Ferroelastic creep of $LaCoO_3$ based perovskites under compression

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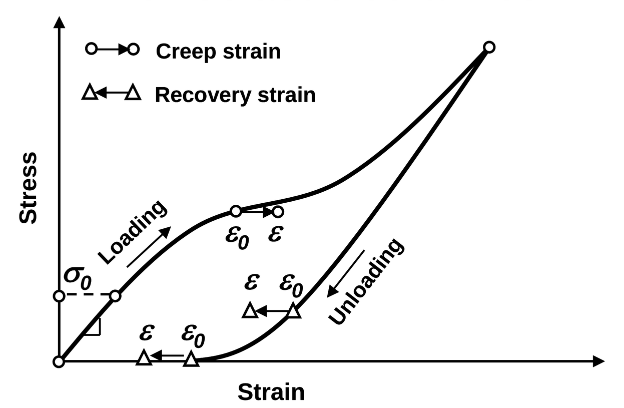
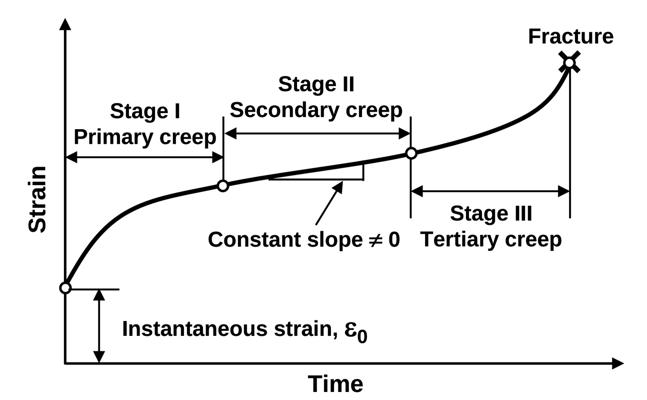
Ferroelastic creep and recovery of perovskites

This study focuses on the experimental investigation of room temperature creep at different stresses in polycrystalline $LaCoO_3$ based ceramics under compression. A new phenomenological approach of ferroelastic creep is developed to identify the most important parameters which affect creep strain over different time periods.

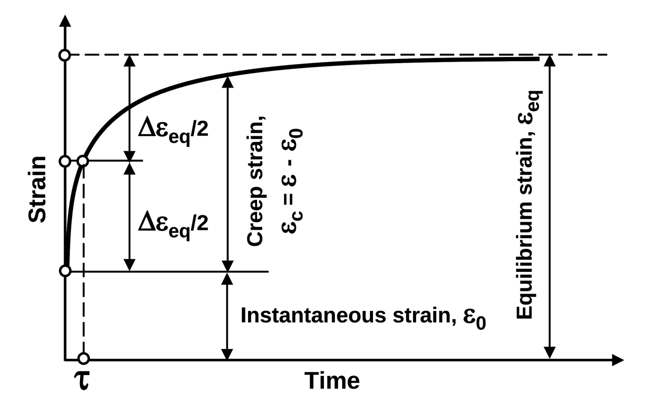
Stress – strain diagram of ferroelastic ceramics



