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In-house Fabrication of Temperature Sensitive Paint for Turbine Cooling Research

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Cover Page Footnote

I would like to thank Dr Mark Ricklick for his guidance and support throughout the project. In addition, I would like to acknowledge Dr Faulkoner, Justin Grillot for helping with safety precautions needed for the project. Lastly, I am grateful for Yogesh and Anish's help during the experiments.

UNDERGRADUATE RESEARCH JOURNAL
Beyond

In-house Fabrication of Temperature Sensitive Paint for Turbine Cooling Research

Mayur D. Patel and Mark A. Ricklick

Abstract

Temperature Sensitive Paint (TSP) is a widely used method in measuring and visualizing flow separation and heat transfer. Compared to the cost and time consumption needed for methods such as pitot tubes, temperature sensitive paint is a cheaper alternative. Due to high usage in College of Engineering research projects, it was determined that in house fabrication of temperature sensitive paint would reduce time and cost limitations. For initial stages, literature research was performed to determine the recipe of intensity based TSP with luminophore and polymer binder that operated optimumly at temperatures from 0-100°C. Europium III thenoyltrifluoroacetonate was determined to be an effective luminophore to create a solvent for turbine cooling and heat transfer research. A standard operating procedure was also created such that it met the environmental and safety risk factors associated with fabrication of paint. Using an acrylic glass test piece with existing experimental setup, intensity data were obtained. Experiments resulted in intensity change magnitude and Arrhenius curve similar to commercially available TSP. In addition, in-house TSP was significantly cheaper and less time-consuming. Further research would involve calibration curve and developing a Pressure Sensitive Paint.

Introduction

Convection cooling has become an industry standard solution for the thermal inefficiency caused by increased turbine inlet temperatures in air-breathing gas turbine engines. For engine components such as turbine stators, rotors and rotor disks, overheating is prevented by cooling[1]. Therefore, understanding of flow and heat transfer under different conditions is a must.

There are several methods used to measure temperature: thermocouples, infrared, liquid crystals. However, thermocouples and liquid crystals require extensive data collection and data can be only obtained for locations where the sensors are placed. This results in limited spatial resolution. Infrared provides a temperature gradient but lacks the accuracy needed to understand the complex turbulent mixing through cooling. A superior number of sensors with higher sensitivity for heat flux measurements results in better data with the drawback of an increase in experimental costs. However, advancements in optical sensors have allowed for full-field measurements on complex aerodynamic models with much higher spatial resolution and a lower cost[2].

Temperature and pressure sensitive paints (TSP & PSP) are measurement sensors based on luminescence quenching that are currently used in research of gas turbine cooling research. As shown in Figure 1, a TSP measurement system consists of an excitation light source, test model with TSP applied, digital camera to take images, and computer for data processing.

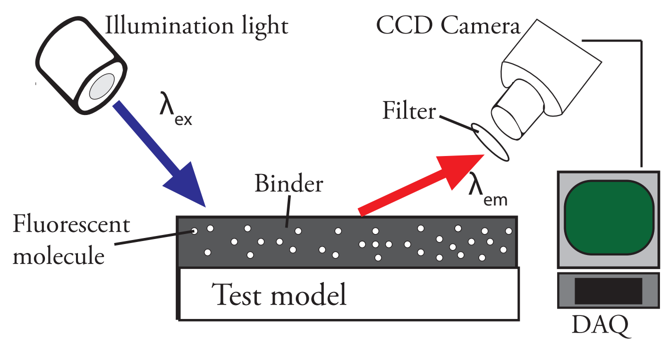


Figure 1. TSP experimental setup1.

This method limits human interaction with the test material, reducing experimental errors while increasing the accuracy of data acquisition due to increased special resolution. Therefore, TSP has proven to be an effective method that is widely utilized in the aerospace industry for a wide range of projects and research[3]. However, despite the advantages, TSP has its downsides when performing research at small universities. Initially developed in the 1970s by Russian scientists, TSP was gradually introduced to aerospace research organizations[4]. Although TSP is utilized at major institutions, cost remains a major disadvantage. Currently researchers at Embry-Riddle use 12-oz aerosol spray, which can cost several hundred dollars for experiments in temperature range of 0-100°C. Therefore, the motivation for this project was to fabricate TSP in-house to reduce cost and time lag associated with commercially available products.

Nomenclature

TSP: Temperature Sensitive Paint
Luminophore: An atom that is responsible for its luminescent properties in a molecule.
E_{nr}: Activation energy; the minimum quantity of energy that the reacting species must possess in Order to undergo a specified reaction.
MLC: Metal-ligand complexes

Background

TSP is composed of two primary components: luminescent molecules and polymer binder. Generally, transparent binder is used to bind luminescent molecules to the test model. Later, luminescent molecules are excited by directing illumination light of proper wavelength. This causes the molecules to be excited to an elevated energy level. The molecules return to their ground state by radiating luminescence, known as the process of thermal quenching. Molecules emit light of longer wavelength as a result of quenching as shown below in Figure 2. Lastly, using a scientific grade camera and computer, data is captured and processed.

Before addressing the details of intensity based TSP, it is important to address the process of luminescence. As shown in Figure 3 (Jablonski diagram), molecules in the paint are excited by an illumination light source, which excites them from their ground state. Immediately, the molecules return to back to their original state by releasing energy.

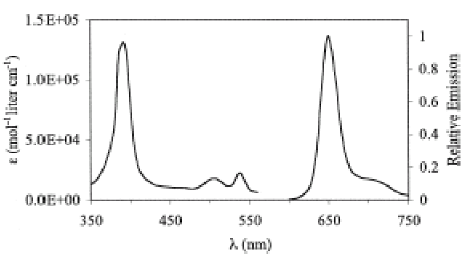


Figure 2. Wavelength of typical TSP during emission (right) and absorption (left) phase[1].

