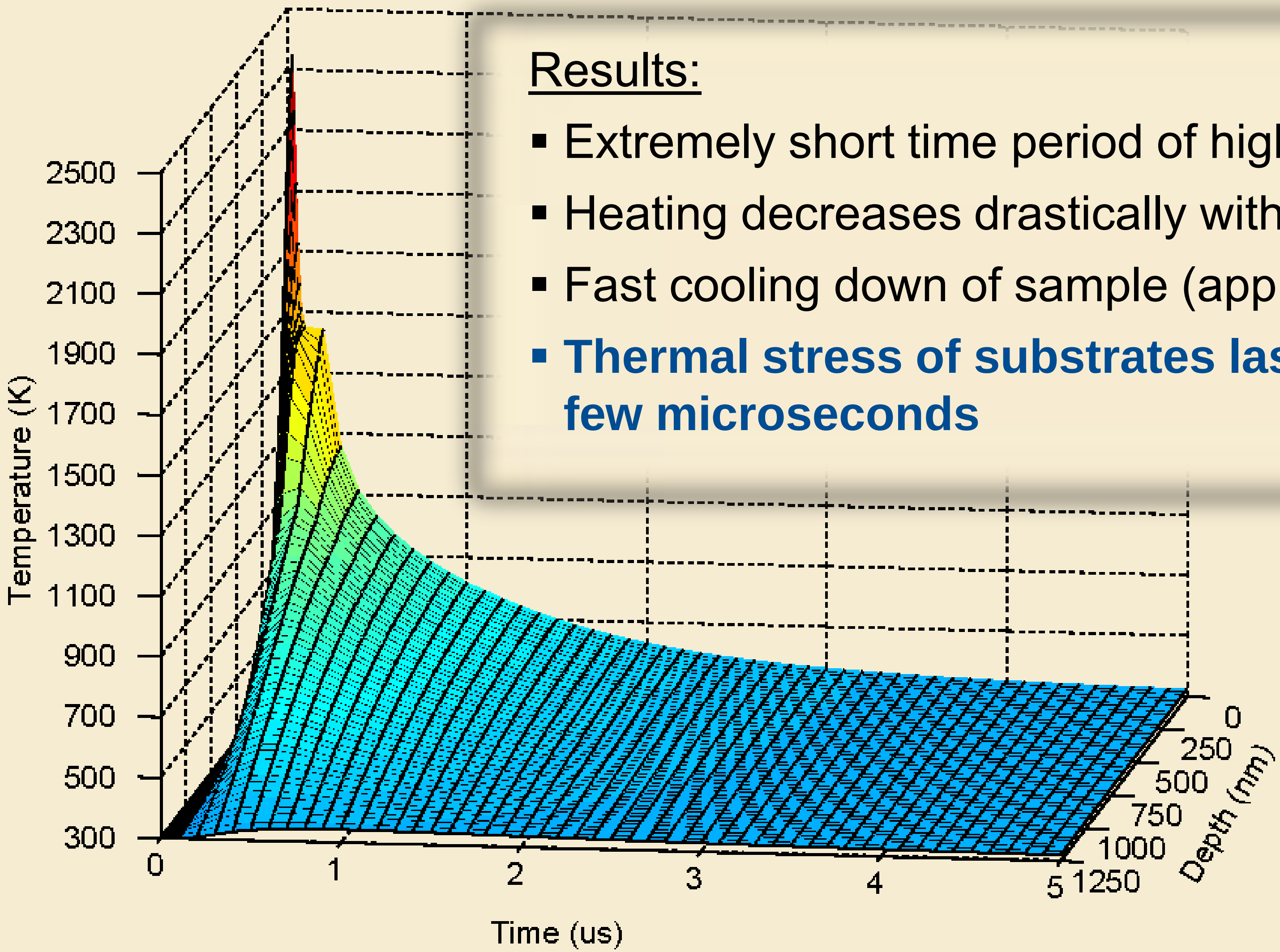
Results:

- Linear increase of l_m with $E_\square$
- **Behaviour as expected!**

Verification:

- Constant offset of 40 nm between calculated values and measured ones
- Offset is most probably due to a systematic error
- Systematic error due to "Explosive Crystallisation" (cannot be included into the model)

Thermal Stress (time-dependent)



Results:

- Extremely short time period of high temperature
- Heating decreases drastically with depth
- Fast cooling down of sample (approx. 3 µs)
- **Thermal stress of substrates lasts only for a few microseconds**

Thermal Stress (energy-dependent)