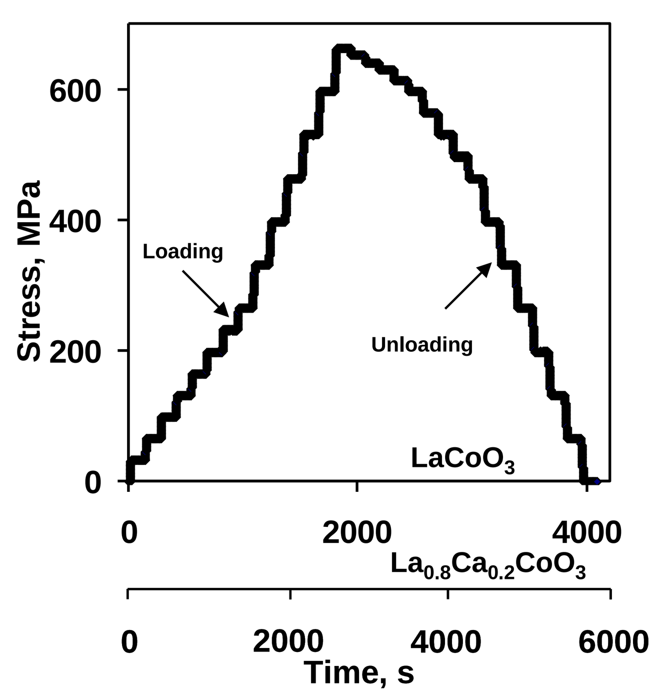
Creep in metals



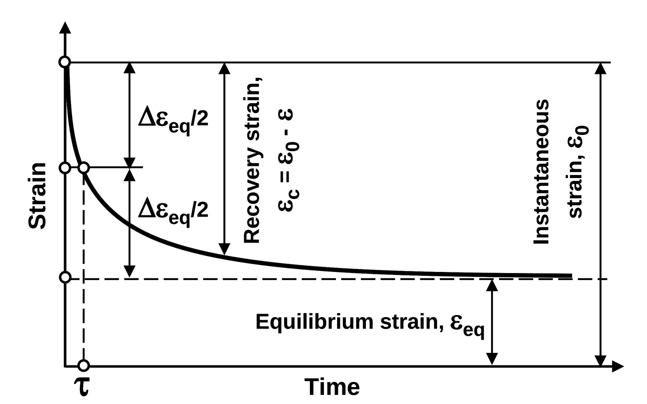
Creep in ferroelastic ceramics



Load-time dependence during uniaxial compression tests

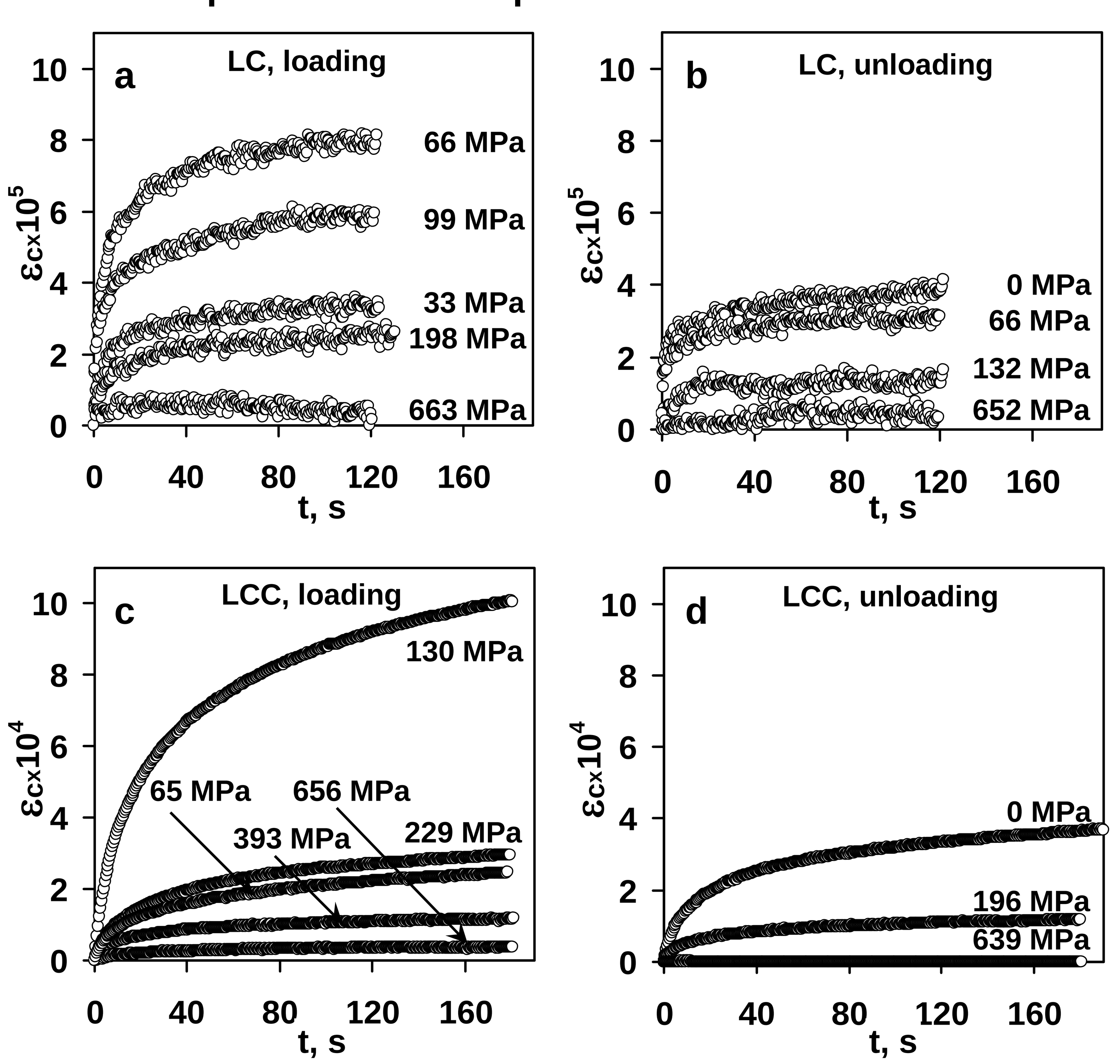


Recovery strain in ferroelastic ceramics



Two compositions $LaCoO_3$ (LC) and $La_{0.8}Ca_{0.2}CoO_3$ (LCC) were investigated

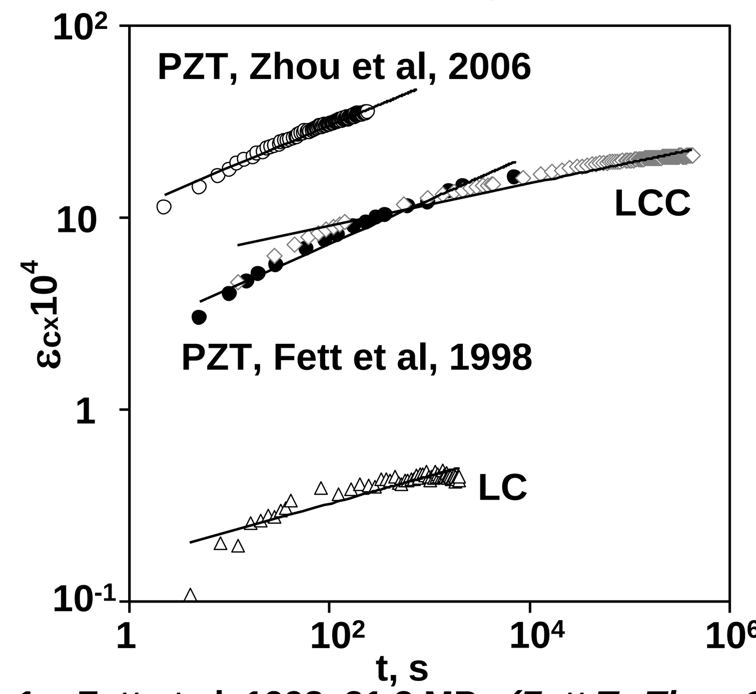
Creep strain – time dependence at constant stress



Model

Creep strain versus time data presented in the logarithmic scale show the deviation from conventional power law as time of the tests increased. While power law demonstrates infinite increase in creep strain with time at constant stress, the experimentally measured creep strain approaches the constant value equal to equilibrium strain increment at a given stress. Therefore, the power law can not be used to describe the room temperature ferroelastic creep and new expression has to be developed.

Creep strain – time dependence at constant stress in logarithmic scale



1 – Fett et al. 1998, 21.3 MPa *(Fett T., Thun G., J Mat Sci Lett 17 (1998) 1929)*; 2 – Zhou et al. 2006, 50 MPa *(Zhou D., Kamlah M., Acta Mat 54 (2006) 1389)*; 3 – LC, 33 MPa; 4 – LCC, 98 MPa. Solid lines correspond to the best fit by power law.

