Temperature dependence of Soft/Hard PZT material properties and impact on the design choice

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Agenda

- AeroPZT project
- Large signal characterisation – approach
- Large signal characterisation - selected results
  - capacitance
  - losses
  - free displacement
- Material selection
- Conclusions

AeroPZT project

- "Development of materials and processes for the application of Piezoelectric materials in aero engine controls"
- EU FP7, Clean Sky Joint Technology Initiative
- Target
  - Aerospace industry
  - Fluid flow control applications
- Objectives
  - Develop more capable piezoelectric ceramics, protective encapsulation systems and actuator designs
  - Reduce NOx emissions
- Other potential applications
  - Sensor devices.

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AeroPZT project

- Partners

Actuator design, Encapsulation design

CEDRAT TECHNOLOGIES
Innovation in Mechatronics

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Piezoelectric element

AEROPZT

Coordinator, Testing, Encapsulation design

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MUL2
Multilayered Structures
Multifield Analyses

FE modelling

Large signal PZT material characterisation - approach

PZT material characterisation

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- Designer's wishes
  - Free stroke, blocking force, capacitance, losses vs. Temperature
  - Coefficient of Thermal Expansion (CTE)
  - Possibility of bipolar operation
- Large signal data
- Comparison of materials
  - Soft-doped: NCE51
  - Hard-doped: NCE46

PZT material characterisation

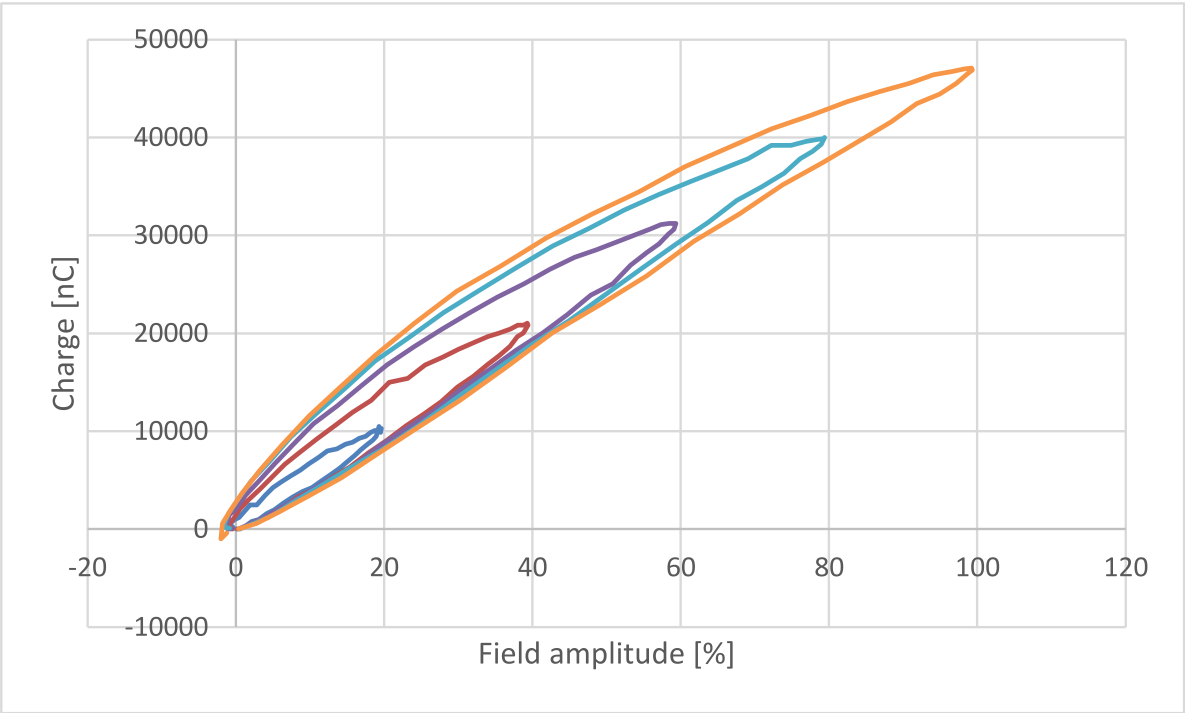
- Challenges
  - Often incomplete data available
  - Small displacements, high stiffness
  - Different boundary conditions (free, blocked)
  - Specific equipment, sub-contracting
  - Speed limitations
  - Drift
- Selected approach : 4-steps test plan
  - Coercive field
  - Capacitance and losses
  - CTE, stroke and creep
  - Stiffness