Change in luminescence can occur either in intensity or decay lifetime. In decay lifetime, the period of emission is traced with slow motion cameras. Whereas in the intensity method, brightness of the emission is traced with a sensitive camera such as a charge coupled camera (CCD). In the intensity method, black and white images are taken at reference temperature, and the intensity is compared with images taken at experimental temperatures. Depending on the needs of the experiment, both

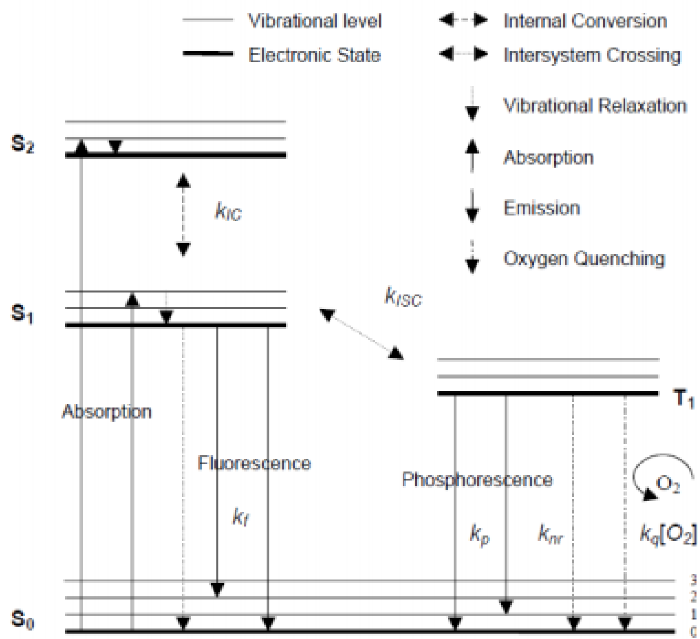


Figure 3. Transitions of energy state for luminophore (Jablonski Diagram)[1].

$$ln\frac{I(T)}{I(T_{ref})}=\frac{E_{nr}}{R}\left(\frac{1}{T}-\frac{1}{T_{ref}}\right) \quad (1)$$

methods have advantages and disadvantages. The intensity method allows for longer exposure times, whereas the lifetime decay method has much shorter exposure times[4]. However, intensity method is directly dependent on the distribution of luminophore on the surface. Due to the existing set-up at Embry-Riddle and its simpler method, fabrication of intensity based TSP was determined to be optimum.

TSPs work based on the process called luminescent quenching, where a change in temperature results in non-radiative emission for excited luminophore. Based on the changes, the relationship between temperature and luminescence can be determined[5]. The arrhenius equation explains the relationship between luminescent intensity *I* and the temperature *T*. The change in thermal energy is directly correlated to the change in the energy level of the molecule[6]. As shown below, E_{nr} refers to the activation energy and *R* is the universal gas constant[2]. Therefore using activation energy to determine the energy level change in the orbits between emitting level and deactivated state, temperature sensitivity can be described.

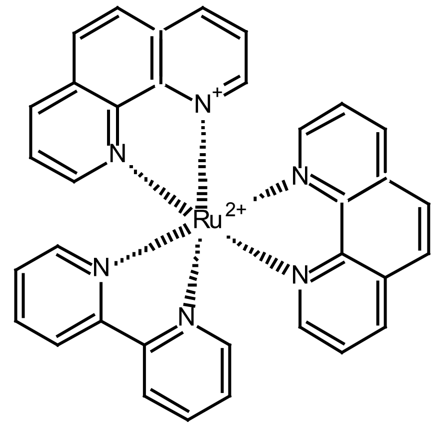
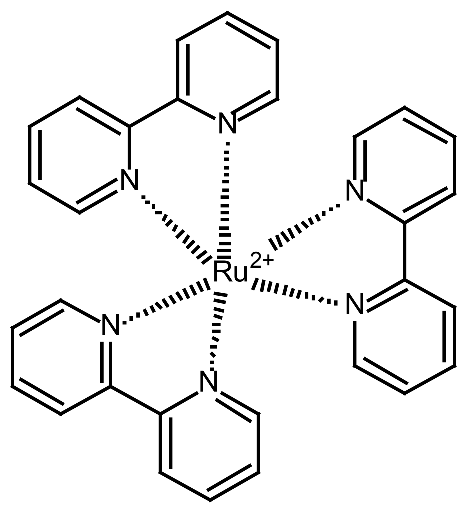
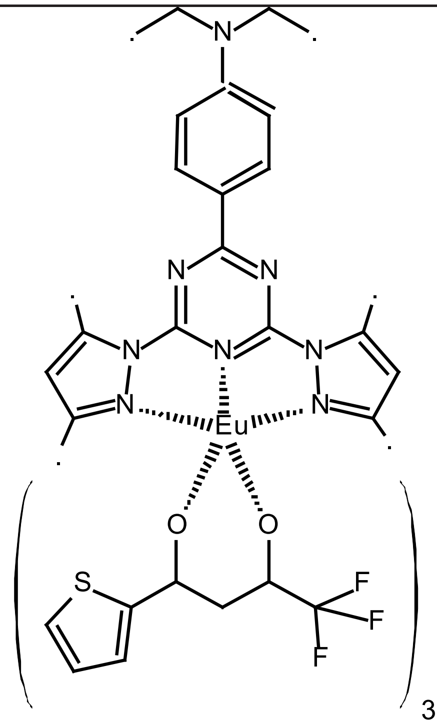
Compond [aconym]	Chemical Structure	λ_{abs}(max)	λ_{em}(max)
$La_2O_2S:Eu^{3+}$	solid state	385 nm	514 nm
Ruthenium-tris (1, 10-phenanthroline) $[Ru(phen)_3^{2+}]$ (various counter ions)		448 nm	579 nm
Ruthenium-tris(2,2'-bipyridne) $[Ru(bpy)_3^{2+}]$ (various counter ions)		320 nm 452 nm	588 nm
Europium(III)-tris(thenoyltrifluoroacetyl-acetonato) (2-(4-diethylaminophenyl-l-yl)-1,3,5-tri-azine) $[Eu(tta)_3(dpbt)$		417 nm	614 nm

Figure 4 TSP indicator compounds and their properties (λ excitation and emission wavelengths)[6].

Luminophore	Binder	Excitation wavelength (nm)	Emission wavelength (nm)	Usefule temp. ranage (degree C)	Max. log slope (%/°C)	Lifetime at room temp. (micor s)
Coumanin	PMMA	UV		20 to 100	-0.4	
CuOEP	GP-197	480-515		-180 to 20	-2.9	
EuTTA	Dope	350	612	-20 to 80	-3.9	500
Perylene	Dope	330-450	430-580	0 to 100	-1.9	0.005
Perylenedicar-boximide	PMMA	480-515		50 to 100	-0.7	
Pyronin B	PMMA	460-580		50 to 100	-4.6	
Pyronin Y	Dope	460-580		0 to 100	-5.5	

Figure 5. TSP indicator compounds and their properties[6].

There are numerous types of indicators that can be used in TSPs, depending on the experimental needs. Thermographic phosphors and MLC are currently two primary substances used in TSP as luminophore. Thermographic phosphors have great thermal stability and are effective at temperatures up to 2000 °C since they emit from singlet (quantum state of a system) excited state[6]. Thus, for combustion or cryogenic wind tunnel research, thermographic phosphors are used. Conversely, MLCs are useful for low temperatures ranging between 0 to 160 °C. As shown in the Figure 4, these are some of the indicators commonly used for TSPs.

The chemical structure of luminophore is important since it reflects the performance in the process of luminescence. Since the excited state is deactivated via molecular collisions, factors such as oxygen ions, transition to an excited state, and have the ability to emit in form of luminescence[6].

