



Ed Wesly  
c/o Harrington College of Design  
200 West Madison Street  
Chicago, IL 60606

Ed,

As we discussed by phone, I am sending you samples of our photopolymer, Bayfol® HX, free of charge. In exchange for these samples, I only ask that you give us feedback on their suitability for your holographic recording needs and that you discuss any findings with me before broad, public distribution.

I am enclosing a light-safe envelope containing unexposed samples of Bayfol HX TP \* photopolymer film. In this envelope is our RGB-sensitive formulation (batch # N36400) prepared on a Makrofol® polycarbonate film substrate (125 µm). This formulation is designed for peak sensitivity in the 450 nm – 650 nm wavelength range. The photopolymer in the film is approximately 55 microns thick. This envelope contains 2 sheets (each sheet is approximately 8.5" x 10"). Please note that this material has two polyethylene cover films (one on the photopolymer and one on the polycarbonate) that must be removed before exposure. These can easily be removed by placing a piece of tape at the corner and peeling away. The cover film adheres slightly better to the photopolymer side, which is helpful for orientation when removing cover films in low-light conditions. This specific sample has been tested in our labs and been shown to reach a  $\Delta n$  of 0.011 at 36 mJ/cm<sup>2</sup> for 633 nm plane-wave reflection gratings and 0.012 at 80 mJ/cm<sup>2</sup> for 532 nm plate-wave reflection gratings.

Obviously, these samples are light-sensitive, but the sensitivity is much lower than photographic film, so handling in darkroom conditions is safe even for extended periods. These materials have the lowest sensitivity in the blue and are quite sensitive in red, so we recommend a blue safelight for brighter working

16 April 2010

David Jurbergs  
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Functional Films & Smart Surfaces  
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conditions; however, short-term handling under any low light condition should not significantly deteriorate the material (we've had customers using the material under room lights for short periods without major problems). The material should be stored in light-safe containers for long-term storage.

For typical use in recording holograms, please be aware of the following:

- The photopolymer has some tack; therefore, once the cover film is removed the material can easily pick up dust or other particulate that can seriously affect the ability to get good lamination and, therefore, good holograms.
- The photopolymer side should be laminated to another surface prior to exposure. Glass plates are commonly used, but other substrates should work fine. Lamination to a glass plate can easily be done with a hand roller.
- For this type of sample, we recommend a minimum power density of  $0.5 \text{ mW/cm}^2$  for red-only exposures, and  $1 \text{ mW/cm}^2$  for blue, green or pan-chromatic exposures. We and others have found issues with getting good holograms regardless of the total dosage for power densities significantly below this level.
- While no post-processing is required, we recommend allowing the sample to stay in low-light conditions after exposure for 5 minutes to allow for photopolymerization so that optimal performance is achieved.
- We recommend flood curing of the samples with visible light after exposure to consume all of the writing chemistry. This usually occurs for modest exposures such as bringing the sample into room lights for several minutes or a brief exposure at high power density visible light (such as sunlight).



- If optical clarity is important, further flood curing is likely required. In our testing, flood curing to a total dosage of  $> 5 \text{ J/cm}^2$  with visible light is required to fully bleach the sensitizer in this formulation. The easiest way to do this for small samples is to place under a halogen lamp for an extended period (often leaving out under room lights overnight will also achieve this).

For further information about handling or exposure, please give me a call or email.

If you have any questions, please do not hesitate to contact me. I hope that these samples meet your needs, and I look forward to discussing your results further once you've had a chance to evaluate this material.

Sincerely,

A handwritten signature in blue ink that reads "David Jurbergs".

David Jurbergs, Ph.D.

# MATERIAL SAFETY DATA SHEET



Bayer MaterialScience

**Bayer MaterialScience LLC**  
Product Safety & Regulatory Affairs  
100 Bayer Road  
Pittsburgh, PA 15205-9741  
USA

## TRANSPORTATION EMERGENCY

CALL CHEMTREC: (800) 424-9300  
INTERNATIONAL: (703) 527-3887

## NON-TRANSPORTATION

Bayer Emergency Phone: Call Chemtrec  
Bayer Information Phone: (800) 662-2927

### 1. Product and Company Identification

**Product Name:** BF.HX TP \*  
**Material Number:** 81946222  
**Chemical Family:** Thermoplastic Polymer Sheet

### 2. Hazards Identification

#### Emergency Overview

**CAUTION! Color:** tint **Form:** solid sheets **Odor:** slight.  
Melted product is flammable and produces intense heat and dense smoke during burning.  
Irritating gases/fumes may be given off during burning or thermal decomposition.  
Contact with hot material will cause thermal burns.