Test plan

- Coercive field
  - Hysteresis (Q-E) curves on unpoled samples in AC
- Capacitance and losses
  - Hysteresis (Q-E) curves on poled samples at 1kHz
- CTE, stroke and creep
  - Displacement curves, 2min activation per temperature step
- Stiffness
  - Small signal, resonance frequency identification

Capacitance and losses

- Example NCE51, 25°C



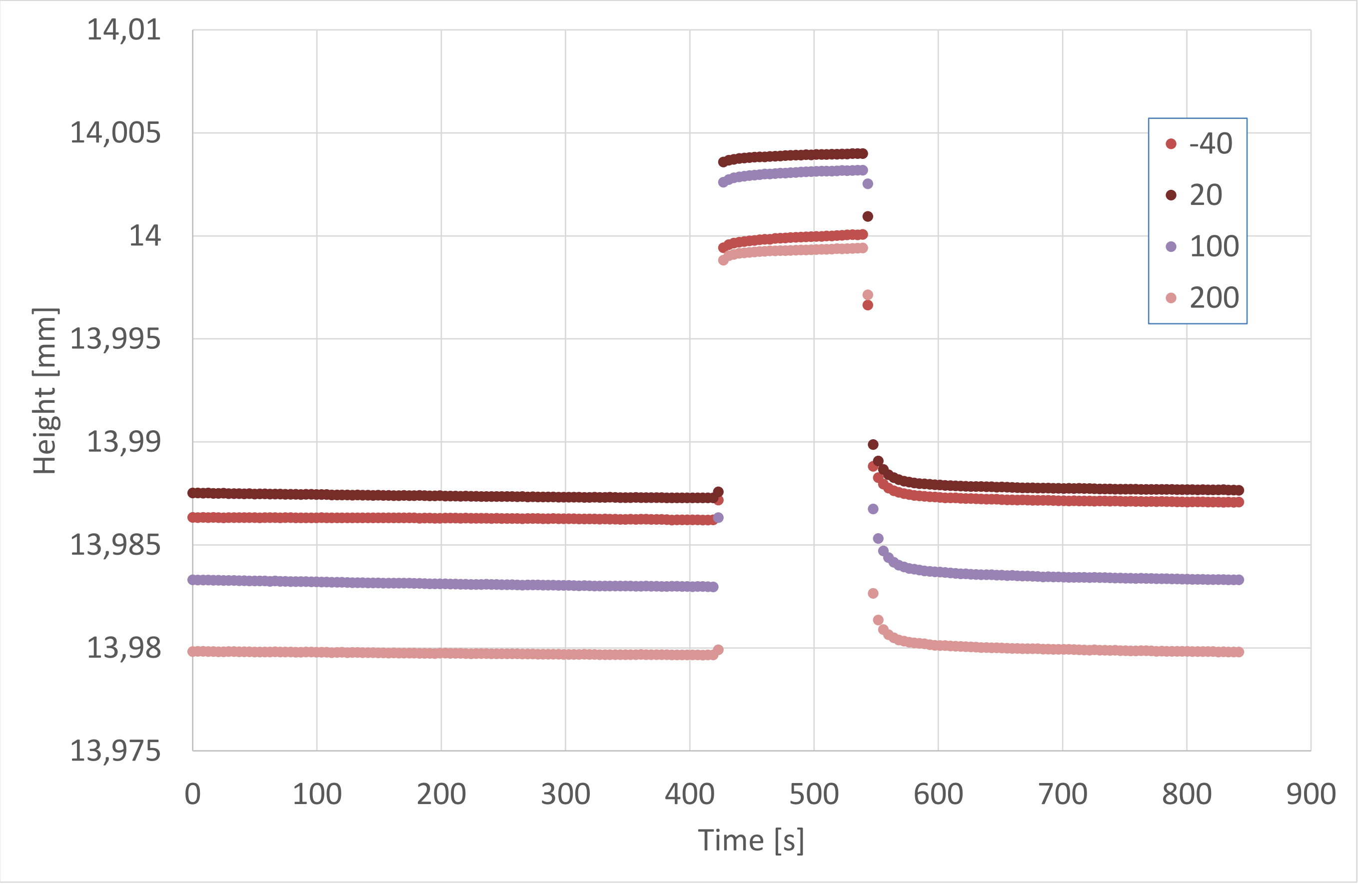
1kHz

$$i_{RMS} = \frac{1}{\sqrt{2}}.\pi.f.C^*.U_{pp}$$

$$P_{loss} = \frac{\pi}{4}.f.C^*.\tan\delta^*.U_{pp}^2$$

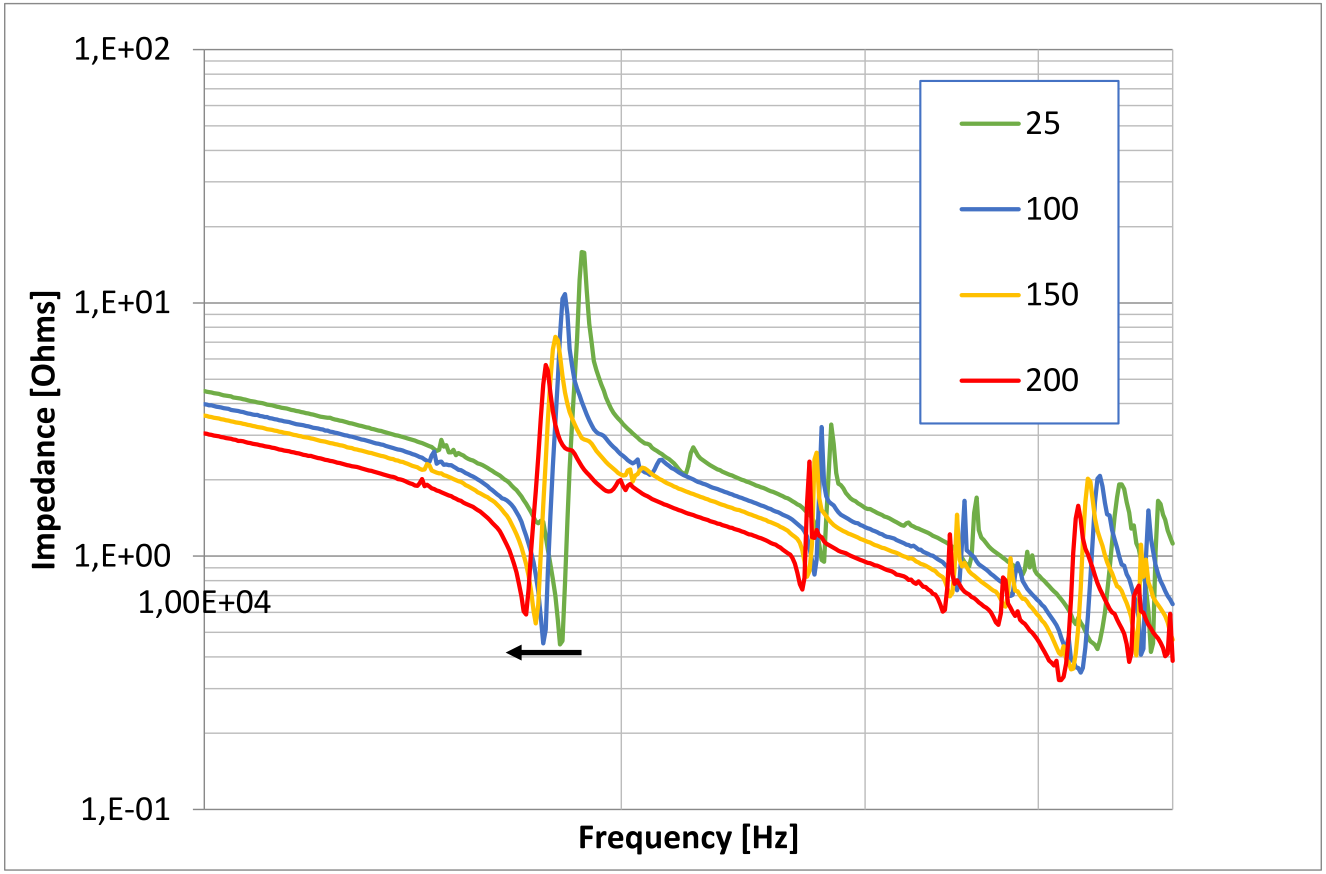