Among several publications of TSP, Lui and Sullivan's publication on TSP was utilized as a reference to compare the performance characteristics of commonly used luminophore. In addition, the arrhenius relationship, which relates the change in intensity ratio with respect to temperature graph was obtained for three different TSPs.

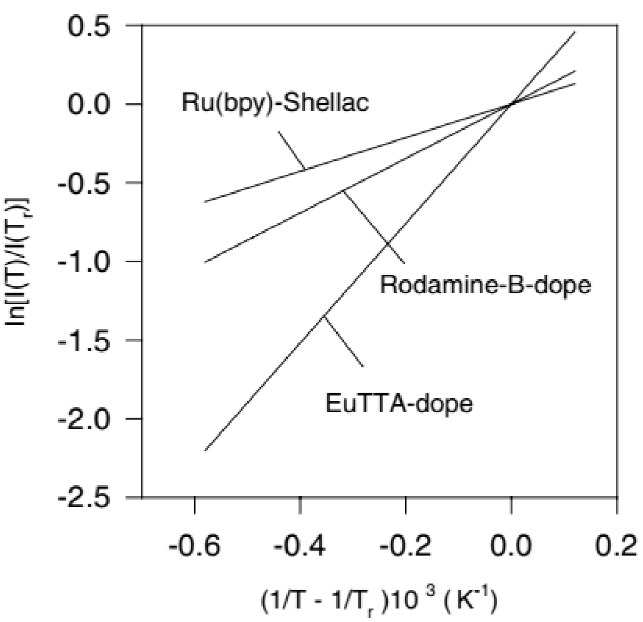


Figure 6. Arrhenius plot for three different type of TSPs[2]..

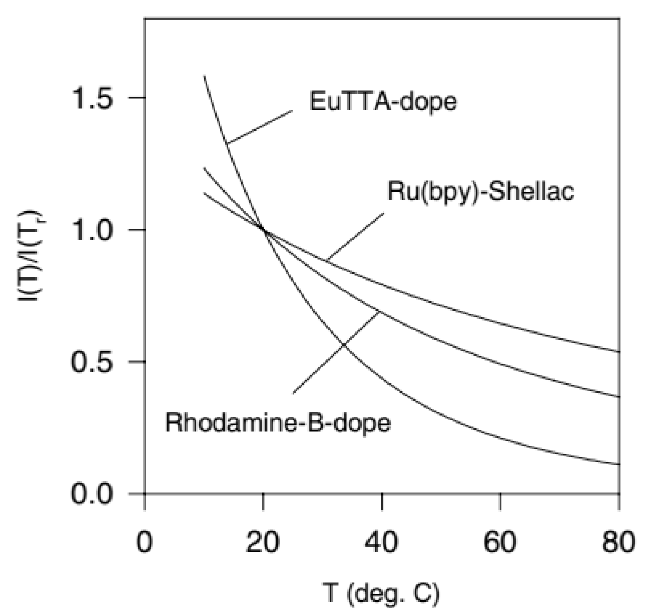


Figure 7. Change in intensity vs temperature of three different TSPs[2].

It was utilized to determine a viable TSP that can be adapted for cooling research.

Based on the available literature review, it was determined that EuTTA-dope TSP would be most applicable for cooling research at Embry-Riddle due to its high change in the intensity ratio. In addition, EuTTA operates within the required temperature range (0-100ºC) for research conducted at Embry-Riddle. In addition, the recipe provided by Lui[2] was used to fabricate the in-house TSP.

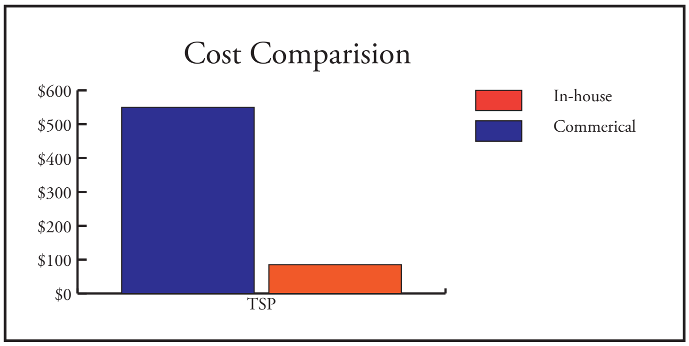


Figure 8. Cost comparison of TSP.

Experimental Setup

Using the recipe for TSP based on EuTTA, in house fabrication of temperature sensitive paint was performed. Due to luminophore's sensitivity to oxygen and ultra-violet light (excitation wavelength for EuTTA), safety precautions were taken. With the guidelines provided by the EuTTA vendor and environmental safety department at ERAU, a safety operating procedure (SOP) was developed such that it met the requirements of health and safety hazards. The setup included a UV resistant desiccator filled with nitrogen gas as required for EuTTA. In addition, ultrasonic sonicator was used to mix chemicals, and fabricated TSP was placed under UV protectant bottles for transportation from the chemistry lab to the gas turbine lab.

The test section is 1-inch thick optically clear acrylic with dimensions of 3 by 3 inches. One of the test section's side was coated with 8 coats of TSP applied uniformly at intervals of 5 minutes with the help of a spray paint gun such that the results can be compared with commercially available TSP. Using a heat gun, the piece was heat treated to the temperature of 100ºC (maximum experimental temperature) for 30 minutes to account for hysteria (excited molecules) and left overnight. Four reference images (cold image) were taken under UV light (excitation wavelength) with a scientific grade CCD camera at the room temperature of 28.9°C. The camera was thermos-electrically cooled, positioned using a computer operated traversing system with a long pass filter (550 nm) to block out excitation light. The camera's aperture was fully open with exposure time less than 1 second. Later, the temperature was raised to 100°C using a hand-held heat gun for data images (hot image). Temperature was measured using an IR gun placed directly above the camera to keep consistent distance for each measurement. Similarly, four hot images were taken.

Results

Four images at reference temperatures of 28°C and at 100°C were taken. Based on the black and white images, there is an evident decrease in the intensity as the temperature increases.

Preprocessed Data

In addition, data images were taken at intervals of 10°C to develop an Arrhenius relationship of TSP. There is a gradual change in the intensity as TSP reacts to the different temperatures.

