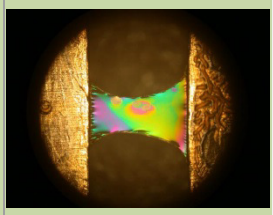
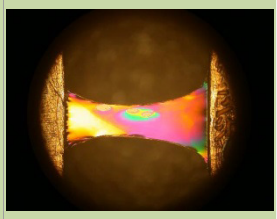


Smectic Elastomers

M. Morys, V. Aksenov, L. Naji, R. Stannarius

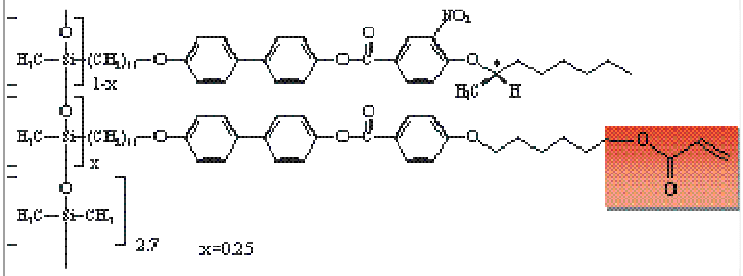
in collaboration with R. Zentel (Mainz)



Smectic elastomer films

Smectic elastomers combine the properties of a one-dimensional crystal and the orientational order of liquid crystalline materials with the entropy elasticity of rubber. They can be prepared from smectic photo-cross linkable polymers. We draw these polymers in free-standing film geometries to prepare a uniformly aligned layer structure. The films are investigated mechanically and electrically.

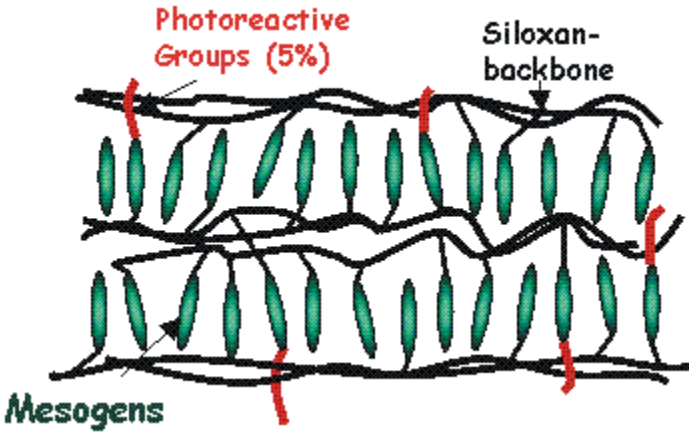
Chemical structure of a smectic side chain polymer



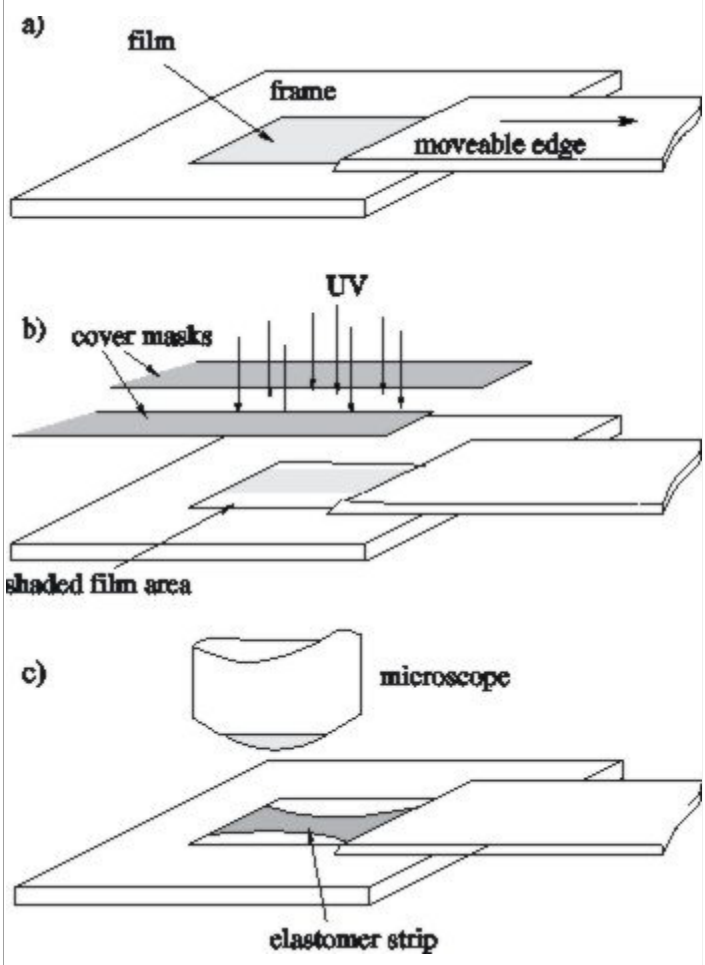
(diluted random copolymer)