CTE, stroke and creep

- Example NCE51, selected temperatures



Stiffness

- Example NCE51, selected temperatures

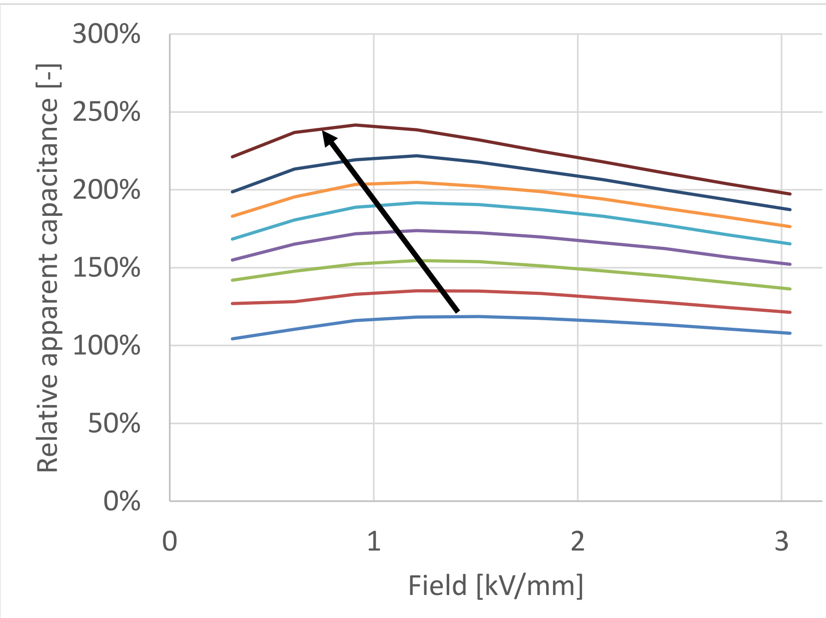


Selected results

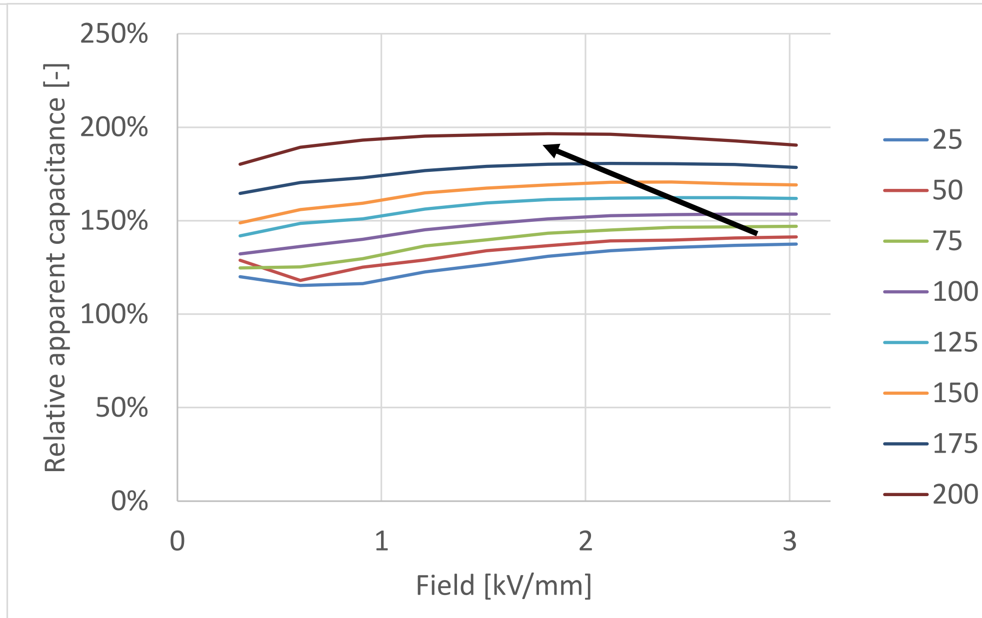
Evolution of apparent capacitance with temperature

