TLC PRODUCTS FOR USE IN RESEARCH AND TESTING APPLICATIONS

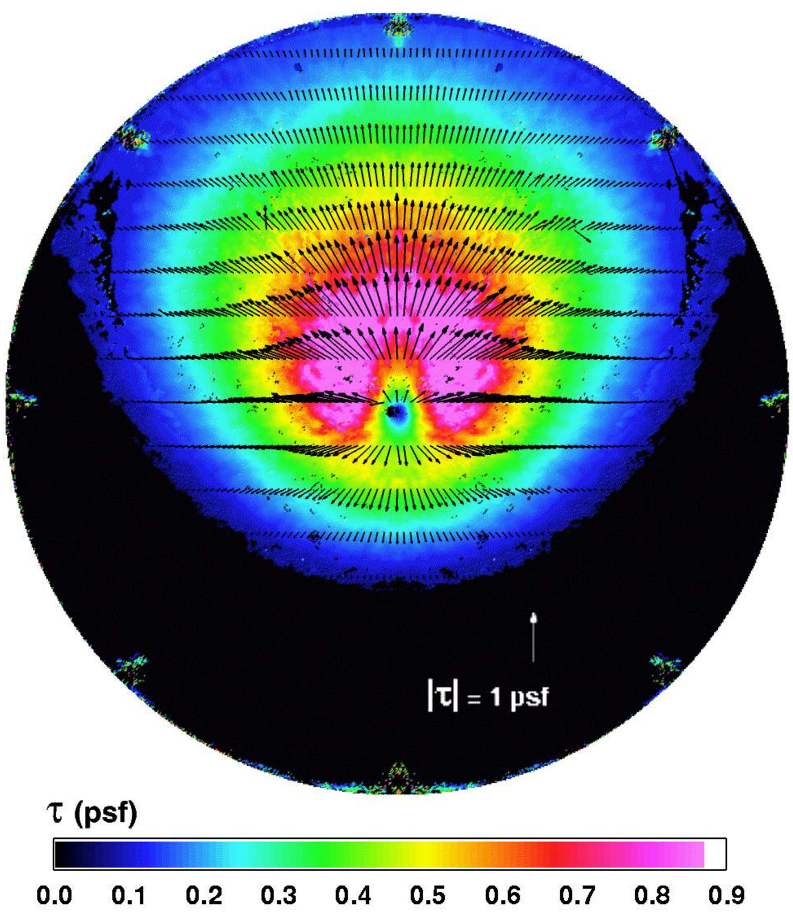
- Unsealed TLC Mixtures -

- Microencapsulated TLC Slurries -

- Sprayable TLC Coatings -

-Sprayable Black Backings and Clear Overcoats/Binders -

- TLC Coated Polyester Sheets -



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TECHNOLOGY BACKGROUND

INTRODUCTION

The use of thermochromic liquid crystal (TLC) products in research and testing continues to grow. The main application areas are in flow visualization and heat transfer studies, although the materials can be used in virtually any work involving indication of temperature fields and thermal mapping. The chemistry, physics and temperature indicating applications of TLCs are well documented in the open and patent literature.

THERMOCHROMIC LIQUID CRYSTALS (TLCs)

TLCs react to changes in temperature by changing color. They have chiral (twisted) molecular structures and are optically active mixtures of organic chemicals. The correct scientific name for the materials is CHOLESTERIC or CHIRAL NEMATIC liquid crystals. The term cholesteric is an historical one, and derives from the fact that the first materials to show the characteristic properties and structure of this particular type of liquid crystal were esters of cholesterol. This can be misleading, as many non-sterol derived optically active chemicals (and mixtures containing them) also show the cholesteric liquid crystal structure. It is important to differentiate these sterol and non-sterol derived materials because, although they change color in the same way, they have different properties and can be used in different ways to achieve different effects.

TLC mixtures can therefore be divided into 3 types based on their compositions:

(a) **CHOLESTERIC** - comprised entirely of sterol-derived chemicals;

(b) **CHIRAL NEMATIC** - comprised entirely of non-sterol based chemicals.

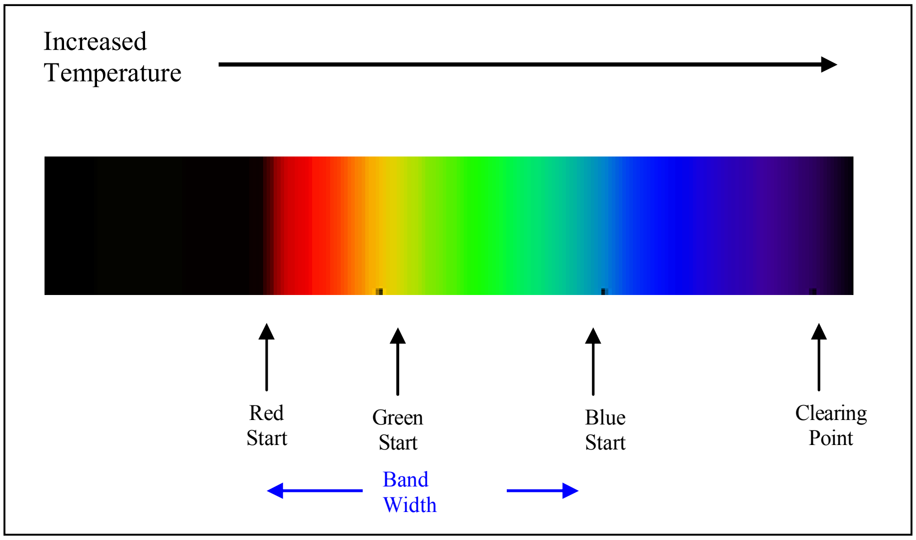
(c) **COMBINATION** - containing both cholesteric and chiral nematic components. Combination mixtures extend the application possibilities and working ranges of TLC formulations by combining the respective advantages of both groups of component chemicals.