Physical structure of the side chain polymer in the smectic A phase

- siloxane main chain (black),
- mesogenic side chains (green)
- and photoreactive groups (red).
- photoreactive units are cross-linked by UV irradiation.



Film preparation and Experimental Setup

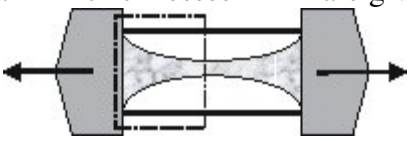


Preparation of thin planar films and microscopic investigation

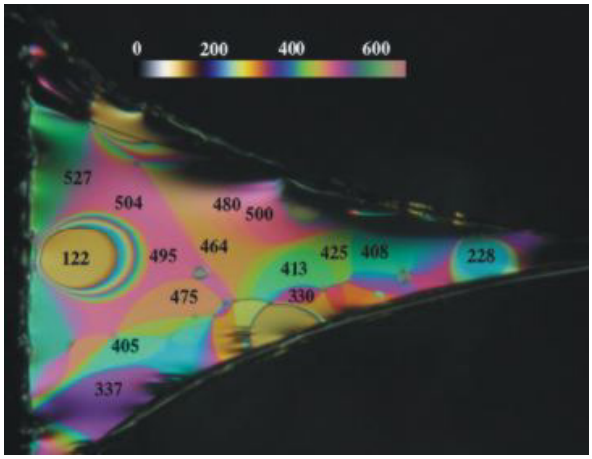
Study of elastic deformations

Free-standing films of smectic elastomers are exposed to uniaxial stress in the smectic layer plane. The Poisson ratio is studied from the film thickness changes observed by optical interferometry.

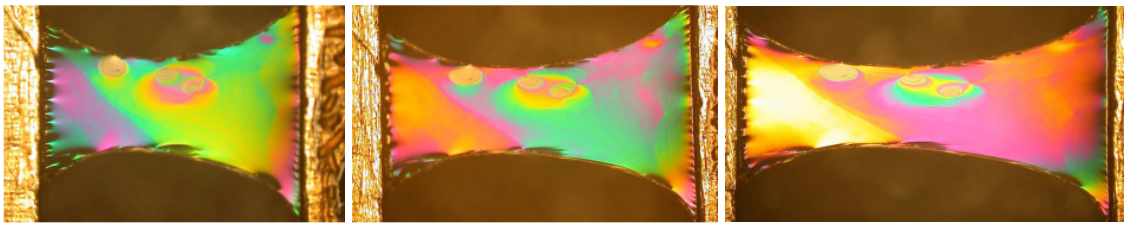
Geometry for the preparation of free standing smectic polymer films and cross linking of elastomer strips [Stannarius2004]: The smectic film is drawn in a frame consisting of two fixed and two moveable holders in the isotropic phase. It is then cooled into the smectic A phase. During cross linking with UV irradiation the two fixed holders and the nearby film are covered by a mask. This allows the preparation of elastomer stripes that are supported only at the moveable edges. Smectic layers are aligned perfectly parallel to the film plane. The image below shows the geometry of the elastomer strip, the color picture (right) shows an experimental image in the reflection microscope, local film thicknesses in nm are given.