- Increase for both materials
- NCE51: more field-dependent

NCE51

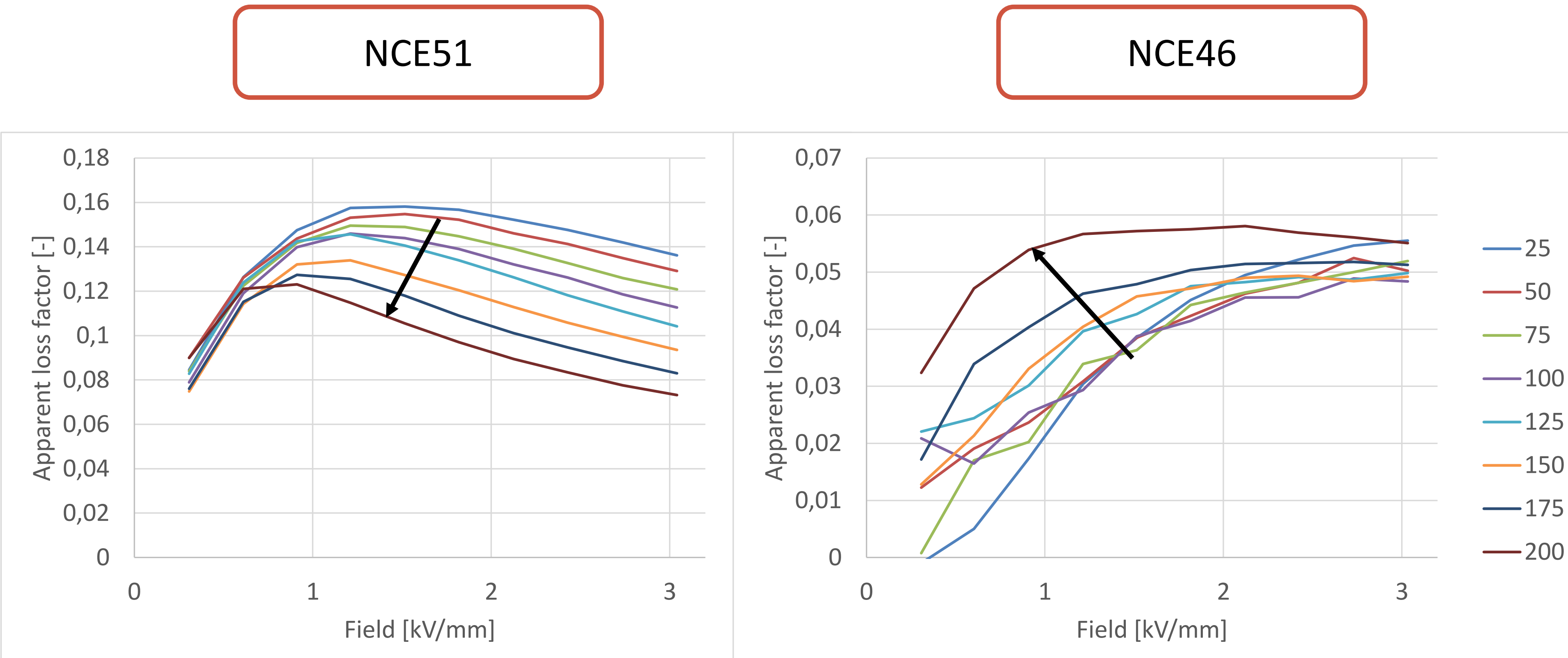


NCE46



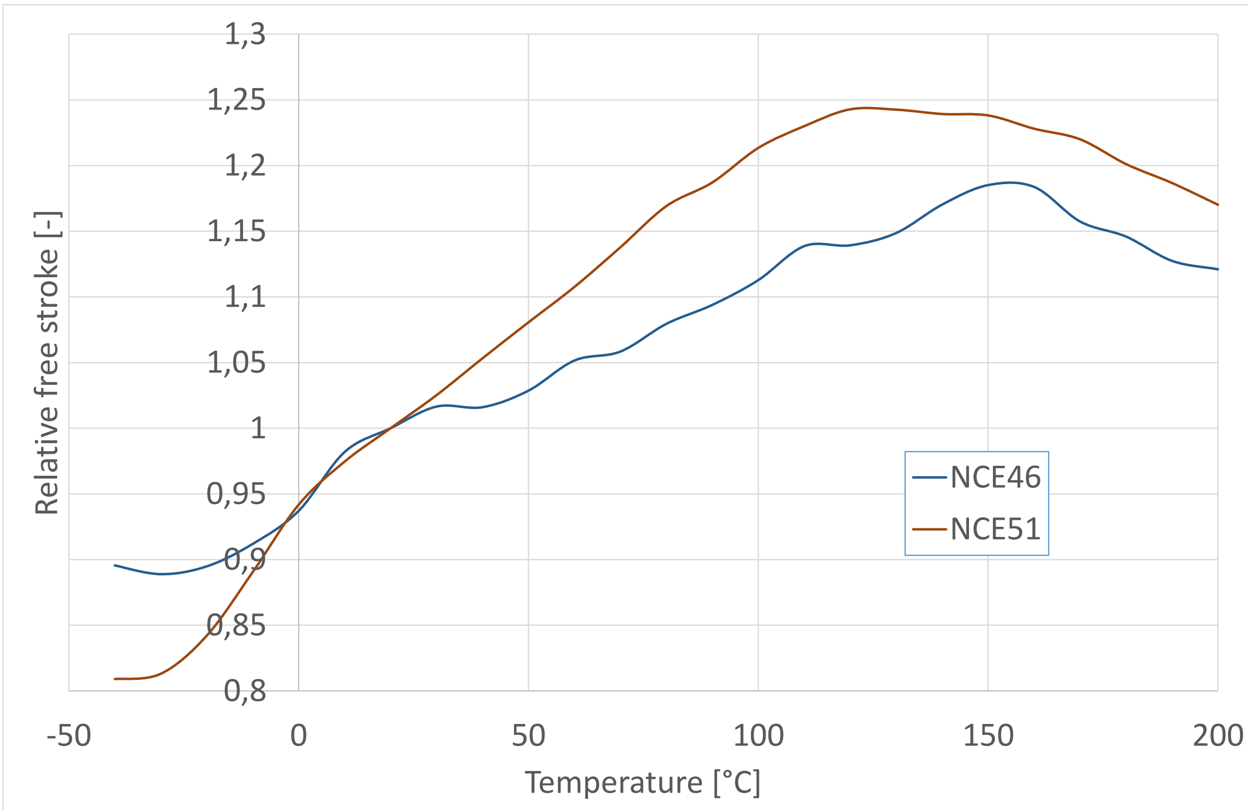
Evolution of loss factor with temperature