New phenomenological approach to creep strain – time dependence at constant stress

$$\varepsilon_c = \Delta\varepsilon_{eq}\frac{\sqrt{t/\tau}}{1+\sqrt{t/\tau}}$$

$$\Delta\varepsilon_{eq} = \varepsilon_{eq} - \varepsilon_0$$

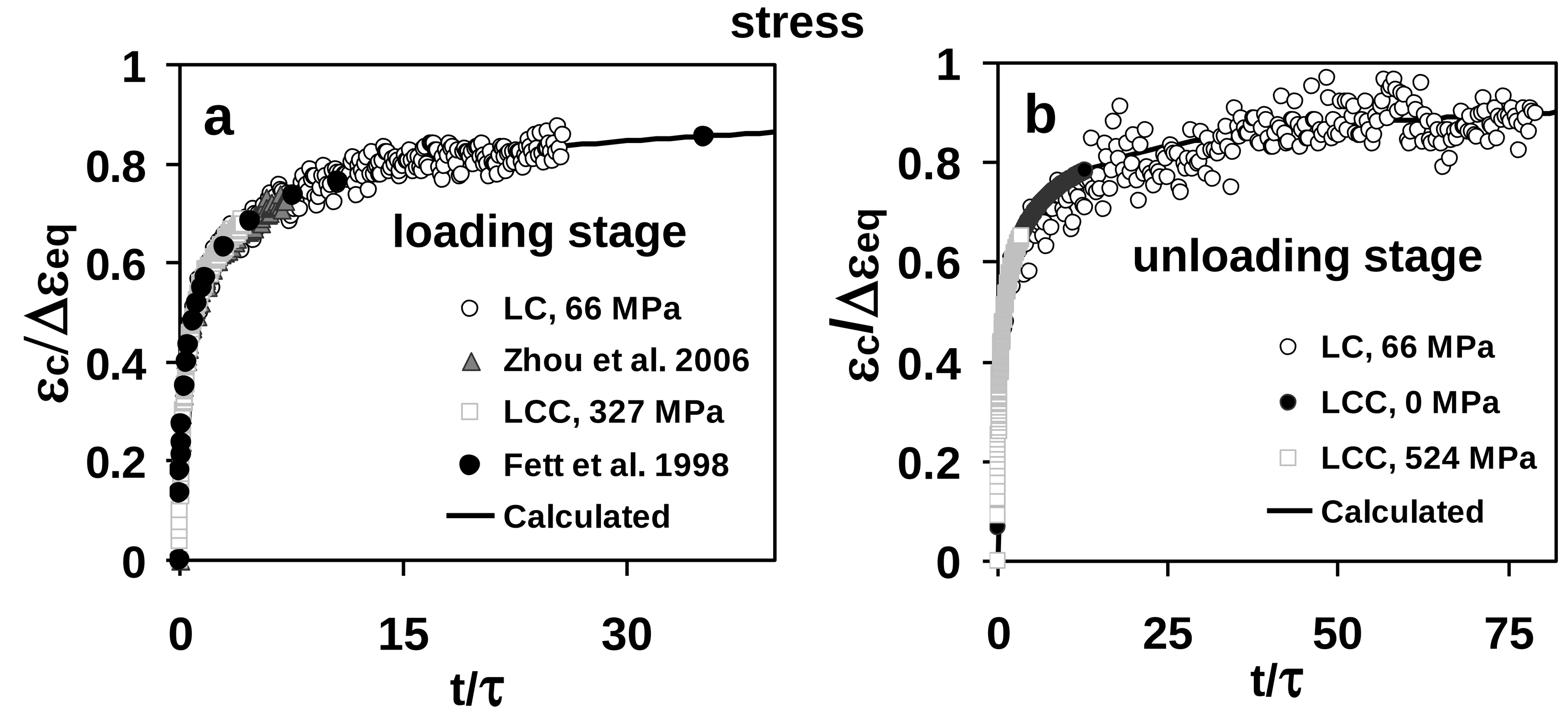
Is the equilibrium strain increment

τ is the characteristic time

New expression allows to evaluate equilibrium strain at given stress from creep strain – time data.

