N70-32672

NASA TECHNICAL
MEMORANDUM

NASA TM X-2044

NASA TM X-2044

ELECTRIC FIELD HYSTERESIS EFFECTS IN THE TRANSMISSION PROPERTIES OF LIQUID CRYSTALS

by Louis Melamed and David Rubin

Electronics Research Center
Cambridge, Mass. 02139

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • JULY 1970

1. Report No.
NASA TM X-2044

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle
Electric Field Hysteresis Effects in the Transmission Properties of Liquid Crystals

5. Report Date
July 1970

6. Performing Organization Code

7. Author(s)
Louis Melamed and David Rubin

8. Performing Organization Report No.
C-108

9. Performing Organization Name and Address
Electronics Research Center
Cambridge, Mass.

10. Work Unit No.
125-25-07-16-25

11. Contract or Grant No.

12. Sponsoring Agency Name and Address
National Aeronautics
and Space Administration

13. Type of Report and Period Covered
Technical
Memorandum

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

Certain room-temperature cholesteric liquid crystals are capable of retaining information on their past history of electric field excitation by exhibiting marked changes in their optical transmission properties. The information retention slowly decays, but, in many cases, persists for at least several days following the removal of excitation. Thus, 100 volts applied across a 25μ sample for 10 minutes caused a change in transmission at 5000Å from 75 percent to about 22 percent. Sixty hours later, the transmission was about 48 percent.

17. Key Words
- Cholesteric Liquid Crystals
- Electric Field Excitation
- Optical Transmission Properties

18. Distribution Statement
Unclassified-Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unlimited	5	$3.00

*For sale by the Clearinghouse for Federal Scientific and Technical Information
Springfield, Virginia 22151

ELECTRIC FIELD HYSTERESIS EFFECTS IN THE TRANSMISSION PROPERTIES OF LIQUID CRYSTALS

By Louis Melamed and David Rubin
Electronics Research Center

SUMMARY

Certain room-temperature cholesteric liquid crystals are capable of retaining information on their past history of electric field excitation by exhibiting marked changes in their optical transmission properties. The information retention slowly decays, but, in many cases, persists for at least several days following the removal of excitation. Thus, 100 volts applied across a 25μ sample for 10 minutes caused a change in transmission at 5000Å from 75 percent to about 22 percent. Sixty hours later, the transmission was about 48 percent.

INTRODUCTION

Certain cholesterol compounds possess a liquid crystal, or mesomorphic phase in which such optical properties as reflection, transmission, and optical rotation can be affected by electric fields (refs. 1,2,3). Hysteresis in these effects has been noted in studies of optical reflection (refs. 1,2). Using materials similar to the ones to be discussed here, Harper (ref. 1) reported that the reflectivity of his samples did not return completely to their initial state after electric fields were removed. Muller (ref. 2) using cholesteryl nonanoate noticed a retention of the "acquired brightness" of his samples after the removal of an electric field.

Heilmeier and Goldmacher (ref. 4) have reported that optical storage capabilities can be added to the normal dynamic scattering observed in anisylidene-p-aminophenylacetate, a nematic liquid crystal, by the addition of ten percent of cholesteryl nonanoate. This mixture retains the optical properties of a nematic liquid crystal.

This note discusses hysteresis observed in the optical transmission of cholesteric materials subjected to electric fields. The magnitude and duration of the fields were varied and the hysteresis effects were recorded for periods up to 60 hours.

TECHNICAL APPROACH

The material examined was a mixture of three cholesteric liquid crystals; 34.0 percent cholesteryl chloride, 26.4 percent cholesteryl nonanoate, and 39.6 percent cholesteryl oleyl carbonate. This mixture was chosen because of its room-temperature cholesteric state and because of its relative temperature insensitivity. Mixtures of these three materials were originally suggested to us by J. Fergason as being relatively temperature-insensitive. Measurements in our laboratory indicate a temperature sensitivity of 50Å/°C.

The material was examined as a 1-mil thick sample between sealed quartz plates. Teflon tape provided the spacing, and the assemblage was then sealed with a high-melting temperature wax. The inside surfaces of the cell had been coated with a transparent layer of tin oxide to which electrodes were attached, thereby allowing electric fields to be applied along the direction of light propagation.

The transmission properties of the cell before, during, and after electric field excitation were recorded using a Coleman Model EPS-3T Hitachi ratio recording spectrophotometer. The sample temperature was maintained at 30°C ± .5°C. No apparent deterioration in the material was observed during several tens of on-off field cyclings.

At the beginning of each run the "memory" of the previous state was "erased" by heating the sample to isotropism and then the mixture was allowed to cool back to the cholesteric state.