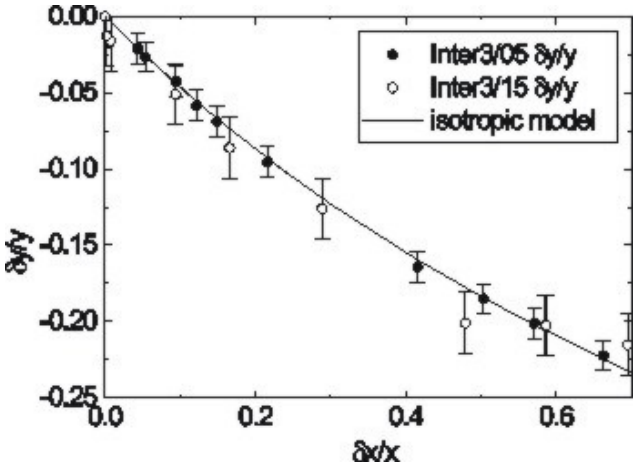
Separation of the two lateral edges allows a controlled stretching of the film.

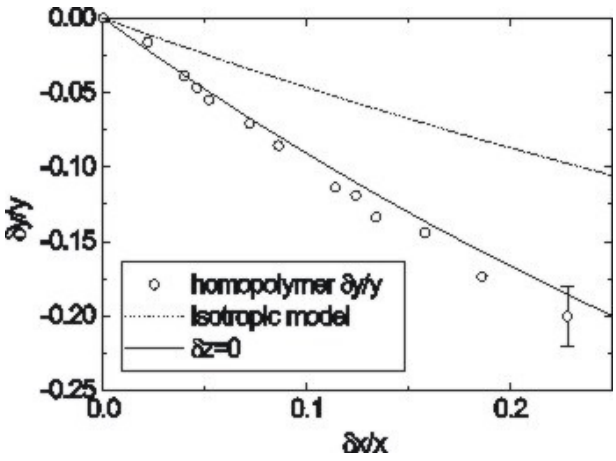


Color changes of the film show that the film of a diluted copolymer becomes thinner with increasing strain. It behaves similar to an isotropic rubber with Poisson ratio 1/2. The three following images show the same smectic A elastomer film at elongations x/x_0 = 1.34, 1.60 and 1.90.



The optical film thickness change as a function of strain is shown in the following images. The diluted elastomer film (left) shows the behaviour of an isotropic rubber, the Poisson ratio is close to 1/2. The homopolymer with the same amount of cross linking units behaves qualitatively very different. It hardly contracts in the direction normal to the smectic planes, the Poisson ratio is close to zero. Molecular orientation and layer structure were studied by means of X-ray scattering [Aksenov2005,Stannarius06] and FTIR spectroscopy [Aksenov2007]



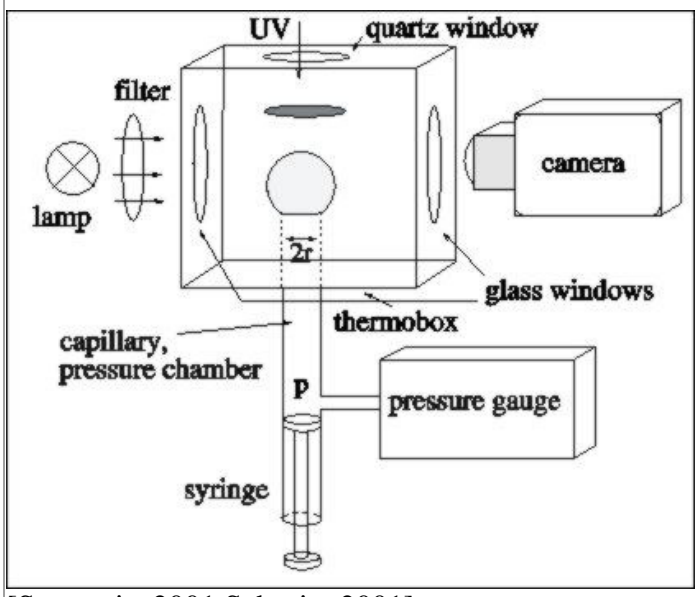


Possible origins of this qualitative influence of the molecular structure on the macroscopic stretching characteristics could be: a) the existence of a *de Vries* smectic A structure in the diluted polymer and b) a strong difference in the enthalpy elastic contributions to the elasticity between both materials. [Aksenov2005,Stannarius2006]

Smectic elastomer ballons

Smectic elastomer balloons allow to measure the mechanical coefficients by means of pressure vs. expansion curves. Inflation of these balloonsis achieved by an excess pressure *p*, and the measurement of the corresponding radius change yields the elastic modulus.