Normalized dependence is one for all compositions.

Dependence of normalized creep strain on normalized time at constant stress



Summary

The room temperature creep and recovery process in ferroelastic ceramics are essentially different from that occurring in metals, since they result from different physical mechanisms responsible for the process. A new phenomenological model of the ferroelastic creep is proposed instead of previously used power law. The model takes into account the existence of the equilibrium strain and allows its estimation for a given stress level, while such estimation is impossible using power law. A driving force of the ferroelastic switching is defined both for the loading and the unloading, and a phenomenological expression is developed to calculate a characteristic time from the driving force. The equilibrium stress – strain diagrams for LC and LCC ceramics are calculated and differences between equilibrium and non-equilibrium deformation diagrams are estimated.

Acknowledgments

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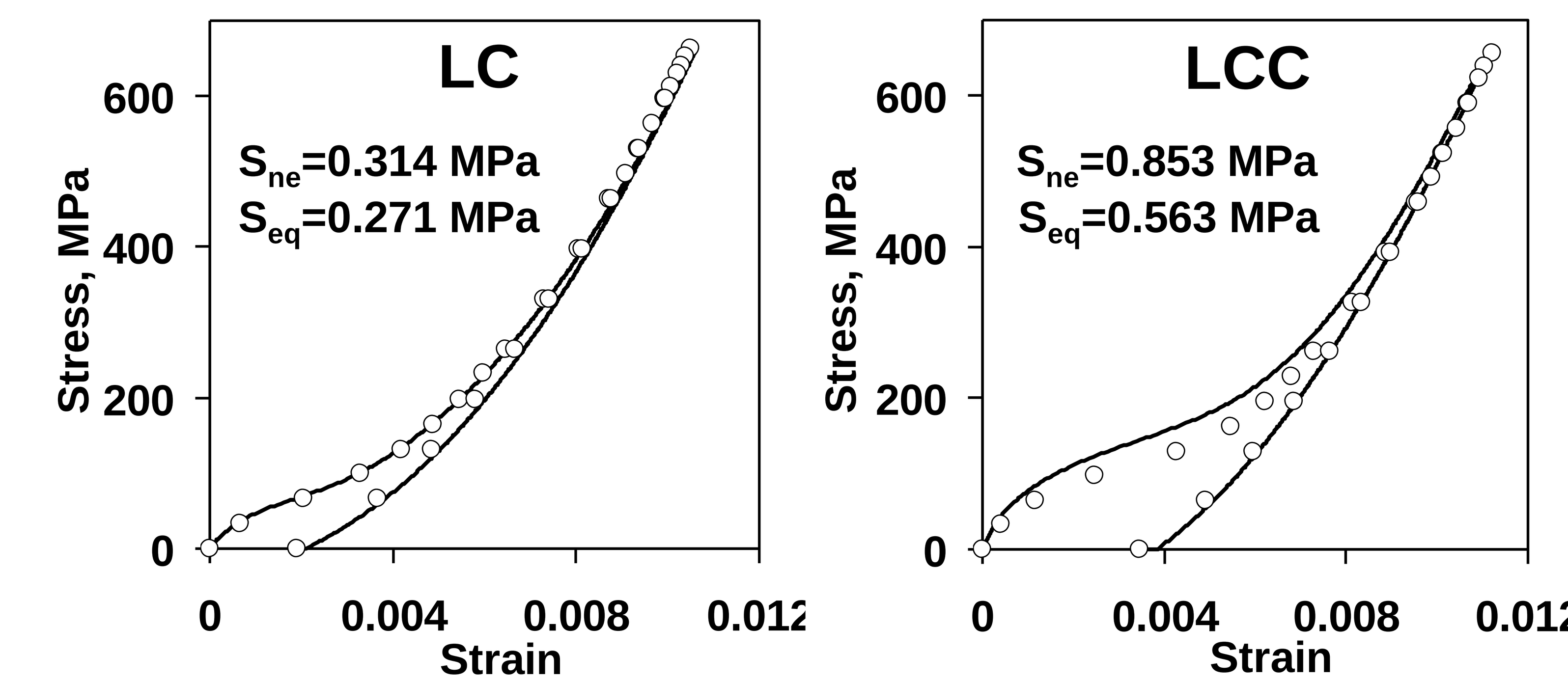
Equilibrium diagrams and characteristic time