MEASURED DATA AND THEIR INTERPRETATION

Curve I of Figure 1 plots transmission vs wavelength for the initial state. Curve II results from applying 100 volts (40,000 V/cm) to the sample. When the field is removed, curve III results which is intermediate in transmission properties between the initial state and the excited state. Curve III, however, is quasi-stable and slowly drifts upwards in the direction of the initial state. This drift amounts to only several percent transmission change after several hours; after a period of 60 hours, however, curve III has recovered to about midway in transmission between state III and state I. Heating the sample to the isotropic phase and re-cooling re-establishes state I.

Although not evident from Figure 1, smaller electric fields caused both a shift (to shorter wavelengths) and a broadening of the transmission minimum. However, at 100 volts the combination of these two phenomena effectively masked the transmission minimum despite the fact that the material, in a separate observation, still displayed a reflection peak at 100 volts excitation. Thus, the reflection properties of this material are believed to be similar to those of cholesteric materials of the type reported by Harper (ref. 1) and others.

A more detailed examination of the influence of field strength and field duration on transmission at 5000Å is plotted in Figure 2 and reveals several new features. Little hysteresis is observed in the 25-volt case. The response time to an electric field is inversely related to the voltage. Thus, the "3 dB" response time is about 100 seconds at 25 volts, 45 seconds at 50 volts, and about 14 seconds at 100 volts. It is apparent from Figure 2 that even after 10 minutes of steady field application, the transmission of the material is still changing. In each case, upon removing the applied voltage, the transmission of the material slowly starts to recover back to the initial unexcited state. For a 10-minute on-time, the recovery rate is very long at least for the 100-volt case. In the latter case, observations made on samples excited for 10 minutes and then left undisturbed revealed that after 16 hours, the transmission had increased to about 45 percent and 60 hours later it had increased to about 52 percent or roughly half-way between the excited and unexcited states. In each case, heating the material to isotropism and re-cooling to room temperature re-established the 75 percent transmission for the unexcited state. As attempt was made to investigate the effect of shorter field-on times on the storage time capability of this material. For 100 volts applied for 5 seconds, it only took 13 seconds for the transmission to recover to the 3 dB level; for 30 seconds on, it took 7 minutes, and for 90 seconds on, it took 28 minutes. No attempt was made to observe the decay times for on-times greater than 10 minutes. One curious feature of the 100-volt curve in Figure 2 remains unexplained. It is not clear why, after about 3 minutes of an applied voltage, the transmission starts rising again. Evidently there exist unknown long-range dynamic effects in the internal structure of these materials. This minimum transmission at about a 3-minute interval has been observed repeatedly.

The possibility was eliminated that the slow decay rate of the transmission following field removal was related to capacitive field effects in the structure. Shorting out the two conductive surfaces enclosing the cholesteric material, did not influence the optical behavior.

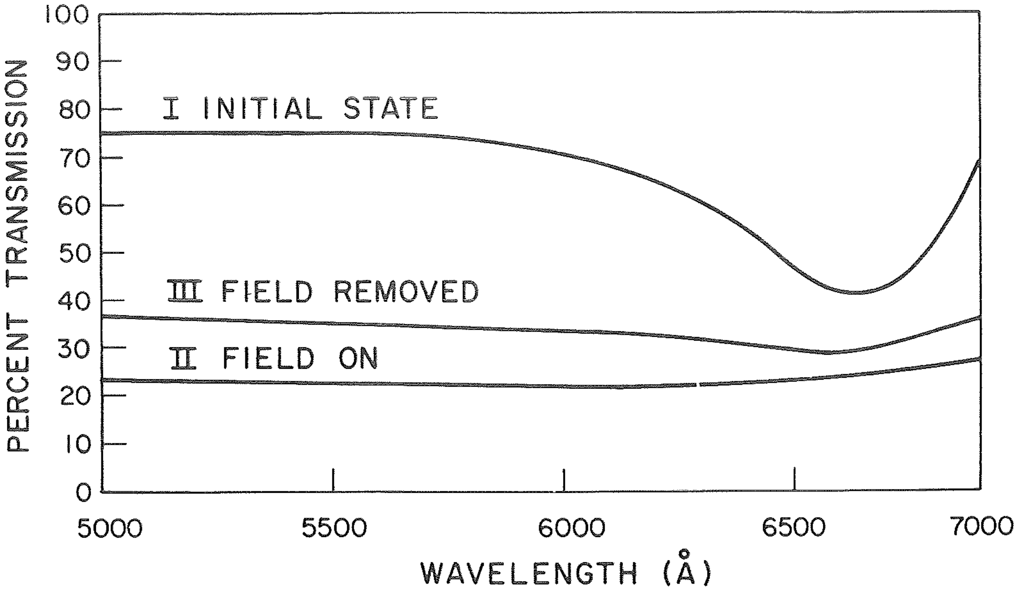

Figure 1.- Hysteresis effects in the transmission of liquid crystals subjected to a 40,000-V/cm field