- NCE51: decreasing with temperature
- NCE46: increasing with temperature



Evolution of free stroke with temperature

- Maximum at 120-150°C
- NCE46 more stable



Evolution of stiffness with temperature

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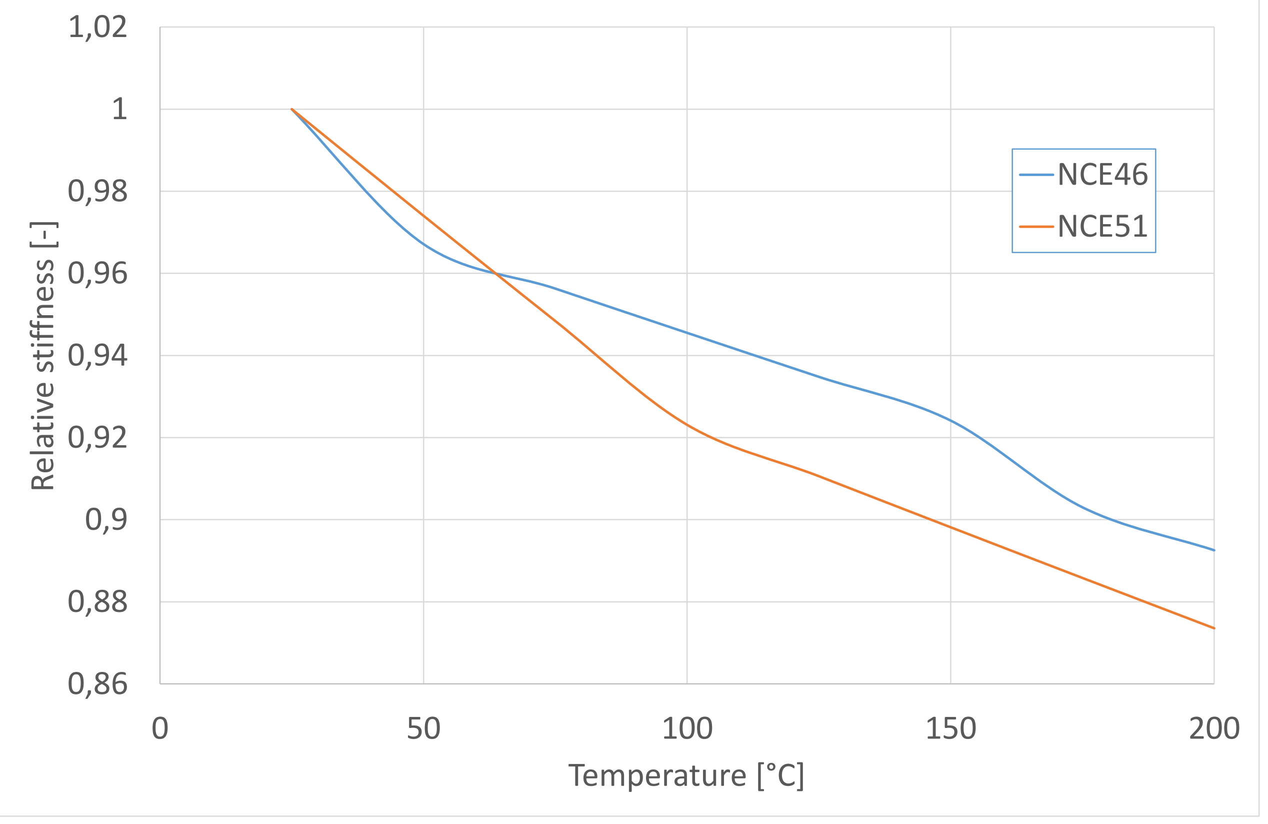
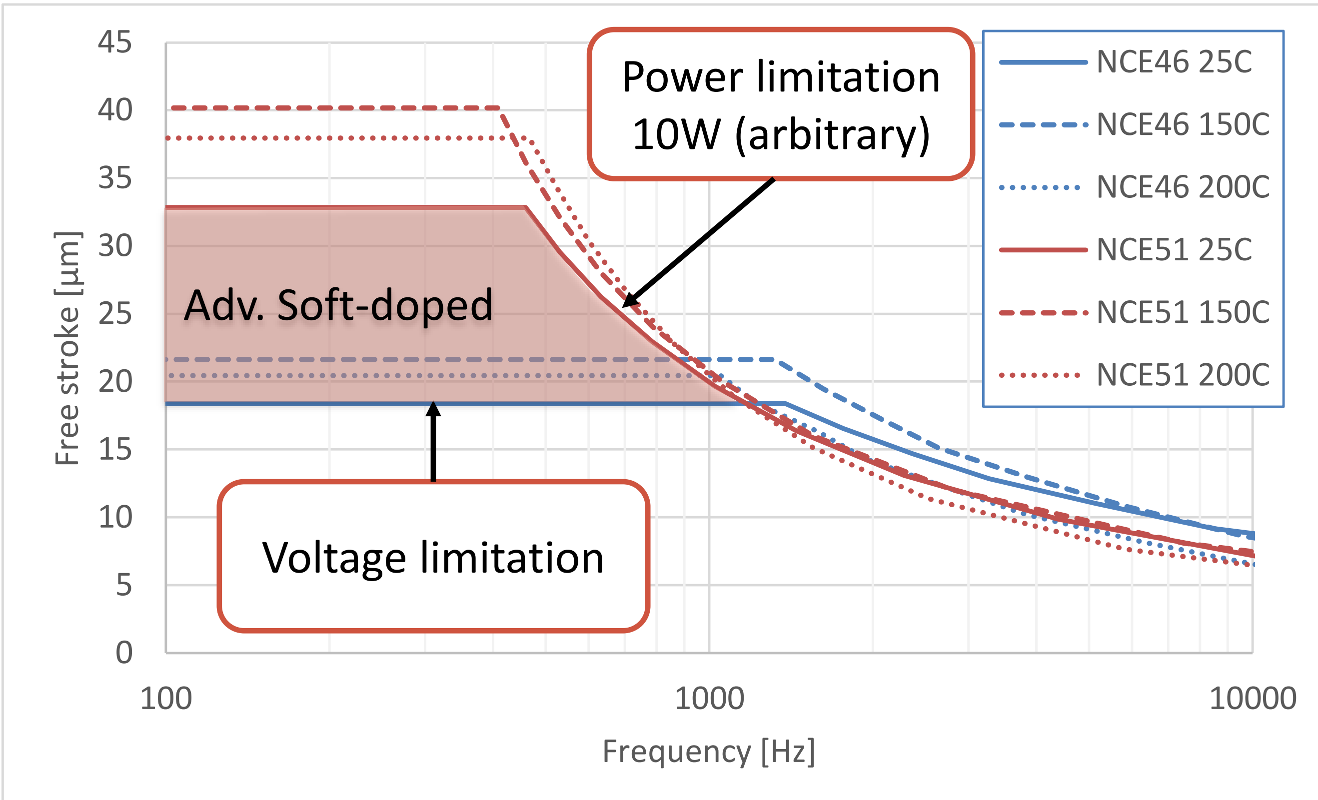
- Both decreasing with temperature
- NCE46 more stable