All TLCs are CHOLESTERIC LIQUID CRYSTALS, whether sterol-derived, non-sterol-derived or a mixture of the two. Cholesterics are one of the three major classes of THERMOTROPIC liquid crystals (produced by the action of heat). The two others are called smectics and nematics. LYOTROPIC liquid crystals result from the action of a solvent. (See the Handbook of TLC Technology for more information. This document is also available as a download).

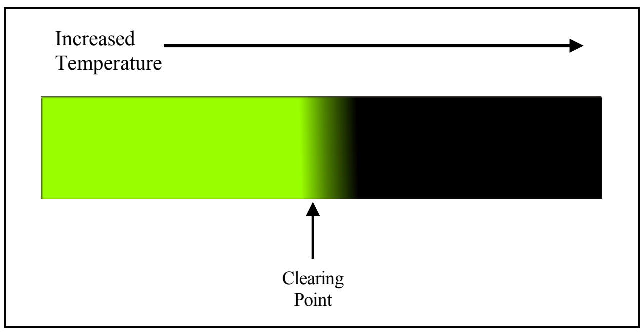
TEMPERATURE-SENSITIVE AND SHEAR-SENSITIVE MIXTURES

TLCs show colors by selectively reflecting incident white light. They should be viewed against non-reflecting backgrounds (ideally black which is totally absorbing) for best visualization of the colors. The nomenclature used to describe and define the color change properties of TLC mixtures is discussed later.

Temperature-sensitive [RGB] mixtures turn from colorless (black against a black background) to red at a given temperature and, as the temperature is increased, pass through the other colors of the visible spectrum in sequence (orange, yellow, green, blue, violet) before turning colorless (black) again at a higher temperature still. The color changes are reversible and on cooling the color change sequence is reversed.



Temperature-insensitive (also called **shear-sensitive** or **single color below [SCB]**) formulations can also be made. These mixtures show just a single color below a given transition temperature (called the clearing point) and change to colorless (black) above it. [NOTE: They are only available as the unsealed liquids for shear-stress studies (see page 7)].



DIFFERENT FORMS OF TLC MATERIALS

The unique properties of TLCs can only be used to advantage if they can be controlled, and the materials made to behave predictably for a given period of time (in research applications, the duration of the experiment or study). TLCs can be used in a number of different forms (see TLC Literature Review A for detailed background information):

(a) As the unsealed liquids or in solution
(b) In the microencapsulated form as aqueous slurries or coatings
(c) Coated (printed) sheets.

UNSEALED LIQUIDS

TLC materials are essentially oils and the consistency of most TLC mixtures at their working temperatures varies between that of a thin oil and a viscous paste. They are difficult to use and are commonly applied as the isotropic melts, or as solutions by air brush or spray. Unsealed TLC mixtures need to be applied in thin, uniform films with thicknesses varying from 5-10 microns for chiral nematics up to as much as 50 microns or more for cholesterics. The resulting large surface area to volume ratio gives rise to a high susceptibility to degradation, particularly from ultra-violet light and oxygen, which can diffuse into the shallow film easily. The color play response can be changed by the presence of even small amounts (ppm levels) of certain chemicals (e.g. fats, greases and common organic solvents). Dust and fibre particles can easily become trapped by viscous TLC films causing additional problems.

The lifetimes of unsealed TLC films can vary from a matter of hours to days, depending on how the materials are used. In studies involving shear-induced color changes, the materials must be used as the unsealed liquids. It is possible to design experiments to take the limited lifetimes of the materials into account. However, the degree of stability offered by the materials as the unsealed liquids falls far short of that required for commercial temperature indicating applications.

IN THE MICROENCAPSULATED FORM (SLURRIES AND COATINGS)

To date, the microencapsulation process has been the most versatile, and successful way of packaging and protecting TLC mixtures. The LC is isolated from the atmosphere by a protective barrier and, at the same time, converted into a comparatively easy-to-use form. In simple terms, a microcapsule is a small sphere with a uniform wall around it, and in the microencapsulation process tiny droplets of liquid crystal are surrounded with a continuous polymer coating to give discrete microcapsules. Microcapsule diameters are generally between a few microns and a few millimeters.