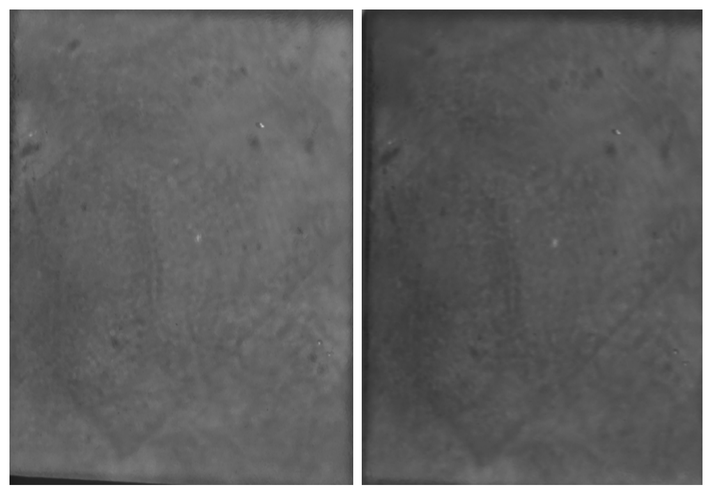


Figure 9. Black and White (B&W) Images of Test piece at 28°C (left) and 100°C (right).

Post-processed Data

In order to determine average intensity, the intensity of five points (one on each corner and one at the center) were determined. Using computer software to post-process data, an arrhenius plot was drawn to compare experimental data with literature research data. Figure 13 is a representation of the experimental data for change in intensity ratio with increase in the temperature superimposed onto Liu's curve.

As seen in the Figure 10, fabricated TSP does have a decrease in the intensity ratio as the temperature increases. In addition, the trend line is similar to the literature

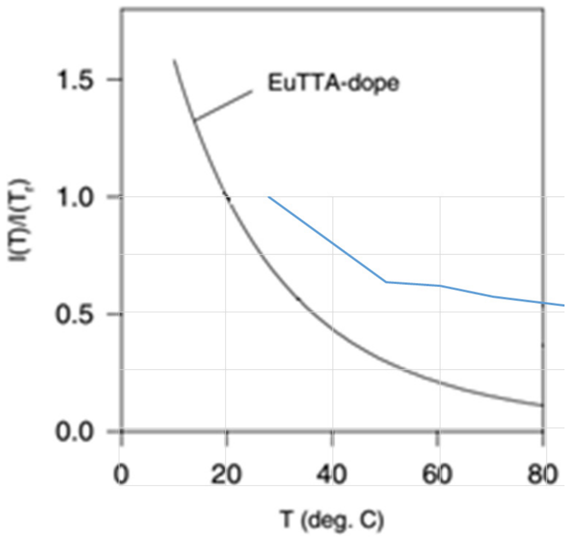


Figure 10. Arrhenius plot for fabricated TSP (blue) and literature data[2].

research data of Lui and Sullivan[2]. Although, it is noteworthy that fabricated TSP does not have the same sensitivity since the intensity ratio is at 0.5 for temperature of 80°C (compared to 0.125 from Lui's experiments). Errors can be the result of several factors such as experimental setup, mixing and processing of data. Measurement errors (only 20 mg of EuTTA required) or uneven distribution of luminophore in binder are two potential factors during the fabrication phase. Additionally, the use of handheld heat gun to heat test piece can result in irregularities. The use of only five data points to measure intensity ratio can also cause discrepancy in the Arrhenius plot.

Based on the images and Figure 11, 12, and, 13, there is an evident reaction of TSP with the increase in the temperature, as predicated. However, it lacks consistency

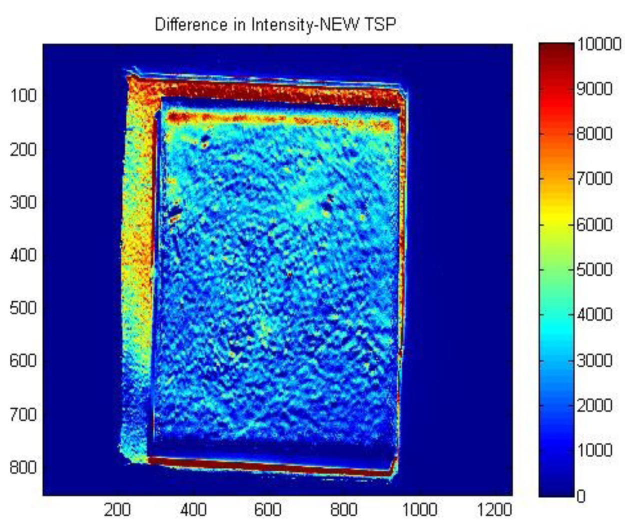


Figure 11. Difference in the intensity ratio between reference temperature and at 50°C.

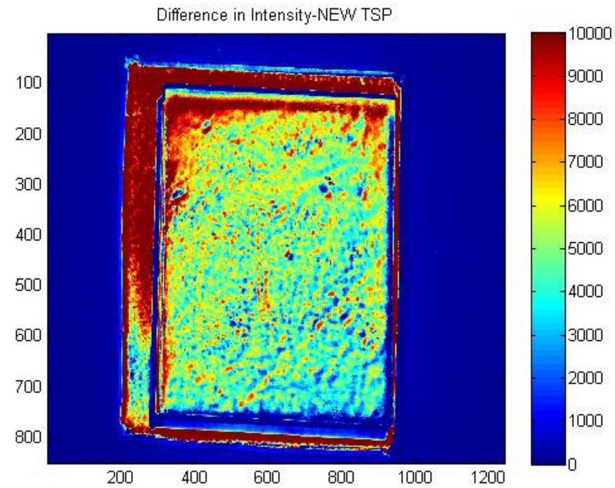


Figure 12. Difference in the intensity between reference temperature and at 90°C.

throughout the piece since some of the regions are reacting more compare to others. As seen in Figure 11 and 12, the left side of the test piece has a major change in intensity compared to the right- a result of uneven distribution of paint. In addition, the Arrhenius plot of experimental data lacks the drastic decrease in intensity ratio as seen in the experiments of Liu. Therefore, the experiment was performed again and accounting for the errors such as paint consistency. This time, even coats and heat treatment were used to raise the temperature

As witnessed, the second experiment resulted in a fairly even distribution of the intensity change over the test piece. However, it is to noteworthy that, unlike the previous experiment, 14 coats of paint were applied evenly at 5 minutes of intervals. Thus, in-house fabricated TSP demonstrates the need for consistency and, more importantly, how the thickness of the paint plays a role in its effectiveness.

For a 60°C change, the difference in the intensity is approximately 10000. Thus, it can be determined that the TSP is working as it should in its operating range of temperatures after comparison with the change in intensity of commercially available UNI-COAT's TSP. Although there is minor variation in the intensity gradient, it is a result of uneven distribution of paint on the surface since TSP was applied with handheld spray paint gun. The intensity ratio graph contains disparities when the experimental data (orange) is compare to Lui's experiment. However, unlike Lui's experiments, our reference temperature (28.9°C) is higher[2]. Therefore, reference images will have a lower intensity compared to Lui and thus result in variation in the Arrhenius curve.