#### Potential Health Effects

**Primary Routes of Entry:** Skin Contact

#### HUMAN EFFECTS AND SYMPTOMS OF OVEREXPOSURE

##### Skin

##### Acute Skin

**For Product: BF.HX TP \***

Contact with heated material can cause thermal burns.

##### General Effects of Exposure

##### Acute Effects of Exposure

**For Product: BF.HX TP \***

Gases and fumes evolved during the thermal processing or decomposition of this material may irritate the eyes, skin or respiratory tract.

##### Chronic Effects of Exposure

**For Product: BF.HX TP \***

Not expected to cause any adverse chronic health effects.

##### Carcinogenicity:

Material Name: BF.HX TP \*

Article Number: 81946222

No Carcinogenic substances as defined by IARC, NTP and/or OSHA

### 3. Composition/Information on Ingredients

#### Hazardous Components

This material is not subject to the Federal OSHA Hazard Communication Standard 29 CFR 1910.1200.

### 4. First Aid Measures

#### Eye Contact

In case of contact, flush eyes with plenty of lukewarm water.

#### Skin Contact

In case of skin contact, wash affected areas with soap and water. Get medical attention if thermal burn occurs.

#### Inhalation

If inhaled, remove to fresh air.

#### Ingestion

Get medical attention.

### 5. Fire-Fighting Measures

**Suitable Extinguishing Media:** water, foam, dry chemical, carbon dioxide (CO<sub>2</sub>)

#### Special Fire Fighting Procedures

Firefighters should be equipped with self-contained breathing apparatus to protect against potentially toxic and irritating fumes.

#### Unusual Fire/Explosion Hazards

Toxic and irritating gases/fumes may be given off during burning or thermal decomposition. Dust may form explosive mixtures with air.

### 6. Accidental release measures

#### Spill and Leak Procedures

If molten, allow material to cool and place into an appropriate marked container for disposal.

### 7. Handling and Storage

#### Storage Temperature:

**maximum:** 77 °C (170.6 °F)



**Storage Period**  
Not Established

**Handling/Storage Precautions**  
Handle in accordance with good industrial hygiene and safety practices. Wash thoroughly after handling.  
Avoid breathing dust.

**Further Info on Storage Conditions**  
Protect equipment (e.g. storage bins, conveyors, dust collectors) with explosion vents.

## 8. Exposure Controls / Personal Protection

**Industrial Hygiene/Ventilation Measures**  
General dilution and local exhaust as necessary to control airborne vapors, mists, dusts and thermal decomposition products below appropriate airborne concentration standards/guidelines, especially during cutting, grinding and high heat operations.

**Respiratory Protection**  
Although no exposure limit has been established for this product, the OSHA PEL for Particulates Not Otherwise Regulated (PNOR) of 15 mg/m<sup>3</sup> - total dust, 5 mg/m<sup>3</sup> - respirable fraction is recommended. In addition, the ACGIH recommends 3 mg/m<sup>3</sup> - respirable particles and 10 mg/m<sup>3</sup> - inhalable particles for Particles (insoluble or poorly soluble) Not Otherwise Specified (PNOS).

**Hand Protection**  
Wear heat resistant gloves when handling molten material.

**Eye Protection**  
safety glasses with side-shields.

**Skin and body protection**  
No special skin protection requirements during normal handling and use.

**Additional Protective Measures**  
Employees should wash their hands and face before eating, drinking, or using tobacco products. Educate and train employees in the safe use and handling of this product. Purgings should be collected as small flat thin shapes or thin strands to allow for rapid cooling.