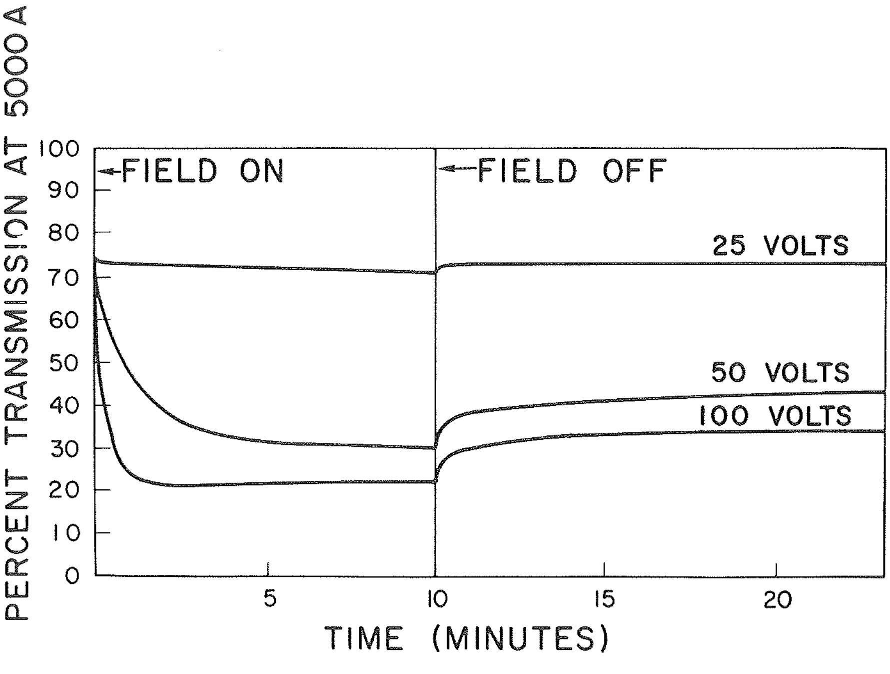

Figure 2.- Hysteresis effects in the transmission at 5000Å observed for several values of field excitation

CONCLUSION

An electric field hysteresis effect in the transmission properties of a mixture of three cholesteric liquid crystals has been demonstrated. The effect is a function of the magnitude and duration of an applied field. The hysteresis slowly decays, but, in many cases, persists for at least several days following the removal of excitation.

REFERENCES

1. Harper, W. J.: Voltage Effects in Cholesteric Liquid Crystals. Molecular Crystals. Vol. 1, 1966, p. 325.

2. Muller, J. H.: Effects of Electric Fields on Cholesteryl Nonanoate Liquid Crystals. Molecular Crystals. Vol. 2, 1966, p. 167.

3. Day, G. W., et al: Electric Field Induced Optical Rotation in Cholestene Liquid Crystals. Proceedings of the IEEE. Vol. 56, 1968, p. 1113.

4. Heimeier, G. H. and Goldmacher, J. E.: A New Electric Field Controlled Reflective Optical Storage Effect in Mixed Liquid Crystal Systems. Appl. Phys. Letters. Vol. 13, 1968, p. 132.

NASA-Langley, 1970 —— 10 C-108

> *"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."*
>
> —NATIONAL AERONAUTICS AND SPACE ACT OF 1958

NASA SCIENTIFIC AND TECHNICAL PUBLICATIONS

TECHNICAL REPORTS: Scientific and technical information considered important, complete, and a lasting contribution to existing knowledge.

TECHNICAL NOTES: Information less broad in scope but nevertheless of importance as a contribution to existing knowledge.

TECHNICAL MEMORANDUMS: Information receiving limited distribution because of preliminary data, security classification, or other reasons.

CONTRACTOR REPORTS: Scientific and technical information generated under a NASA contract or grant and considered an important contribution to existing knowledge.

TECHNICAL TRANSLATIONS: Information published in a foreign language considered to merit NASA distribution in English.

SPECIAL PUBLICATIONS: Information derived from or of value to NASA activities. Publications include conference proceedings, monographs, data compilations, handbooks, sourcebooks, and special bibliographies.

TECHNOLOGY UTILIZATION PUBLICATIONS: Information on technology used by NASA that may be of particular interest in commercial and other non-aerospace applications. Publications include Tech Briefs, Technology Utilization Reports and Notes, and Technology Surveys.

Details on the availability of these publications may be obtained from:

SCIENTIFIC AND TECHNICAL INFORMATION DIVISION
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D.C. 20546