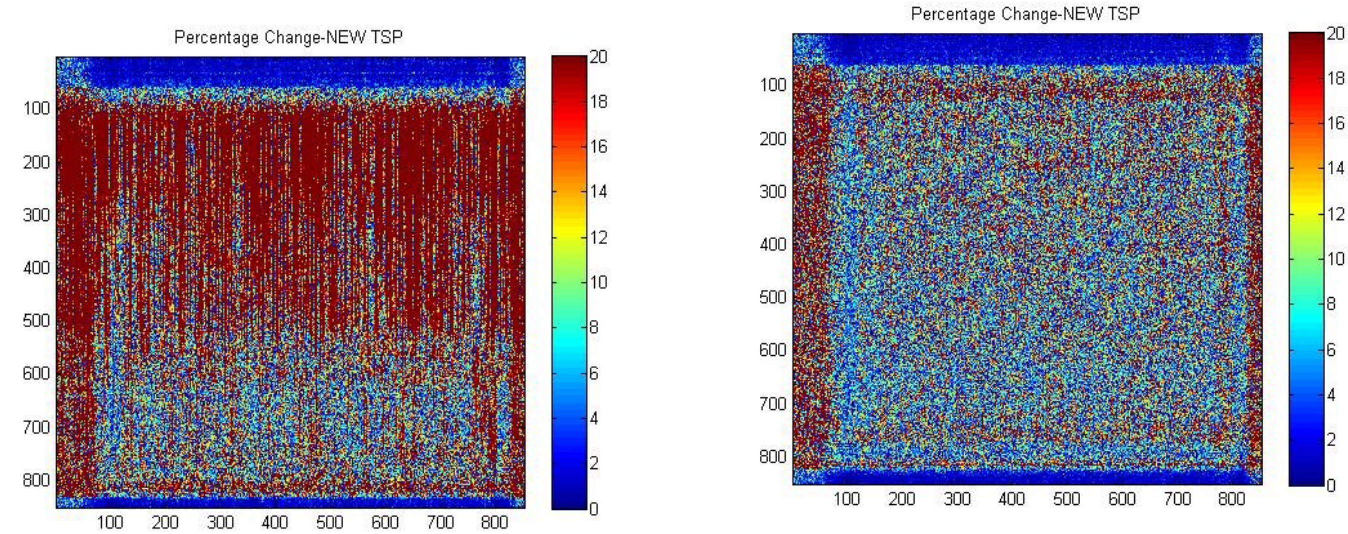


Figure 13. Percent change in the intensity ratio of TSP at 90°C (top) and 50°C (bottom).

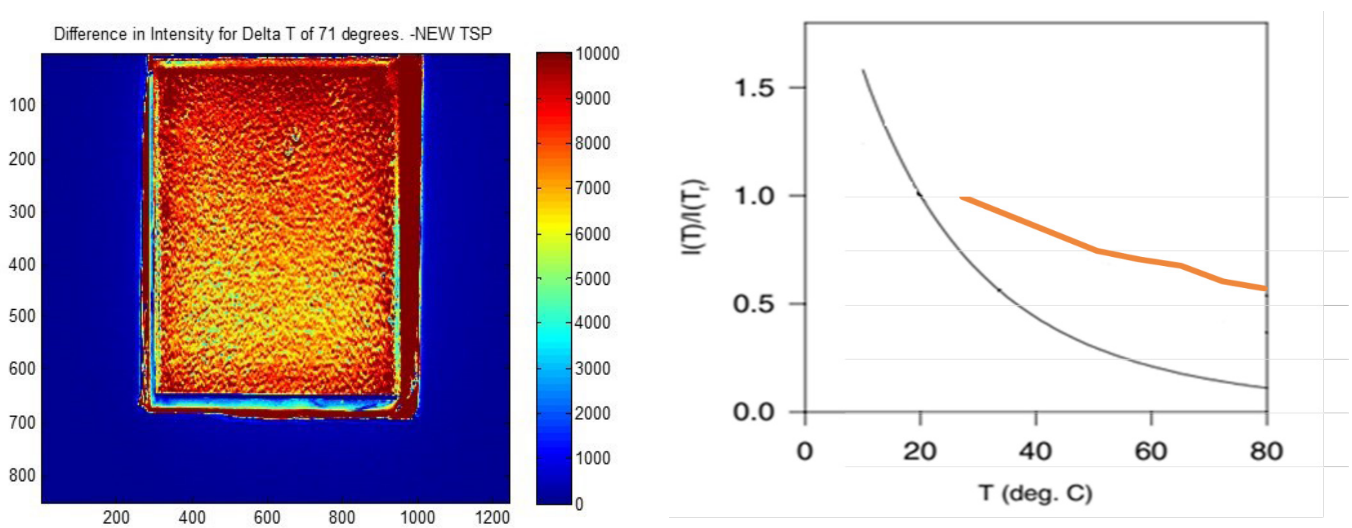


Figure 14. Difference in the intensity at 90°C (top) and Intensity ratio vs Temperature (bottom)[2].

Conclusion

Temperature sensitive paint was at one fifth the cost of commercially available TSP and in only 30 minutes to fabricate. The TSP's effectiveness was verified using a simple temperature change experiment. Based on the inconsistencies resulted from the first experiment, a standard operating procedure was developed such that the experiment resulted in comparable result to industry available TSP. Further experiments would be done to develop a temperature calibration curve for in-house TSP so that it can be utilized for heat transfer experiments. Future studies would also include fabrication of Pressure Sensitive Paint (PSP) that factors in the temperature changes.

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Author

Mayur D Patel

Mayur Patel is an accelerated masters student of Embry-Riddle Aeronautical University, pursing a degree in Aerospace Engineering with a focus in Aerodynamics & Propulsion Track. He has worked on campus as teaching assistant and participated in projects such Quiet Flight Challenge (Eagle Flight Research Center) and Robotics Quadcopter. Currently, he is studying the design of Turbine Cascade Wind Tunnel to further the computational heat transfer experiments by implimenting experimental validation.

Dr. Mark A. Ricklick

Dr. Mark A. Ricklick is an Assistant Professor in the Aerospace Engineering Department, since January 2014. He obtained his Doctorate degree and served as a Post-Doctoral Researcher at the University of Central Florida. From 2012 until 2013 he supported companies in the Turbomachinery, Automotive, Aerospace, and Agricultural industries with CAE investigations as an Applications Engineer.

Dr. Ricklick is author/co-author on more than 30 publications, including one ASME Best-Paper Award. His research interests lie primarily in the areas of thermal management of propulsion systems.

Appendix

EuTTA in Dope

Ingredients
12 mg Europium (III) Thenoyltrifluoroacetonate (EuTTA),
20 ml model airplane dope,
20 ml dope thinner.