The product of the microencapsulation process is an AQUEOUS SLURRY. This can be used directly (e.g. in hydrophilic liquids as tracer particles in flow field studies) or can be incorporated as a pigment, into a COATING FORMULATION optimised for a particular method of application (e.g. spraying, etc.). The dry coating should ideally support the liquid crystal in a uniform film with the minimum degradative effect on the intensity and purity of the reflected light. Microencapsulated TLC mixtures offer improved stability and versatility of use over their unsealed precursors. Further protection can be achieved by using materials with UV absorbing properties in combination with the TLCs whenever possible. Water resistant coatings can also be made.

COATED (PRINTED) SHEETS

Most TLC temperature indicating devices are comprised of a thin film of liquid crystal sandwiched between a transparent substrate (sheet), and a black background. They are usually made by printing an ink containing microencapsulated TLC onto the reverse side of the substrate. A black ink is then applied on top of the dry TLC coating and color change effects are viewed from the uncoated side.

The different forms of the materials each have relative advantages and disadvantages and are suited to different applications. Details are given in later sections.

STANDARD AND CUSTOM PRODUCTS

Across the range, standard products are available for each major application area. In addition, products can be custom-made to meet specific performance requirements.

The sale of our products is supported by extensive reviews of the open and patent literature (see TLC Literature Reviews B and C).

COLOR CHANGE PROPERTIES - COLOR PLAYS

The color change properties of TLC mixtures and products made from them are identified by a code called the COLOR PLAY. This specifies the temperatures at which the colors shown by the TLC change.

TEMPERATURE-SENSITIVE MIXTURES

The color play gives EITHER the red start temperature (R) OR mid-green temperature (MG), the temperature scale (C or F) and the bandwidth (W). The bandwidth is defined as the difference between the red start and blue start temperatures (see page 4).. For example, R35C1W describes a TLC mixture with a red start at 35°C and a bandwidth of 1°C, (i.e.) a blue start 1°C higher at 36°C; MG60C5W describes a mixture with a mid green at 60°C and a bandwidth (red start to blue start) of 5°C

Red start temperatures can be made to vary from -30°C to 120°C and bandwidths from 1.0°C to 20°C. Green starts, blue starts, mid greens and clearing points vary accordingly. Tolerances depend on the color play. Details are given in the tables below:

TRANSITION	TOLERANCE
Red Start Temperature (R) Green Start Temperature (G)	±0.5°C OR ± 10% of the bandwidth, whichever is greater
Mid Green Temperature (MG) Blue Start Temperature (B) Clearing Point (CP)	± 1.0°C OR ± 20% of the bandwidth, whichever is greater

TEMPERATURE-INSENSITIVE (SHEAR-SENSITIVE) MIXTURES

The color play gives only the color and clearing point. For example, R45C describes a LC mixture showing red below its clearing point of 45°C and G60C describes a mixture showing green below its clearing point of 60°C. Red, green and blue mixtures are available with clearing points (Ch-I transitions) between 0°C and 60°C.

SHEAR-SENSITIVE CHOLESTERIC LC MIXTURES
For flow visualization studies on solid surfaces

The use of unsealed shear-sensitive cholesteric liquid crystal mixtures has now become an established method for diagnostic flow visualization. Experimental techniques have been used to illustrate laminar boundary layer transitions, laminar bubbles, shocks and separation in both flight and wind tunnel environments.

STANDARD MIXTURES

Three standard mixtures are available, details of which are given in the table below. All reflect red light under no shear conditions and should not crystallize above 0°C.

	CLEARING POINT (Ch-I Transition Temperature)	RELATIVE VISCOSITY AT 30°C	FLOW SPEED WORKING RANGE (m/sec)
BN/R50C	50°C ± 1°C	1	<30
BCN/192	49°C ± 1°C	4	30 – 75
CN/R3	53°C ± 1°C	15	75 – 200

CUSTOM MIXTURES

Mixtures with a variety of physical properties can be made. From the performance viewpoint, the physical properties of importance are:

1) The color of reflected light
2) The viscosity
3) The clearing point

These three variables can all be controlled with good accuracy within predetermined limits, and we will be happy to work with the customer to optimise and custom-formulate mixtures to meet precise application and performance requirements

PACK SIZES

25g, 100g and 250g

GUIDELINES FOR USE

1. Clean surface thoroughly to remove all dirt, grease, fingerprints, etc. Acetone, petroleum ether, and other common organic solvents may be used. Ensure that the surface is completely dry before proceeding.

2. Coat surface black. If the surface is already black, or sufficiently dark, the TLC may be applied directly. A black water-based paint (SPB100) is available and will dry in 30-45 minutes when sprayed through a good quality compressed gas sprayer like an artist's airbrush. Applying the black paint by brush is not recommended, as uneven coatings affect the thermal response properties of the TLC. The black paint supplied will isolate the TLC from traces of grease, which may be left on the surface after cleaning. The black backing paint must be dry before applying the TLC. Drying times may vary with ambient temperature and humidity, and can be accelerated by gentle blowing with hot air.