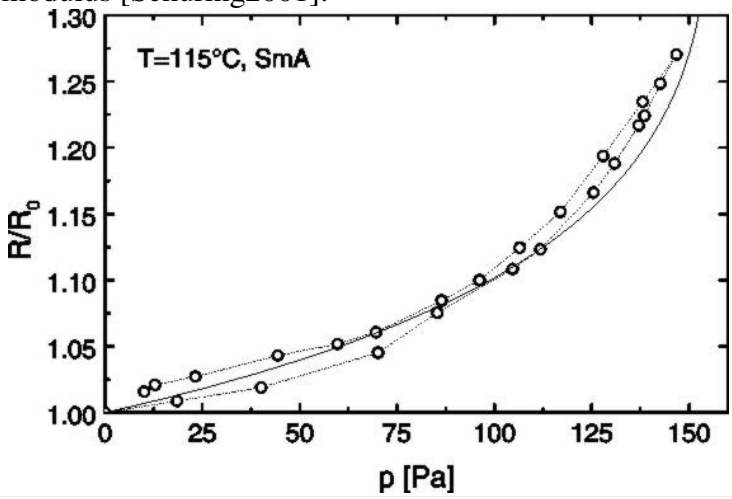
Setup for the preparation of elastomer ballons



[Stannarius2001,Schüring2001]

Smectic elastomer balloon on a glass capillary. The balloon diameter is 3.9 mm and the thickness of the film is ~ 3.5 micrometers.

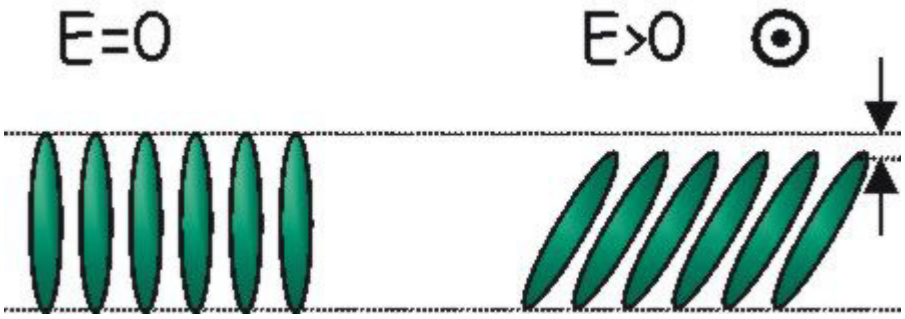
Radius/pressure characteristics of a smectic elastomer balloon.
The slope at small deformations yields the elastic modulus [Schüring2001].



Electro-mechanical response

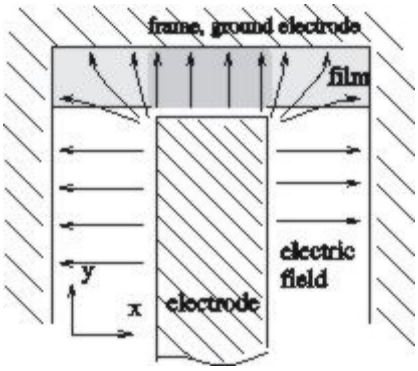
Electroclinic effect

Application of an electric field in the smectic layer plane in the vicinity of the smectic A to smectic C* transition induces a tilt angle of the mesogens with respect to the layer normal, as sketched in the image to the right. This electroclinic effect is well known from chiral smectic low molecular mass materials. It is expected to lead to a layer shrinkage, accompanied with strong electrostriction (change of the tilt linear with the electric field strength, change of the film thickness with the square of the applied electric field).