Material comparison and selection

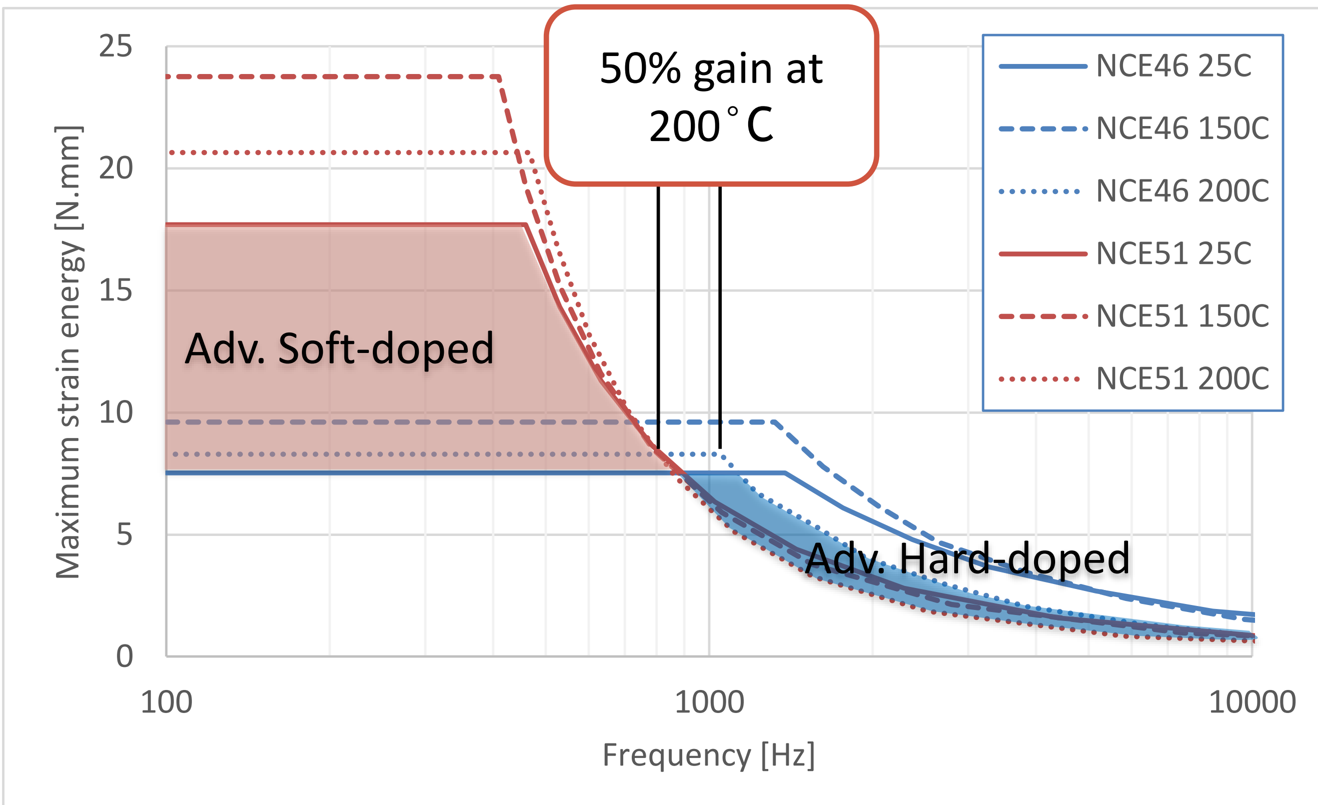
Material comparison

- Actuators of similar dimensions (10x10x20mm)
- For stroke-driven applications:



Material comparison

- For energy-driven applications:



Conclusions

Conclusions

- Set of parameters available vs. temperature
  - Capacitance, losses @ high field
  - Stiffness @ low field (blocking force)
  - Free displacement
- Two materials
  - Soft-doped: NCE51
  - Hard-doped: NCE46
- Material choice
  - Marginal advantage of hard-doped for high frequency
    - For stroke up to 150°C
    - For energy up to 200°C
  - Advantage of soft-doped for low frequency

Thank you for your attention

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