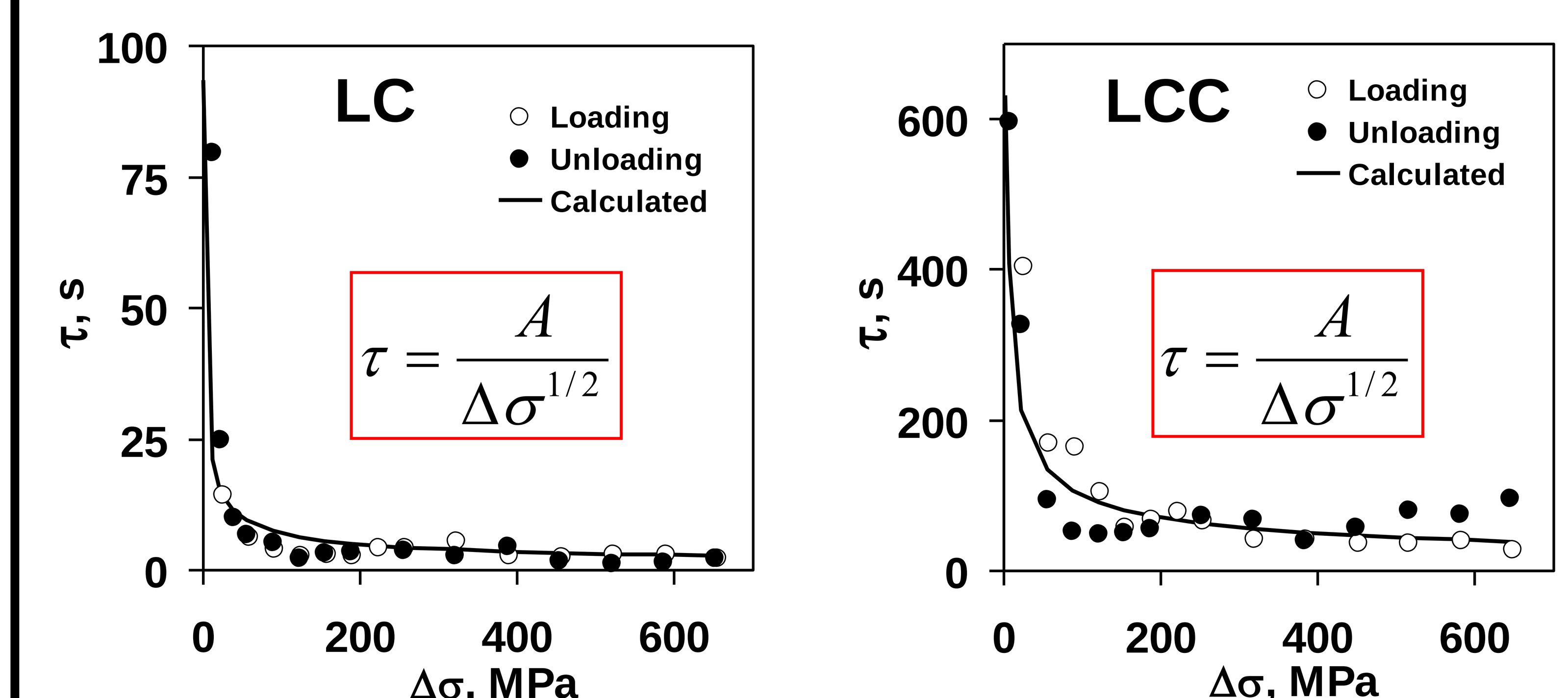
Stress – strain diagrams for LC and LCC



Open circles correspond to equilibrium strain values

Solid lines are non-equilibrium diagrams at a loading rate of 3 MPa/s

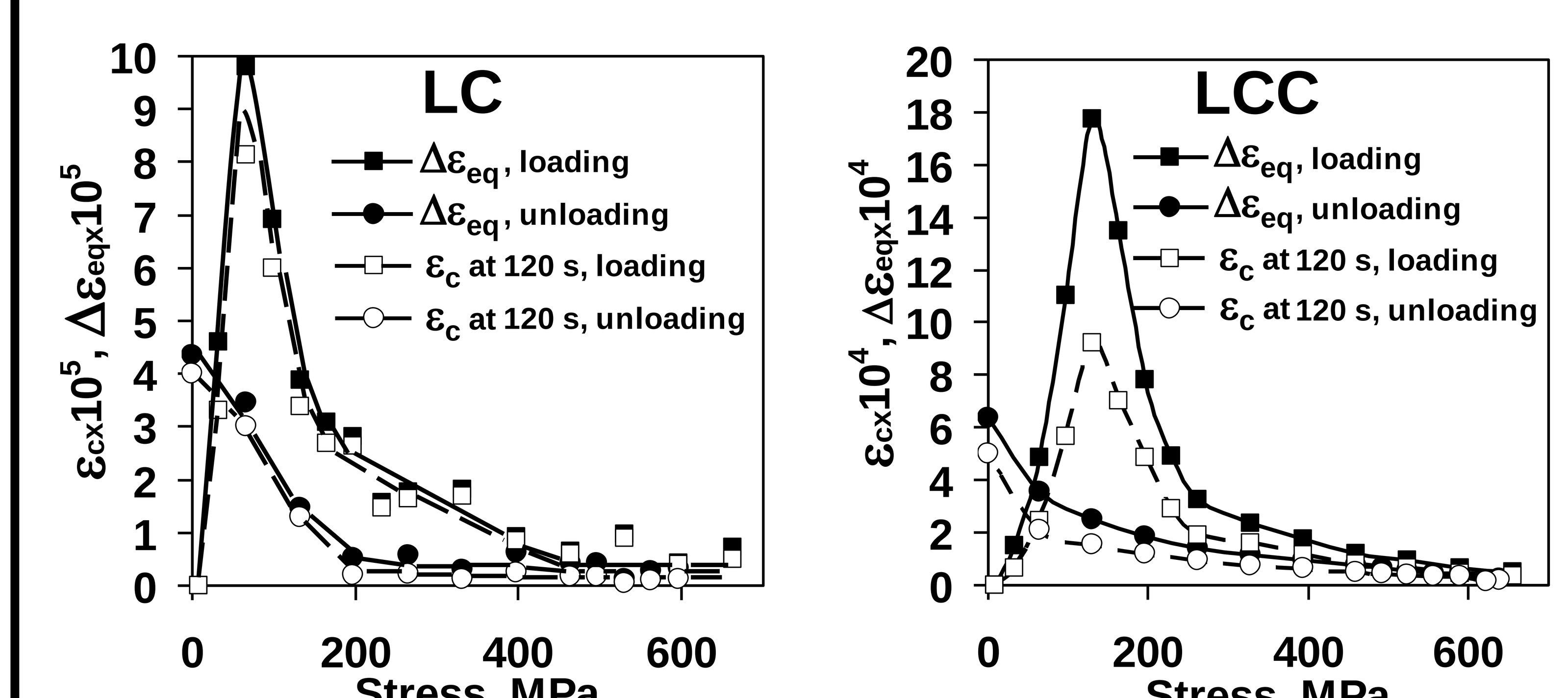
A characteristic time versus creep and recovery driving force



A driving force is the difference between applied stress and yield point during loading

A driving force is the difference between maximum stress and applied stress during unloading

A creep strain at 120 s and equilibrium strain increment as a function of applied stress



A creep strain at 120 s is very close to the equilibrium strain increment for LC perovskite

There is a maximum at stress corresponding to inflection points of each compositions during loading