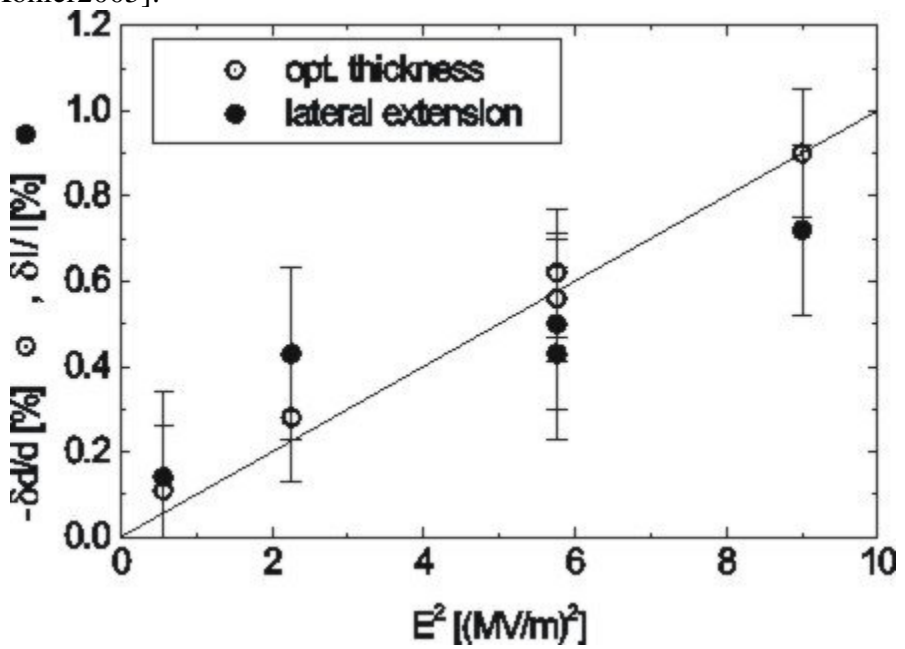


Setup

Geometry of the experimental setup for the measurement of the electroclinic response by means of optical reflectometry. The film thickness change is determined from the reflectivity change under monochromatic illumination in the region of the most homogeneous electric field (dark grey area)

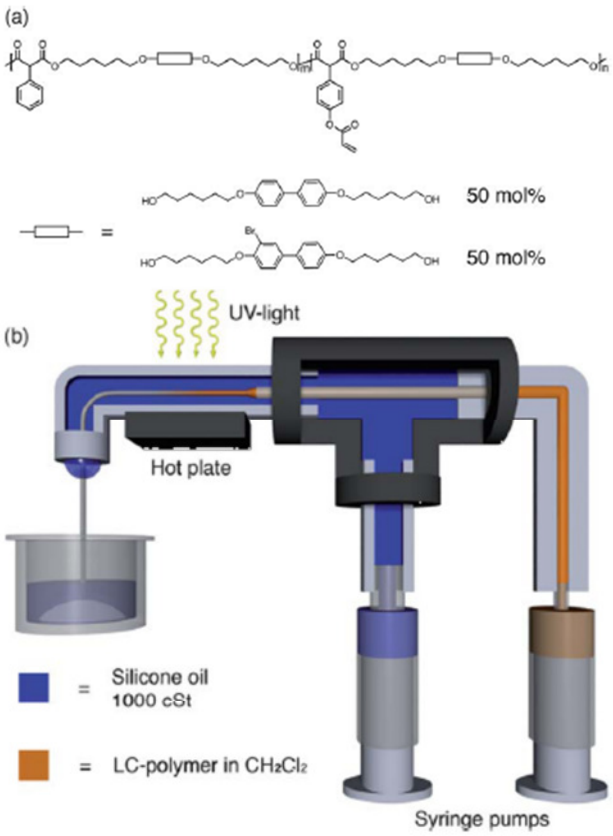


Measured film thickness and film width changes attributed to a layer shrinkage of the ferroelectric smectic elastomer near the phase transition smectic A to smectic C*. The tilt sisceptibility is in reasonable agreement with optical measurements, but the results are in contradiction with a pure de Vries model of the smectic A phase (in that case, the electroclinic effect concerns only the optic axis but not the layer thickness) [Köhler2005].