3. Apply the TLC.

a) Unsealed Mixtures: Heat the TLC mixture gently on a hot place until it clears (turns [melts] to an isotropic liquid). TLC mixtures are comparatively insensitive to short periods of heating as isotropic liquids; however, care should be taken to avoid excessive heating for prolonged periods of time. The clear liquid can be brushed onto the dry black surface. Gentle warming with a heat gun as the liquid is applied may be necessary to achieve a uniform thin coating.

b) Solutions: Apply the TLC solutions through a good quality compressed gas sprayer, such as an artist's airbrush. The colours will not appear until all the solvent has evaporated. Gentle blowing with a fan, hair dryer, or heat gun may speed up the evaporation, but care must be taken not to disturb the TLC film. The TLC coating is now ready for use.

Cleaning Up: The TLC coating can be removed with acetone, petroleum ether and other common solvents. The SPB100 can be washed off with water. A hot, soapy wash will normally remove both the TLC and the black paint.

Storage: Unsealed TLC mixtures should be stored out of direct sunlight. Surfaces coated with unsealed TLC should ideally be cleaned (the TLC removed) each day. If coated surfaces are stored overnight, they should be kept out of UV light, and in a solvent and dust-free environment. The colour-temperature response of all coated surfaces should be checked at regular intervals to ensure that no loss of calibration has occurred during use, or between experiments, etc..

NOTES ON THE USE OF TLC SOLUTIONS

The preferred solvent for use with TLC mixtures is acetone (CAS Registry No. 67 - 64 - 1). An alternative is petroleum ether, boiling range 40 - 60^{o}C (CAS Registry No. 8032 - 32 - 4). Both solvents are flammable and readily available through laboratory chemical suppliers.

The use of 15% (weight) TLC solutions is recommended, however, it should be possible to increase the liquid crystal concentration to 20% in most cases with no problems.

Because of the nature of the preferred solvents for TLCs and the care that needs to be exercised in their use, it is recommended that the materials are applied as the isotropic melts.

MICROENCAPSULATED TLC SLURRIES (SLN40 SERIES)

Pigments for use in the manufacture of temperature-sensitive color change coatings

Temperature-sensitive color change tracer particles for use in fluid flow field studies

SLURRIES FOR COATING MANUFACTURE

TLCs can be used as color change pigments in the form of microencapsulated slurries in water. The products are available as 40% (weight) solids content with microcapsule diameters centered in the range 10-15 microns. They are custom formulated to the required color change properties. These slurries can be used to make sprayable TLC coatings by addition to aqueous binders. They are designated by the product code SLN40 followed by the color play (e.g. SLN40/R35C1W).

TRACER PARTICLES FOR FLUID FLOW STUDIES

In the microencapsulated slurry form, TLCs can also be readily used as tracer particles in fluid flow studies. An optimized microcapsule diameter range for such products has been determined to be 50-100 microns, and products with microcapsule diameter distributions in this range are recommended for this type of application. Other microcapsule diameter distributions can be made to order. Again, 40% is the preferred solids content.

CUSTOM MANUFACTURE

All microencapsulated slurries are manufactured to order. They can be tailor-made to customer requirements of, for example, colour change properties, microcapsule diameter distribution and solids content. For most common applications where average capsule diameters are between 10 and 100 microns, the preferred solids content is 40%, but products with higher and lower solids levels can be made.

PACK SIZES

100g, 250g and 500g

Note: Since all slurries are manufactured to order, 100g is the minimum order quantity.

GUIDELINES FOR USE AS TRACER PARTICLES

1. Some simple tests need to be carried out before proceeding.

   i) **The compatibility of the carrier fluid must be determined**. This can be done by adding some TLC slurry to a small sample of the carrier fluid and checking the stability of the color play response with time. The color-temperature response should be stable for the duration of the study.

   ii) **The optimum doping level should be evaluated**. This will depend on the nature of the study. As a starting guide, a doping level between 0.01 and 0.1% is recommended. However, it may be that the optimized level falls outside this range.

2. The TLC slurry can be added directly to the carrier fluid. The composition of the slurry provided (40% capsule solids) should be borne in mind throughout to keep check on the doping levels. Alternatively, the slurry can be filtered before use if the carrier is not 100% water, and the excess water in the slurry is not required. A note of the amount of water removed should always be kept for doping level calculations to be made accurately. Because the doping levels are relatively low (a 50 litre tank will only require approximately 65ml slurry (40% capsule solids) to dope to a level of 0.05% capsules), it may be easier to add the slurry/microcapsules to a small sample of the carrier fluid 1:1 and then add this to the remainder of the carrier.

3. For optimum performance, refer to the general notes below, particularly (a), (d) and (e).

STORAGE

Microencapsulated slurries should be stored in a refrigerator (5 -10^{o}C) when not in use - DO NOT FREEZE.
If stored correctly, the materials should have shelf lives of at least 6 months.