## 9. Physical and chemical properties

<b>Form:</b>	solid
<b>Appearance:</b>	sheets
<b>Color:</b>	tint
<b>Odor:</b>	slight
<b>pH:</b>	not applicable
<b>Melting Point:</b>	220 - 250 °C (428 - 482 °F)
<b>Boiling Point/Range:</b>	not applicable
<b>Flash Point:</b>	> 450 °C (> 842 °F)
<b>Lower Explosion Limit:</b>	Not Established
<b>Upper Explosion Limit:</b>	Not Established
<b>Vapor Pressure:</b>	not applicable
<b>Specific Gravity:</b>	approximately 1.1 - 1.2
<b>Solubility in Water:</b>	Insoluble
<b>Autoignition Temperature:</b>	> 450 °C (> 842 °F)

**Decomposition Temperature:** 380 °C (716 °F)  
**Softening Point:** 102 - 113 °C (215.6 - 235.4 °F)  
**Bulk Density:** 38 - 42 lb/ft<sup>3</sup>

#### 10. Stability and Reactivity

##### **Hazardous Reactions**

Hazardous polymerization does not occur.

##### **Stability**

Stable

##### **Materials to avoid**

None known.

##### **Conditions to avoid**

None known.

##### **Hazardous decomposition products**

By Fire and Thermal Decomposition: Carbon Dioxide; Bisphenol A; Phenol; Carbonic Acid, Diphenyl Ester; Carbon monoxide, hydrocarbons, phenol derivatives

#### 11. Toxicological Information

No information available.

#### 12. Ecological Information

No information available.

#### 13. Disposal considerations

##### **Waste Disposal Method**

Waste disposal should be in accordance with existing federal, state and local environmental control laws.

#### 14. Transportation information

##### **Land transport (DOT)**

Non-Regulated

##### **Sea transport (IMDG)**

Non-Regulated

##### **Air transport (ICAO/IATA)**

Non-Regulated

## 15. Regulatory Information

### United States Federal Regulations

OSHA Hazcom Standard Rating: Non-Hazardous

US. Toxic Substances Control Act: Excluded: Article.

US. EPA CERCLA Hazardous Substances (40 CFR 302):

#### Components

None

SARA Section 311/312 Hazard Categories:

Non-hazardous under Section 311/312

US. EPA Emergency Planning and Community Right-To-Know Act (EPCRA) SARA Title III Section 302 Extremely Hazardous Substance (40 CFR 355, Appendix A):

#### Components

None

US. EPA Emergency Planning and Community Right-To-Know Act (EPCRA) SARA Title III Section 313 Toxic Chemicals (40 CFR 372.65) - Supplier Notification Required:

#### Components

None

US. EPA Resource Conservation and Recovery Act (RCRA) Composite List of Hazardous Wastes and Appendix VIII Hazardous Constituents (40 CFR 261):

If discarded in its purchased form, this product would not be a hazardous waste either by listing or by characteristic. However, under RCRA, it is the responsibility of the product user to determine at the time of disposal, whether a material containing the product or derived from the product should be classified as a hazardous waste. (40 CFR 261.20-24)

### State Right-To-Know Information

The following chemicals are specifically listed by individual states; other product specific health and safety data in other sections of the MSDS may also be applicable for state requirements. For details on your regulatory requirements you should contact the appropriate agency in your state.

## 16. Other Information

### HMIS Rating

Health	0
Flammability	1
Physical Hazard	0

0=Minimal 1=Slight 2=Moderate 3=Serious 4=Severe

\* = Chronic Health Hazard

The method of hazard communication for Bayer MaterialScience LLC is comprised of Product Labels and Material Safety Data Sheets. HMIS and NFPA ratings are provided by Bayer MaterialScience LLC as a customer service.



Contact Person: Product Safety Department  
Telephone: (412) 777-2835  
MSDS Number: 000000011284  
Version Date: 04/20/2009  
Report Version: 1.1

This information is furnished without warranty, express or implied. This information is believed to be accurate to the best knowledge of Bayer MaterialScience LLC. The information in this MSDS relates only to the specific material designated herein. Bayer MaterialScience LLC assumes no legal responsibility for use of or reliance upon the information in this MSDS.

2011



Rob Taylor  
Forth Dimension Holographics  
214 Deer Rd., PO Box 259  
Nashville, Indiana USA 47448  
(812) 340-9161  
rtaylor@forthdimension.net

Rob,

It was a pleasure speaking to you by phone earlier. As we discussed by phone, I am sending you a sample of our newest Bayfol® HX photopolymer film for your evaluation. Our only request for sending a free sample is that you provide information about how this material performed in your evaluation.