Directions
Mix EuTTA with the dope thinner, shake and then sonicate for a few minutes. Add the dope, shake and sonicate. Acetone is used as a solvent to clean up the paint.

Cost
EuTTA – Approx $600.00 for 5g
Model Airplane Dope and Dope Thinner $10.00 for 100 ml

Cost Comparison
Commercial TSP vs in-house for 12 oz of TSP

Standard Operating Procedures for Temperature Sensitive Paint

High Hazard Chemical/Operation

- **Title of Procedure:** Mixing of Chemicals for Temperature Sensitive Paint
- **Date of Last Review:** February 20, 2016
- **Principal Investigator:** Mayur Patel – patelm16@my.erau.edu – 551-689-0131
- **Lab Location:** College of Arts and Sciences – Room 118
- **Lab Personnel who have reviewed SOP/Date:** Emily Faulconer, Ph.D. reviewed 2/10/2016

SOP Purpose: The purpose of TSP SOP is to distinctively identify the safety risks associated with creating the paint from base materials. In addition, demonstrate the needs and requirements needed for implementing the procedure as a routine for future research. The ultimate goal is to develop a method that can be utilized at Lehman Engineering to produce a paint that can be directly applied to the test specimen for the wind tunnel usage.

Responsibilities: PI responsible for being properly trained in chemical safety It is the responsibility of the individual in charge of the activity to assure that safety practices are adhered to. Persons participating in the chemical activation steps are responsible for accessing and abiding by the SDS of the specific chemical agent(s). If those individuals fail to follow the guidelines presented, they will be subject to disciplinary action.

Definitions: TSP: Temperature Sensitive Paint

References: SDS: http://www.acros.com/Product/Find.aspx?Product=Europium%20(III)%20thenoyltrifluoroacetonate,%20trihydrate

http://www.spikeaerospace.com/about/careers/https://www.fishersci.com/shop/products/europium-iii-thenoyltrifluoroacetonate-trihydrate-95-acros-organics-2/p-132787

Approval Required:

- Justin Grillot – EH&S Director
- Dr Mark Ricklick – Research Advisor

Training

1.1. All employees participating in the activities described in this SOP must be trained yearly on this SOP. Additionally, employees must be trained on Chemical Container Labeling and PPE within the last 12 months. Retraining may be required if a lab employee is found to violate any aspect of this SOP.

Risk Assessment for hazardous chemicals

Substitution of Less Hazardous Chemicals: None

Chemical Name	CAS #	Signal Word	Hazard Class	Hazard Statements
Ethanol	64-17-5	DANGER	2 4 2, 2A 3	Highly flammable liquid and vapor Acute oral toxicity Skin and serious eye damage, corrosion, or irritation Specific target organ toxicity, single exposure: respiratory tract irritant
Sodium Sulfate, anhydrous	7757-82-6	WARNING	5	May be harmful in contact with skin
Europium (III) Thenoyltrifluoro acetonate (EuTTA)	21392-96-1	DANGER	2 4 2, 2A 3	Highly flammable liquid and vapor Acute oral toxicity Skin and serious eye damage, corrosion, or irritation Specific target organ toxicity, single exposure: respiratory tract irritant

Control Measures

Personal Protective Equipment (PPE):

1) Gloves – Rubber, neoprene or nitrile gloves White Lab Coats, Suits, Aprons
2) Chemical worker's safety goggles as described by OSHA's eye and face protection regulations in 29 CFR 1910.133
3) Respirator – NIOSH approved Dust and Mist Respirator.

Eyewear: ✓ **Safety Glasses** □ Safety Glasses with Side Shield □ Safety Goggles □ Face Shield

Gloves: □ Disposable Nitrile ✓ **Thermal**/Cryogenic □ Abrasion Resistant □ Butyl Rubber/Neoprene

Respirator: *if available, keep a respirator nearby*

Protective Clothing: ✓ Lab Coat (cotton or flame retardant) □ Synthetic Lab Apron □ Tyvek Suit □ Shoe Covers □ Formed Boots

Personal Attire: Avoid synthetic materials due to the high flammability of these materials and their tendency to melt under high temperatures. Wear sturdy flat-soled, closed shoes.

Engineering Controls:

1) Use of fume hood #1 in COAS 116
2) Nitrogen storage container for EuTTA

Storage Procedures: Store in sealed containers under Nitrogen. Store acetone using grounding wire. Final product will be stored in glass sealed container from McMaster in same cabinet as EuTTA.

Transportation Procedures: N/A

Waste Disposal Procedures: Dispose as a Chemical Solid Waste. Chemical is not p-listed and therefore dispose it in solid waste container provided by Environmental Health and Safety Department. Each chemical waste will be disposed in separate containers with designated labels that specify the waste.

Emergency Procedures:

Spills or Releases: Sweep material and transfer to a suitable container for disposal as chemical waste.

Spill Cleanup Procedures: If there is an emergency spill such as dropping any chemicals or paint on floor. If it is a solid, sweep material and transfer to a suitable container for disposal as hazardous waste. Chemical waste containers will be labeled to identify where it will be disposed. Whereas for paint, paper with acetone will be used to clean up and disposed in a designated container.

Fire:

- Extinguishing Media: Water spray, foam, carbon dioxide, dry chemical.
- Special Fire Fighting Procedures: Avoid eye and skin contact. Do not breathe fumes or inhale vapors.

Exposures:

- EYES: In case of contact, immediately flush eyes with flowing water for at least 15 minutes. Get medical attention.
- SKIN: Flush with water, then wash with soap and water.
- INHALATION: Move exposed individual to fresh air. Administer oxygen if needed. Call a physician.
- INGESTION: Never give fluids or induce vomiting if patient is unconscious or having convulsions. Get medical attention.

Chemical	Routes of Exposure	Symptoms of Exposure	Toxicity	Exposure Monitoring
Ethyl Alcohol	✓ Eye contact ✓ Inhalation ✓ Ingestion ✓ Skin contact ☐ Skin absorption	Inhalation causes irritation to upper respiratory tract and eyes. High concentrations cause symptoms similar to ingestion. Continuous contact with skin causes dermatitis. Symptoms from ingestion vary with volume from stimulation and mental excitement to nausea, dizziness, headache, depression, drowsiness, impaired vision, atoxia, and stupor.	IHL-RAT LC_{50} 20,000ppm/10H ORL-RAT LD_{50} 7060 mg/kg	PEL 1000ppm (OSHA) Ceiling 1000ppm (ACGIH)
Sodium Sulfate	☐ Eye contact ☐ Inhalation ☐ Ingestion ✓ Skin contact ☐ Skin absorption	Skin irritation	n/a	n/a
EuTTa	✓ Eye contact ✓ Inhalation ✓ Ingestion ✓ Skin contact ☐ Skin absorption	Inhalation causes irritation to upper respiratory tract and eyes. High concentrations cause symptoms similar to ingestion. Continuous contact with skin causes dermatitis. Symptoms from ingestion vary with volume from stimulation and mental excitement to nausea, dizziness, headache, depression, drowsiness, impaired vision, atoxia, and stupor.	n/a	n/a