NOTES

a) Studies should always be carried out against a dark, preferably black background.

b) The interactions likely to occur between the TLC and any materials used with it to produce color change effects must always be considered. The color change properties of TLCs are produced by a very delicate and sensitive arrangement of molecules, and it is very easy to change and even destroy them.

c) The carrier fluids must be aqueous. Recommended fluids include water, glycerol, ethylene glycol, and other similar low molecular weight polyhydric alcohols. Using mixtures of such highly hydroxylated materials with water, it is possible to produce a range of carrier fluids with a variety of viscosities to suit most applications.

d) The colors observed depend not only on temperature, but also on the angles of illumination and observation. Color play specifications supplied with materials have been calibrated using a technique with both incident and reflected light normal to the surface of a thin film of TLC. In the use of the materials as tracer particles in fluids, illumination and viewing are generally not carried out from the same direction, and the observed color change properties will probably be different to those supplied in the materials specification. In addition, TLCs have different properties when suspended as droplets in bulk fluids as opposed to their use in thin films on solid surfaces. Therefore, it may be necessary for the user to recalibrate the color play properties of the materials to suit the particular method of use.

e) As with all TLC applications, the better the illumination, the brighter the colors reflected by the TLC. However, the use of incandescent lamps close to the materials should be avoided if possible, as the materials are sensitive to UV light, and the color play properties will change on prolonged exposure. Color temperature profiles should be checked at regular intervals to ensure that no shift has occurred.

SPRAYABLE TLC COATINGS

SPN100 and SPN300 Series

Two series of TLC coatings are available. Both are aqueous, acrylic-based and designed for application by spraying through an airbrush or similar compressed gas sprayer. They have good adhesion to most surfaces and matt and gloss finishes are achievable by varying the coating thickness.

SPN100 Series - For optimum color brightness and ease-of-use.
They can be removed easily by washing with water.

SPN300 Series - For some degree of water resistance.
They can be used underwater for limited periods of time.

Note: Once formulated, SPN300 Series coatings have limited lifetimes before the color play profile changes and the color brightness diminishes. The coating is supplied as a 2-part system and it is recommended that the coatings are made up immediately before use. Useful lifetimes are not more than four (4) weeks from the date of mixing.

The use of microencapsulated sprayable TLC coatings overcomes many of the problems associated with using unsealed TLC mixtures, although the reflected colors are less bright. Applied as a thin film, the coatings will dry to give a finish, which will resist light abrasion. They can be sprayed directly onto the test surface and are particularly useful when the surface is not flat.

PACK SIZES

250g and 500g

Note: Since all SPN Series coatings are produced to order, 250g is the minimum order quantity.

GUIDELINES FOR USE

1. Clean surface thoroughly to remove all dirt, grease, fingerprints, etc. Acetone, petroleum ether, and other common organic solvents may be used. Ensure that the surface is completely dry before proceeding.

2. **Coat surface black**. If the surface is already black or sufficiently dark, the TLC coating may be applied directly. Black water-based paints SPB100 and SPB300 are available which will air dry in 20-45 minutes when sprayed through a good quality compressed gas sprayer like an artist's airbrush. Applying the black paint by brush is not recommended, as uneven coatings affect the thermal response properties of the TLC. The black coating must be completely dry before the TLC coating is applied.

3. **Apply the TLC coating**. The TLC coating may separate to some extent on storage, and should be mixed thoroughly before use. The following instructions are a guide to provide the user with a starting point from which to optimise the application techniques (coating thickness, etc.) specific to their needs. Minimum application, surface and drying temperatures of 20°C are required for best results.

   i. Spray through airbrush (15-20cm) above substrate surface.
   ii. Air brush pressure = 20 psi/1.41kgcm^{-2}/1.3 bar (approx)
   iii. Drying times at 20-25°C are 30-45 minutes for SPN100 and 20-30 minutes for SPN300, depending on coating thickness. This can be accelerated by gently blowing warm air onto the coating.
   iv. The coating thickness alters the surface texture. Thin coats are matt and slightly rough. Thicker coats flow together more, giving smoother gloss finishes.
   v. Coating thickness and surface texture will affect the brightness and shade of the color produced, and may also affect the temperatures at which each color appears. Generally, the thicker the coat the lower the onset of color. Too thick a coating results in the normally bright colors appearing milky, more noticeably at the red end of the spectrum.
   vi. Optimum dry film thicknesses are around 10 microns. To achieve this, a total wet film thickness of around 100 microns will need to be applied. Best results are likely to be achieved by building up the coating gradually, drying between applications.
   vii. 250 grams should be adequate to cover 2.5m^2.

4. The microencapsulated TLC coating is now ready for use. The colour play should be checked and calibrated if necessary. Prolonged exposure to temperatures in excess of 70°C should be avoided if possible.

5. **Cleaning up**: Dry SPN300 coatings have a good degree of water resistance. They can be removed by vigorous scrubbing with hot, soapy water or, alternatively, acetone. SPN100 coatings can be easily removed by washing with water.

6. **Storage**: Ideally, all TLC coatings should be stored in a refrigerator at 5-10°C but MUST NOT BE FROZEN. They should be allowed to warm up to room temperature (20-30°C) before use. Surfaces coated with microencapsulated TLC coatings should be stored out of UV light, and in a solvent free environment. Ideally, no stress should be applied to the coated surface. The color play response should be checked at regular intervals to ensure that no loss of calibration has occurred. If stored correctly, microencapsulated TLC coatings have a useful shelf life of at least 6 months.