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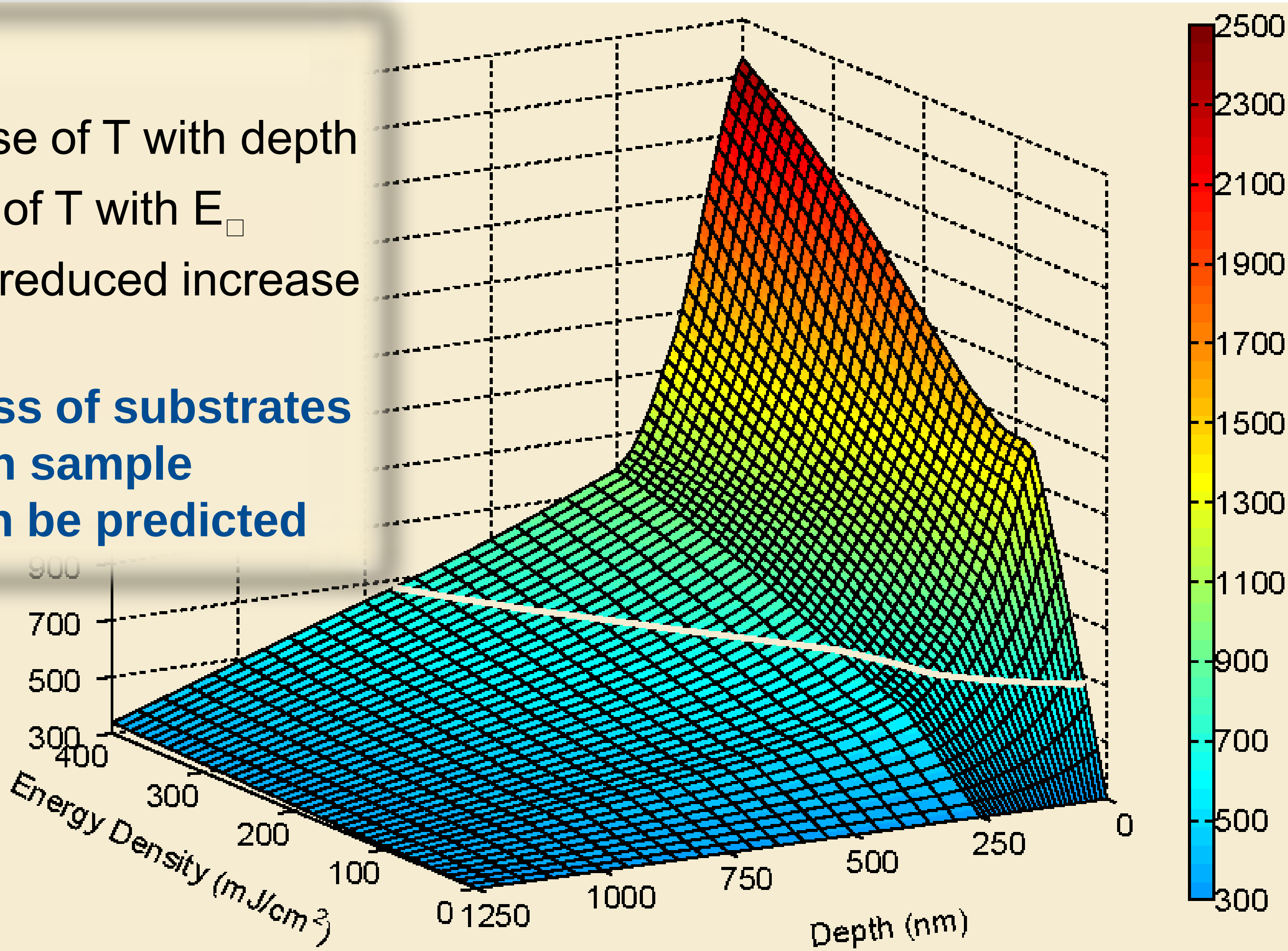
<u>Results:</u>

- Rapid decrease of T with depth
- Fast increase of T with $E_{\square}$
- Upon melting reduced increase of T with $E_{\square}$
- **Thermal stress of substrates dependent on sample geometry can be predicted**



Conclusion

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- Design of an one-dimensional model of ELA of a-Si layers in COMSOL Multiphysics
- Implementation of temperature-dependent values for specific heat $C_p(T)$, thermal conductivity k(T), surface reflectivity R(T) of a-Si
- Implementation of phase change by introducing latent heat L_m of a-Si
- **Model successfully validated by comparison of calculated values with experimental ones**
- **Model gives valuable insights on sample temperature and reliable predictions on thermal stress of substrates**
- **Therefore, model prevents from time-consuming and very expensive ELA test**
- **Model reduces time to first successfully produced prototype**

Thank you for your attention!

Interested?
Please visit me at my poster (No. 25) for more details!