Chemical	Inhalation	Skin	Eyes	Ingestion
Ethyl Alcohol	Remove to fresh air.	Immediately remove all contaminated clothing. Rinse skin with water.	Rinse cautiously with water for several minutes. Remove contact lenses if present. Continue rinsing.	Rinse mouth. Call Poison Center or physician if you feel unwell.
Sodium Sulfate	Remove to fresh air.	Wash with plenty of water	Rinse cautiously with water for several minutes. Remove contact lenses if present. Continue rinsing.	Rinse mouth. Call Poison Center or physician if you feel unwell.
Eutta	Remove from exposure, lie down. Move to fresh air. If breathing is difficult, give oxygen. If not breathing, give artificial respiration	Wash off immediately with soap and plenty of water while removing all contaminated clothes and shoes.	Rinse immediately with plenty of water, also under the eyelids, for at least 15 minutes. Obtain medical attention.	Clean mouth with water. Get medical attention

Protocol:

I. Chemicals

12 mg Europium (III) Thenoyltrifluoroacetonate (EuTTA)
20 ml Model Airplane Dope (Aeroglass)
20 ml Dope Thinner (Aeroglass)
Acetone

II. Materials

500 ml beaker
Sonicator
Glass containers from McMaster
Weight Scale
100 ml beaker – (2)
Weight Scale
Nitrogen Storage Container
Chemical Hood
Nitrile Gloves

III. Recipe

Mix 12 mg of EuTTA with the 20 ml of dope thinner, shake and then sonicate for a few minutes. Add the dope, shake and sonicate. Acetone is used as a solvent to clean up the paint.

IV. Methods

1. Using a plastic tote placed on a wheeled cart, transfer all three chemicals from chemical storage to the chemical hood 1.
2. Take a 500 ml beaker and place it under the vent 1.
3. Place 12 mg of the EuTTA onto the beaker.
4. Gather the two additional components required for the experiment. (Model Airplane Dope and Paint Thinner).
5. Measure the required amount of 20 ml for model airplane dope and dope thinner.
6. Following the recipe, mix the chemicals accordingly.
7. Take the produced paint and pour it in the designated chemical storage container. Glass container for chemical storage from McMaster will be used to store chemical. Container will be pre-labeled as "Paint". No chemical risks are associated with chemical produced.
8. Tightly seal all the remaining chemicals.
9. Dispose waste if any in solid chemical waste storage container.
10. Wash the mixing container with Acetone to clear up the remaining paint. Use paper towel to catch the rinsate and place it in solid chemical storage container.
11. Dispose waste following the guidelines of chemical pollution control regulations. Acetone and EuTTA are not p-listed and therefore will be disposed as solid chemical waste in two different containers.

SAFETY DATA SHEET

Creation Date 10-Feb-2011 **Revision Date** 10-Feb-2015 **Revision Number** 1

1. Identification

Product Name **Europium (III) thenoyltrifluoroacetonate, trihydrate**

Cat No. : **AC423190000; AC423190010; AC423190050**

Synonyms Eu-TTA; Trisó4,4,4-trifluoro-1-(2-thienyl)-1,3-butanediono!europium

Recommended Use Laboratory chemicals.

Uses advised against No Information available

Details of the supplier of the safety data sheet

Company	**Entity / Business Name**	**Emergency Telephone Number**
Fisher Scientific One Reagent Lane Fair Lawn, NJ 07410 Tel: (201) 796-7100	Acros Organics One Reagent Lane Fair Lawn, NJ 07410	For information **US** call: 001-800-ACROS-01 / **Europe** call: +32 14 57 52 11 Emergency Number **US:**001-201-796-7100 / **Europe:** +32 14 57 52 99 **CHEMTREC** Tel. No.**US:**001-800-424-9300 / **Europe:**001-703-527-3887

2. Hazard(s) identification

Classification

Classification under 2012 OSHA Hazard Communication Standard (29 CFR 1910.1200)

Based on available data, the classification criteria are not met

Label Elements

None required

Hazards not otherwise classified (HNOC)

None identified

Unknown Acute Toxicity
.? % of the mixture consists of ingredients of unknown toxicity.

3. Composition / information on ingredients

Component	CAS-No	Weight %
Europium (III) thenoyltrifluoroacetonate, trihydrate	21392-96-1	95
Europium, tris[4,4,4-trifluoro-1-(2-thienyl)-1,3-butanedionato-O, O']-	14054-87-6	-

4. First-aid measures

Eye Contact Rinse immediately with plenty of water, also under the eyelids, for at least 15 minutes. Obtain medical attention.

Skin Contact Wash off immediately with soap and plenty of water while removing all contaminated clothes and shoes.

Inhalation Remove from exposure, lie down. Move to fresh air. If breathing is difficult, give oxygen. If not breathing, give artificial respiration.

Ingestion Clean mouth with water. Get medical attention.

Most important symptoms/effects No information available.

Notes to Physician Treat symptomatically

5. Fire-fighting measures

Suitable Extinguishing Media Water spray. Carbon dioxide (CO_2). Dry chemical.

Unsuitable Extinguishing Media No information available

Flash Point No information available

Method - No information available

Auto ignition Temperature No information available

Explosion Limits

Upper No data available

Lower No data available

Sensitivity to Mechanical Impact No information available

Sensitivity to Static Discharge No information available

Specific Hazards Arising from the Chemical
Keep product and empty container away from heat and sources of ignition.

Hazardous Combustion Products
Carbon monoxide (CO) Carbon dioxide (CO_2) Sulfur oxides Gaseous hydrogen fluoride (HF)

Protective Equipment and Precautions for Firefighters
As in any fire, wear self-contained breathing apparatus pressure-demand, MSHA/NIOSH (approved or equivalent) and full protective gear.

NFPA

Health	Flammability	Instability	Physical hazards
0	0	0	N/A

6. Accidental release measures

Personal Precautions Ensure adequate ventilation. Use personal protective equipment.

Environmental Precautions See Section 12 for additional ecological information.

Methods for Containment and Clean Up Sweep up or vacuum up spillage and collect in suitable container for disposal.

7. Handling and storage

Handling Avoid contact with skin and eyes. Do not breathe dust. Do not breathe vapors or spray mist. Use only in area provided with appropriate exhaust ventilation.

Storage Keep in a dry, cool and well-ventilated place. Keep container tightly closed. Keep under nitrogen.

8. Exposure controls / personal protection

Exposure Guidelines This product does not contain any hazardous materials with occupational exposure limits established by the region specific regulatory bodies.