TO MAKE TLC COATINGS YOURSELF

Use the appropriate SLN40 Series TLC slurry and binder: CC100 for SPN100 Series and CC300 for SPN300 Series. Add the binder to the slurry, 3 parts binder to 1 part slurry, with thorough mixing. Both the binder and slurry should be mixed well before use. Ideally the finished coating should also be filtered before use.

SPRAYABLE BLACK BACKING PAINTS AND CLEAR OVERCOATS/BINDER SYSTEMS

SPB100 and SPB300

CC100 and CC300

BLACK BACKING PAINTS

Two water-based, TLC-compatible, sprayable black-backing paints are available. Both adhere well to most surfaces and can be modified to give matt or gloss finishes by varying the coating thickness.

SPB100 - For use in air (not under water).

SPB300 - Dries to give a good degree of water-resistance.
Can be used in underwater studies for limited periods of time.

CLEAR OVERCOATS/BINDER SYSTEMS

Two aqueous binder systems are available for addition to SLN40 Series TLC slurries to enable the customer to make finished coatings. The products can also be used as clear protective over-varnishes.

CC100 - Acrylic system for manufacture of SPN100 Series coatings.

CC300 - Acrylic system for manufacture of SPN300 Series water-resistant coatings

PACK SIZES

250g and 500g

GUIDELINES FOR USE

The following instructions are a guide to provide the user with a starting point from which to optimise the application techniques (coating thickness, etc.) specific to their needs. Minimum surface application and drying temperatures of 20°C are required for best results throughout

SPB100 and CC100 (as an over-varnish)

1. Spray through air-brush/spray gun 15-20cm above the surface. Pressure approximately 20psi/1.41kgcm^{-2}/1.3bar.

2. Drying times at 25-30°C are 30-40 mins. These can be shortened by gently blowing warm air.

3. Surface texture depends on coating thickness. Thin coats are matt and slightly rough. Thicker coats flow together more and give smoother, gloss finishes.

4. The dry coating can be removed by washing with hot, soapy water.

SPB300 and CC300 (as an over-varnish)

1. Spray through air-brush/spray gun 20-25cm above the surface for a gloss finish, and 35-30cm for a matt finish. One heavy coat gives the best gloss finish and several light coats give the best matt finish. Pressure approximately 30psi/2.11kgcm^{-2}/2.0bar.

2. Drying times at 25-25°C are 20-30 mins. A minimum drying temperature of 20°C is required.

3. A continuous unbroken coating is necessary for best water resistance. The coating must be completely dry before immersion. Pin holes in the dried coating surface allow water to get beneath the coating and cause it to lift.

4. Removal: either Scrub vigorously with hot, soapy water or wash with acetone.

NOTES

a) All equipment (e.g. spray gun, containers, etc.) should be washed with hot, soapy water immediately after use.
b) The coatings will separate to some extent on standing, and should be mixed thoroughly before use.
c) Store at 20-30°C. DO NOT FREEZE.
d) All coatings can be diluted with water.

TLC COATED POLYESTER SHEETS

STANDARD PRODUCTS

Standard sheets use a substrate of 100 micron clear polyester film (Mylar). The sheets are printed on one side, first with the microencapsulated TLC coating, then with a black backing ink. The colour change properties of the TLC coating are viewed through the clear, uncoated side of the sheet. Standard sheets are available with, or without, adhesive-backing (pressure-sensitive adhesive); the protective release-liner can be removed for easy adhesion to a variety of flat surfaces. Standard size is 12 in x 18 in (30cm x 45cm) and the color plays held as standard stock items are set out in the table below.

SPECIFICATIONS

Substrate:	Polyester sheet, 100 microns thick
Size:	12 in x 18 in (30cm x 45cm)
Total thickness:	Without adhesive: 100-175 microns; with adhesive: 175-225 microns
Colour Change:	Black to red, through the other colours of the visible spectrum to blue, with increasing temperature, and finally to black again.

Colour Play	Red Start (Black to red) ºC	Green Start ºC	Blue Start ºC	Clearing Point (Blue to Black) ºC	Bandwidth (Blue start minus red start) ºC
R20C5W	20.0	21.0	25.0	41.0	5.0
R25C5W	25.0	26.0	30.0	44.0	5.0
R30C5W	30.0	31.0	35.0	46.0	5.0
R35C1W	35.0	35.2	36.0	49.0	1.0
R35C5W	35.0	36.0	40.0	49.0	5.0
R40C5W	40.0	41.0	45.0	52.0	5.0

TOLERANCES

For C5W sheets, Red start temperatures are ±1ºC and the bandwidth is ±1ºC
For C1W sheets, Red start temperatures are ±0.5ºC and the bandwidth is ±0.2ºC

For example; for R25C5W, the red start can be between 24 and 26 ºC: if the red start is 24 ºC, the blue start will be between 28 and 30 ºC and if the red start is 26 ºC, the blue start will be between 30 and 32 ºC. Likewise, for R35C1W, the red start can be between 34.5 and 35.5 ºC: if the red start is 34.5 ºC, the blue start will be between 35.3 and 35.7 ºC and if the red start is 35.5 ºC, the blue start will be between 36.3 and 36.7 ºC.