I am enclosing a light-safe envelope that contains sample sheets of unexposed Bayfol HX 102 photopolymer film. This is our 2<sup>nd</sup> generation RGB-sensitive formulation (batch # N72302G) prepared on a Makrofol® polycarbonate film substrate (175 µm). This photopolymer formulation is designed for peak sensitivity in the 440 nm – 670 nm wavelength range. It is suitable for recording either reflection or transmission holograms, but this version has been optimized for panchromatic reflection holograms. The photopolymer in the film is approximately 16 microns thick. This envelope contains 10 sheets (each sheet is approximately 20 cm x 25 cm). Please note that this material has a polyethylene cover film on the photopolymer that must be removed before exposure. It can easily be removed by placing a piece of tape at the corner and peeling away. Testing in our labs has shown this material to reach a  $\Delta n$  of 0.03 at 18 mJ/cm<sup>2</sup> for 633 nm plane-wave reflection gratings, 0.03 at 25 mJ/cm<sup>2</sup> for 532 nm plane-wave reflection gratings and 0.03 at 30 mJ/cm<sup>2</sup> for 473 nm plane-wave reflection gratings.

29 April 2011

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**Bayfol HX film Handling Recommendations**

Obviously, these samples are light-sensitive, but the sensitivity is much lower than photographic film, so handling in darkroom conditions is safe even for extended periods. These materials have the lowest sensitivity in the blue and are most sensitive in red, so we recommend a blue safelight for brighter working conditions; however, short-term handling under any low light condition should not significantly deteriorate the material (we've had customers using the material under room lights for short periods without noticeable deterioration). The material should be stored in light-safe containers for long-term storage.

For typical use in recording holograms, please be aware of the following:

- The film has a polyethylene cover film on the photopolymer side that must be removed before exposure. This is easily done by placing a piece of tape at the corner and peeling away.
- The photopolymer has some tack; therefore, once the cover film is removed the material can easily pick up dust or other particulate that can seriously affect the ability to get good lamination and, therefore, good holograms.
- The photopolymer side should be laminated to another surface prior to exposure. Glass plates are commonly used, but other substrates should work fine. Lamination to a glass plate can easily be done with a hand roller. Proper lamination will result in good optical contact such that other index-matching materials are unneeded at this interface.
- For the Bayfol HX 102 film, we recommend a minimum power density of 0.1 mW/cm<sup>2</sup> for red-only exposures and 0.5 mW/cm<sup>2</sup> for blue, green or pan-chromatic exposures. We and others have found issues with getting good



holograms regardless of the total dosage for power densities significantly below this level.

- No post-processing is needed to reach optimal hologram formation.
- We recommend flood curing of the samples with visible light after exposure to consume all of the writing chemistry. This usually occurs for modest exposures such as bringing the sample into room lights for several minutes or a brief exposure at high power density visible light (such as sunlight).
- If optical clarity is important, further flood curing is likely required. In our testing, flood curing to a total dosage of  $> 5 \text{ J/cm}^2$  with UV light is required to reach maximum transparency for this formulation. Visible light can also be used to flood cure, but tint will be slightly greater than for UV exposure.

For further information about handling or exposure is needed, please give me a call or email.

I look forward to discussing your results and how it fits into your current project once you've had a chance to evaluate this material and we have a mutual NDA executed. Let me know if there is anything else with which I can help.

Sincerely,

A handwritten signature in cursive script, appearing to read "David Jurbergs".

David Jurbergs, Ph.D.  
Business Development – ID and Holographic Films

David Jurbergs

Bayer

Austin TX

(512) 990 0043

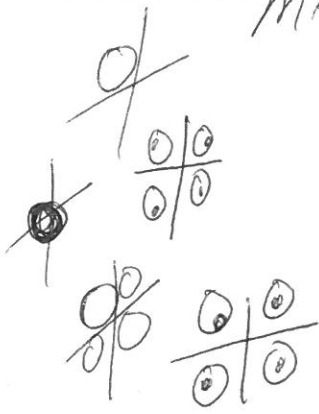
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Q

DAVID JORBURGS  
SURFACE RELIEF NOT POSSIBLE  
MATRIX TOTALLY CURED



PANCHRO

15-20 mJ/cm<sup>2</sup> R

60- mJ/cm<sup>2</sup> G

100- B

6000 lines/mm