Engineering Measures Ensure that eyewash stations and safety showers are close to the workstation location.

Personal Protective Equipment

Eye/face Protection Wear appropriate protective eyeglasses or chemical safety goggles as described by OSHA's eye and face protection regulations in 29 CFR 1910.133 or European Standard EN166.

Skin and body protection Wear appropriate protective gloves and clothing to prevent skin exposure.

Respiratory Protection A NIOSH/MSHA approved air purifying dust or mist respirator or European Standard EN 149.

Hygiene Measures Handle in accordance with good industrial hygiene and safety practice.

9. Physical and chemical properties

Physical State	Solid
Appearance	Yellow
Odor	Odorless
Odor Threshold	No information available
pH	No information available
Melting Point/Range	142 - 147 °C / 288 - 297 °F
Boiling Point/Range	No information available
Flash Point	No information available
Evaporation Rate	No information available
Flammability (solid,gas)	No information available

Flammability or explosive limits Upper	No data available
Lower	No data available
Vapor Pressure	No information available
Vapor Density	No information available
Relative Density	No information available
Solubility	No information available
Partition coefficient; n-octanol/water	No data available
Autoignition Temperature	No information available
Decomposition Temperature	No information available
Viscosity	No information available
Molecular Formula	C24 H12 Eu F9 O6 S3 . 3 H2 O
Molecular Weight	869.54

10. Stability and reactivity

Reactive Hazard	None known, based on information available
Stability	Stable under normal conditions.
Conditions to Avoid	Incompatible products.
Incompatible Materials	Strong oxidizing agents
Hazardous Decomposition Products	Carbon monoxide (CO), Carbon dioxide (CO_2), Sulfur oxides, Gaseous hydrogen fluoride (HF)
Hazardous Polymerization	No information available.
Hazardous Reactions	None under normal processing.

11. Toxicological information

Acute Toxicity

Product Information	No acute toxicity information is available for this product
Oral LD50	Based on ATE data, the classification criteria are not met. ATE > 2000 mg/kg.
Dermal LD50	Based on ATE data, the classification criteria are not met. ATE > 2000 mg/kg.
Mist LC50	Based on ATE data, the classification criteria are not met. ATE > 5 mg/l.
Component Information	
Toxicologically Synergistic Products	No information available

Delayed and immediate effects as well as chronic effects from short and long-term exposure

Irritation	No information available
Sensitization	No information available
Carcinogenicity	The table below indicates whether each agency has listed any ingredient as a carcinogen.

Component	CAS-No	IARC	NTP	ACGIH	OSHA	Mexico

Europium (III) thenoyltrifluoroacetonate, trihydrate	21392-96-1	Not listed	Not listed	Not listed	Not listed	Not listed
Europium, tris[4,4,4-trifluoro-1-(2-thienyl)-1,3-butanedionato-O,O']-	14054-87-6	Not listed	Not listed	Not listed	Not listed	Not listed

Mutagenic Effects No information available

Reproductive Effects No information available.

Developmental Effects No information available.

Teratogenicity No information available.

STOT - single exposure None known

STOT - repeated exposure None known

Aspiration hazard No information available

Symptoms / effects, both acute and No information available **delayed**

Endocrine Disruptor Information No information available

Other Adverse Effects The toxicological properties have not been fully investigated.

12. Ecological information

Ecotoxicity

Do not empty into drains.

Persistence and Degradability No information available

Bioaccumulation/ Accumulation No information available.

Mobility No information available.

13. Disposal considerations

Waste Disposal Methods Chemical waste generators must determine whether a discarded chemical is classified as a hazardous waste. Chemical waste generators must also consult local, regional, and national hazardous waste regulations to ensure complete and accurate classification.

14. Transport information

DOT Not regulated

TDG Not regulated

IATA Not regulated

IMDG/IMO Not regulated

15. Regulatory information

International Inventories

Component	TSCA	DSL	NDSL	EINECS	ELINCS	NLP	PICCS	ENCS	AICS	IECSC	KECL
Europium, tris[4,4,4-trifluoro-1-(2-thienyl) -1,3-butanedionato-O,O']-	X	X	-	237-892-8	-		-	-	-	-	-

Legend:
X - Listed
E - Indicates a substance that is the subject of a Section 5(e) Consent order under TSCA.
F - Indicates a substance that is the subject of a Section 5(f) Rule under TSCA.
N - Indicates a polymeric substance containing no free-radical initiator in its inventory name but is considered to cover the designated polymer made with any free-radical initiator regardless of the amount used.
P - Indicates a commenced PMN substance
R - Indicates a substance that is the subject of a Section 6 risk management rule under TSCA. S - Indicates a substance that is identified in a proposed or final Significant New Use Rule T - Indicates a substance that is the subject of a Section 4 test rule under TSCA.
XU - Indicates a substance exempt from reporting under the Inventory Update Rule, i.e. Partial Updating of the TSCA Inventory Data Base Production and Site Reports (40 CFR 710(B).
Y1 - Indicates an exempt polymer that has a number-average molecular weight of 1,000 or greater.
Y2 - Indicates an exempt polymer that is a polyester and is made only from reactants included in a specified list of low concern reactants that comprises one of the eligibility criteria for the exemption rule.

U.S. Federal Regulations

TSCA 12(b) Not applicable

SARA 313 Not applicable

SARA 311/312 Hazardous Categorization

Acute Health Hazard	No
Chronic Health Hazard	No
Fire Hazard	No
Sudden Release of Pressure Hazard	No

Reactive Hazard No

Clean Water Act Not applicable

Clean Air Act Not applicable
OSHA Occupational Safety and Health Administration Not applicable

CERCLA
Not applicable
California Proposition 65 This product does not contain any Proposition 65 chemicals
State Right-to-Know Not applicable
U.S. Department of Transportation
Reportable Quantity (RQ): N
DOT Marine Pollutant N
DOT Severe Marine Pollutant N

U.S. Department of Homeland Security
This product does not contain any DHS chemicals.

Other International Regulations

Mexico - Grade No information available

Canada
This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all the information required by the CPR
WHMIS Hazard Class Non-controlled

16. Other information

Prepared By Regulatory Affairs
Thermo Fisher Scientific
Email: EMSDS.RA@thermofisher.com
Creation Date 10-Feb-2011
Revision Date 10-Feb-2015
Print Date 10-Feb-2015
Revision Summary This document has been updated to comply with the US OSHA HazCom 2012 Standard replacing the current legislation under 29 CFR 1910.1200 to align with the Globally Harmonized System of Classification and Labeling of Chemicals (GHS)
Disclaimer
The information provided on this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as a guide for safe handling, use, processing, storage, transportation, disposal and release

and is not to be considered as a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other material or in any process, unless specified in the text.

End of SDS