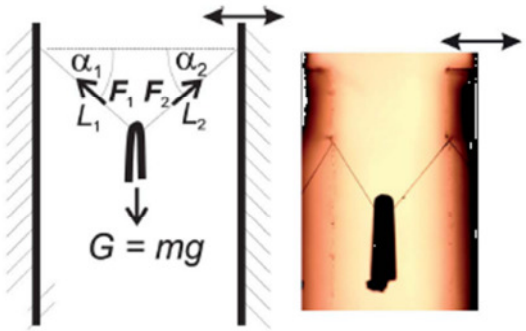


Smectic Fibers

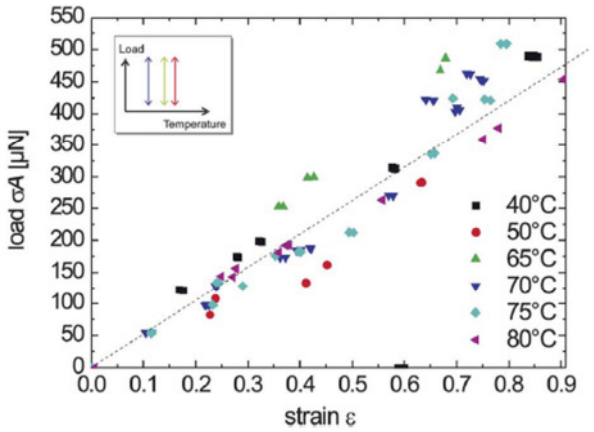
A specially developed wet spinning technique offers the oppurtunity to produce continuously spun smectic A elastomer fibers of arbitrary length. We study the orientational order of the smectic layers in these filaments, the thermo-mechanical properties and the mechanically induced optical effects in those fibers



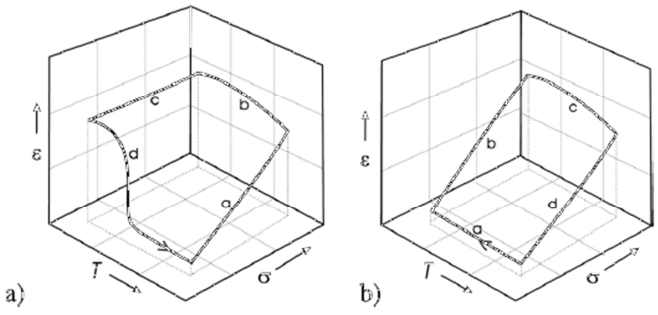
Setup for the preparation of smectic main chain elastomer fibers by means of a wetspinning technique [Ohm2011]



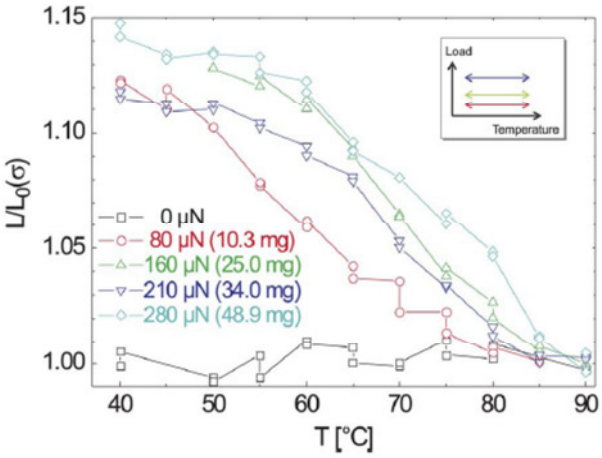
Measurement of tensions by means of a load attached to a vertically suspended smectic fiber [Stannarius2012]. The tension is determined from the known load and the angles α between the fiber arms and the vertical.



Stress vs strain curves of 30 micron thick smectic elastomer fibers at different temperatures [Stannarius2012]



Thermo-elastic behaviour in the temperature-stress-strain diagram. When the parameter changes in the σ-T plane are clockwise, we find shape memory effects, when the parameter variation is counterclockwise, the material behaves normally [Stannarius2012].



Length changes of the filament with attached weights at cooling from the isotropic phase down to room temperature [Stannarius2012]

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