CUSTOM MANUFACTURE

In addition to the standard range of sheets, LCR HALLCREST offers a custom-manufacturing service, tailor-making products to customer requirements. A wide range of substrates can be used, both rigid and flexible, with different thicknesses. Specific problems, like UV stability and water-resistance, for example, can also be addressed.

GUIDELINES FOR USE

1. Clean surface thoroughly to remove all dirt, grease, etc. Acetone, petroleum ether and similar organic solvents may be used. Ensure that the surface is *completely* dry before proceeding.
2. Remove protective backing from adhesive and place sheet lightly in position on surface. Press down firmly with fingers in center of sheet and smooth outward, in each direction in turn, to ensure that no air bubbles are trapped between the sheet and the surface.

REMOVAL

After use, the sheet can be removed from the surface by pulling it off, although the sheet will be probably destroyed in the process. Residual adhesive can be removed by washing with a suitable solvent. The choice of solvent will depend on the nature of the surface to which the sheet was attached.

STORAGE

Unused sheets should be stored out of direct sunlight at room temperature (20-25°C), in a solvent-free environment. Sheets in position on test surfaces should be protected from UV light and organic solvents wherever possible. The color play properties of the sheets should be checked at regular intervals. If stored correctly, the sheets should have shelf lives of up to a year or more.

LIFETIMES

TLC coated sheets should retain their color play characteristics for many months under normal handling conditions. Continued submersion and temperature cycling in hot (50ºC+) water baths will accelerate degradation, as will continued temperature cycling at elevated temperatures in general, and exposure to UV light.

SIMPLE EXPERIMENTS FOR STANDARD PRODUCTS

1. Dampen the tip of a small cloth or sponge with water and "write" with it on the surface of the R20C5W sheet. The evaporative cooling that takes place will cause color changes.

2. Place the R20C5W film in a refrigerator and observe the change in colors (from blue to green to red to black). Remove it from the refrigerator and observe the reverse order of color changes as the temperature rises (from black to red to green to blue). In the winter time, a window pane may also be used to cool the film.

3. Using the R25C5W and R30C5W sheets, you can determine the relative hand temperatures of a group of people. Due to variations in blood circulation, a wide range of temperature results may be obtained in the group. Even though normal body temperature is 37°C, you will note immediately that skin temperatures fluctuate considerably from this value. Should a person not be able to cause a color reaction, even on the R25C5W, move the sheet away from the fingertips to the wrist area. You will eventually find a warmer temperature.

These simple experiments are designed as an introduction to the usefulness of TLC products. The materials have many applications, not only in testing, but also in industry, medicine and the home.

Note: As with all TLC applications, the better the incident lighting, the brighter the colors reflected by the TLC. However, the use of incandescent lamps too close to the TLC sheet should be avoided, as the materials are sensitive to UV light and the colour play properties will change on prolonged exposure.

FREQUENTLY ASKED QUESTIONS

Are there any standard color plays available?

All microencapsulated TLC slurries and sprayable coatings are manufactured to order. However, HAND TOUCH formulations (R25C5W - red start 25°C bandwidth 5°C [blue start 30°C]) are routinely used to make promotional products and this formulation is available as the microencapsulated TLC slurry and sprayable TLC coating , in small packs, from the www.thermometersite.com website. Color plays of the standard TLC coated polyester sheets are given on page 15 of this document.

Over what temperature range can TLCs be used?

TLC mixtures can be made with red start temperatures between -30°C and 120°C and bandwidths (red start to blue start) between 1°C and 20°C. Single color below [SCB] (also known as clearing point or temperature-insensitive) LC mixtures are available with Ch-I transitions between 0°C and 60°C. Even though TLC mixtures are available with color-change properties over a wide temperature range, for most practical purposes, the working temperature range for TLC mixtures is 0°C to 50°C. Below 0°C, response times increase significantly to the point where many experiments become impractical. For microencapsulated TLC products, prolonged exposure to elevated temperatures above 50°C will cause degradation of the polymers used in microencapsulation and coating manufacture. This will initially result in a loss of calibration and color brightness and eventually lead to complete loss of color change properties. The higher the temperature is above 50°C, the faster the degradation. Most TLC products have very short useful lives when used above 75°C. Unsealed TLC mixtures with color change properties at elevated temperatures (50 to 100°C) are generally much more stable at their working temperatures than TLC mixtures with color change properties at lower temperatures. More detailed information on the stability of TLC mixtures is available in TLC Technical Note S.

What are the response times of TLCs to temperature changes?

