Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

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Version of record first published: 24 Sep 2006

To cite this article: Y. C. Chen, Th. Geue, U. Pietsch, S. Manukow & E. Schmeer (1999): Defect Structure Characterization of Metal Surfaces with Induced Phase Changes of a Coated Ferroelectric Liquid Crystal, Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals, 329:1, 401-404

To link to this article: http://dx.doi.org/10.1080/10587259908025962

Mol. Cryst. Liq. Cryst., 1999, Vol. 329, pp. 401-404
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Defect Structure Characterization of Metal Surfaces with Induced Phase Changes of a Coated Ferroelectric Liquid Crystal

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The modification of the morphology of metal surfaces such as steel AISI 316 (ordered γ-phase) resulting from the material fatigue or distorted dislocations can be characterized by a coated ferroelectric liquid crystal. Hereto a free-standing smectic-C* LC-film was prepared and coated onto the treated steel surface. We found that both the d-spacing of the LC-film and the S_c*-S_A phase transition temperature are significantly changed after coating. Both parameters can be used to characterize the morphology of the steel surface.

INTRODUCTION

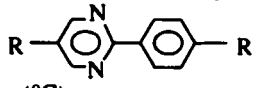
In recent years a lot of research has been devoted to liquid crystal-solid interfaces because orientational ordering exhibits a rich variety of exciting physical behaviors. The physical properties, such as layer structure, molecular orientation and phase transition temperature, of liquid crystals show a sensitive relationship with the interface interaction. In this paper, our experimental results will prove that the LC phase transition temperatures (S_C*-S_A, S_A-N*) and layer thicknesses reveal sensitive dependence on the different surface states (roughness, wetability etc.) of the investigated steel substrates. Particularly when the tension is smaller than 0.4 mm, the layer thickness of LC-film indicates a linear relationship with the tension or strain.

EXPERIMENTAL

Material

As an indicator for the defect structure of the steel surface caused by stretch serves a ferroelectric LC, a phenyl-pyrimidine-derivative, which shows a smectic-C* phase at a broad temperature range from 6°C to 54°C. The broad temperature range of smectic-C* with molecular layered arrangement allows the formation of free-standing films over an aperture in a frame. Using a self-constructed equipment the steel plate will be lifted up to contact with the film.

(a) Molecular structure:



(b) Phase transition temperaturs (°C)

$$X \xrightarrow{6} S_C^* \xrightarrow{54} S_A \xrightarrow{59} N^* \xrightarrow{68} I$$

Substrate

A steel plate was water cut in size of 11x4x1 mm and then diamond polished with different diamond grain sizes. The cut steel plates with original dislocation density of $10^7/cm^2$ was stretched along its longitudinal direction using a computer controlled tension machine. The stretching range varies from 0.2 mm to 0.8 mm. The following materials were used:

(a) Original state of the steel: Fe-Ni Polycrystal AISI 316 with dislocation density about 10^7 /cm^2.

(b) Compounds of the steel AISI 316:

C	Si	Mn	P	S	Cr	Mo	Ni	Fe
≤0.08	≤1.00	≤2.00	≤0.045	≤0.03	≤0.08	≤0.08	≤0.08	rest

EXPERIMENTAL RESULTS AND DISCUSSION

X-ray reflectivity

The evaluation of the X-ray reflectivity curves (fig. 1-3) provides the following properties:

1. At a fixed temperature the LC-layer spacing varies as (fig. 1, 2):

$$\mathbf{d_{ff} < d_{gl} < d_{un} < d_{ls} < d_{ss}}$$

here: d_{ff}: layer thickness of the free-standing LC-film;

d_{gl}: layer thickness of LC-film, deposited on glass;

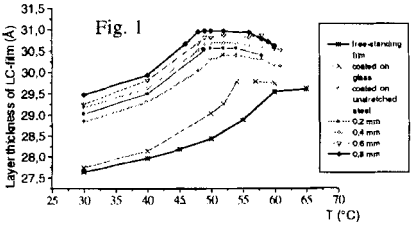
d_{un}: layer thickness of LC-film, deposited on unstretched steel;

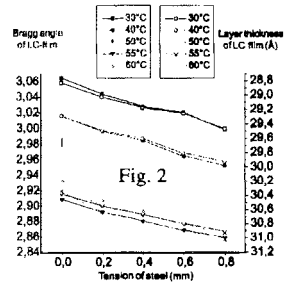
d_{ls}: layer thickness of LC-film, deposited on slightly stretched steel;

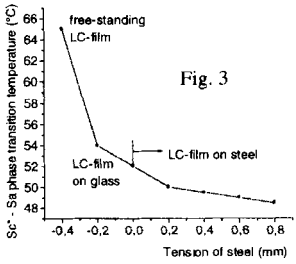
d_{ss}: layer thickness of LC-film, deposited on strongly stretched steel .

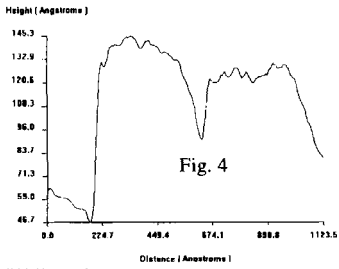
2. The S_C^* -> S_A and S_A -> N^* phase transition temperature varies as (fig. 3):

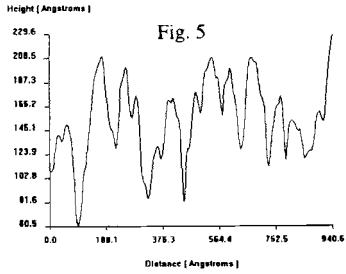
$$\mathbf{T_{ff} > T_{gl} > T_{un} > T_{ls} > T_{ss}}$$

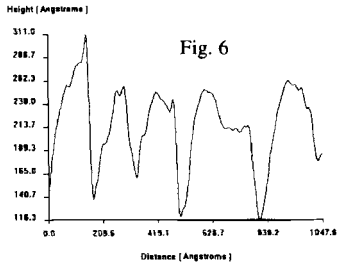












Scanning Tunneling Microscope (STM)

Figures 4-6 were taken with STM and show the height profils of metal surface. They describe the following physical properties:

1. Whereas the unstretched steel exhibits a long-range wavyness (fig. 4), the stretched steel is characterized by a short-frequent wavyness (fig. 5).
2. The morphology of the stretched steel surface corresponds with that of the coated LC-film (fig. 5, 6).
3. After LC-film coating the very short-frequent wavyness disappears (fig. 6).

SUMMARY

The experimental results from X-ray reflectivity curves and STM provide that the layer thickness and phase transition temperature of LC are influenced by the different surface morphology of the steel substrates. Furthermore it was shown that the morphology of LC-film can serve as an indicator for the wavyness of the steel surface which is modified under mechanical treatment.

ACKNOWLEDGEMENT

This work is supported in part by DFG. Thanks are also due to Hahn-Meitner-Institute for the steel sample preparation.

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