Response times very, depending on the composition of the TLC mixture, the form in which it is used, how it is applied – and the temperature. At ambient temperatures (15 to 25°C), generally accepted values vary from a few tens of milliseconds for chiral nematics to a few hundreds of milliseconds for cholesterics. Values as low as a few milliseconds have been measured by some researchers for chiral nematic TLC mixtures, when they have been applied as coatings with dry film thicknesses of about 10 microns. As indicated above, at temperatures below 0°C, response times increase significantly. Since the color changes are produced by the movement of molecules (winding and unwinding the helices), response times are greater at lower temperatures because there is less kinetic energy available for the molecules to move. Response times are the same in both the heating and cooling cycles.

Do TLCs exhibit hysteresis?

Hysteresis is found in some TLC mixtures when the cholesteric phase is entered from higher temperatures (through the Ch-I transition) in the cooling cycle. This is particularly common in SCB (temperature-insensitive or clearing point) mixtures but it can be minimized by optimizing the TLC mixture composition. Hysteresis is not usually noticeable in most temperature-sensitive TLC mixtures. More details are given in the Handbook of TLC Technology.

Are TLCs UV stable?

Most TLCs are very sensitive to UV light and exposure should be avoided. For most research and testing applications, UV exposure is not an issue because of the nature of the experimental protocols and the short timeframes. However, for applications requiring some degree of UV stability, further protection can be achieved by using materials with UV absorbing properties in combination with the TLCs whenever possible (e.g. in overcoats, etc.). More detailed technical information on the stability of TLC mixtures is available in TLC Technical Note S.

What chemicals are TLCs incompatible with?

TLC mixtures are essentially oils and are very sensitive to contact with common organic solvents, oils and waxes, particularly low molecular weight materials. These have small molecules which can penetrate the microcapsule walls and destroy the highly ordered molecular structure of the TLC which is what gives them their unique color change properties. TLC products are much more likely to be stable when they are used in combination with aqueous/hydrophilic materials. Even then, success cannot be guaranteed which led us to develop our own range of compatible black backing and clear overcoat/binder systems, details of which are given on pages 13 and 14 of this document. At all times, care must be taken to ensure that solvents and oils do not contaminate TLC products.

Do the TLC products contain any heavy metals?

No - they do not contain any heavy metals. TLC mixtures are comprised of organic esters which have low inherent toxicity.

What is the shelf life of the TLC products?

A shelf life of at least 6 months is guaranteed for all TLC products provided that they are stored correctly. Details are given on the relevant page for each different type of product earlier in this document. All TLC products are sensitive to UV light and elevated temperatures (see above and TLC Technical Note S) and exposure will cause degradation. This will initially result in loss of calibration and color brightness and eventually lead to complete loss of thermochromic functionality.

Can TLCs be made to reflect right and left handed circularly polarized light?

Yes – see the Handbook of TLC Technology for more details.

Can TLCs be made to reflect in the UV and IR regions?

Yes – see the Handbook of TLC Technology for more details.

What are the values for the common physical properties of TLC mixtures?

Over the years, different researchers have used different techniques to give different values for different TLC products. The generally accepted values fall into the following ranges: Specific heat: 1600 - 1800 J/kg /°K; Thermal conductivity: 0.2 - 0.4 W/m//°K; Refractive index: 1.5 - 1.6

What is the best size for TLC microcapsules in Flow Visualization studies in Fluids?

Most researchers have claimed that they have achieved the best results with TLC microcapsules having diameters around 100 microns. We recommend using this size range, however, we also offer TLC slurries with average microcapsule diameters as low as 10 microns and as high as 1000 microns or more.

Can TLCs be used as tracer particles in liquids other than water?

Yes – but water should ideally always be present (i.e. the carrier fluid must always be aqueous). Recommended fluids include glycerin (glycerol), ethylene glycol and other similar low molecular weight polyhydric alcohols. Using mixtures of such highly hydroxylated materials with water, it is possible to produce a range of carrier fluids with a variety of viscosities to suit most applications.

Why are color play bandwidths narrower when TLCs are used as tracer particles in fluid flow studies?

The colors observed depend not only on temperature but also on the angles of illumination and observation. Color play measurements are carried out using a technique with both incident and reflected light normal (at right angles) to the surface of a thin film of TLC. In the use of TLCs as tracer particles in fluids, illumination and viewing are generally not carried out from the same direction and the observed color change properties will probably be different to those on the product certificate (the bandwidth will appear narrower). More details are given in the Handbook of TLC Technology.

What is the relationship between the viscosity of shear-sensitive LC mixtures and their working flow speed ranges?

There is a qualitative relationship between the viscosity of the LC and its flow speed operating range – the lower the viscosity, the more sensitive the response of the LC. Low viscosity LC mixtures work at lower flow speeds and higher viscosity LC mixtures work at higher flow speeds. We are not aware of any firm quantitative relationship between LC viscosity and working flow speed range.

Can two different TLC products be used together?

Unsealed TLC mixtures cannot be used together without changing their properties. However, microencapsulated products - slurries and sprayable coatings - can. The properties of the individual TLC mixtures are protected by the microcapsule walls. For sprayable coatings, best results are achieved if the coatings are applied individually (rather than mixed), with the coatings with the lowest temperature color plays being closest to the observer.