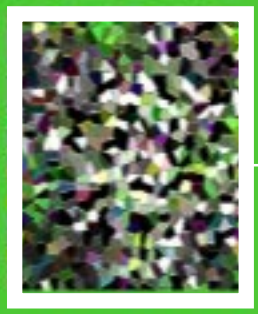
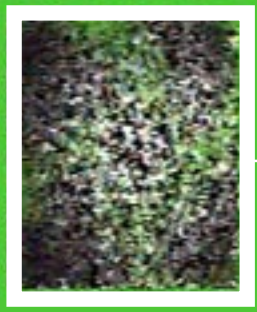
Emulsions For Holography

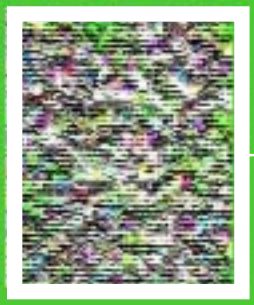


Fine Grain

GEOLA



Ultra-Fine Grain



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TECHNICAL PRODUCT SPECIFICATIONS AND SALES INFORMATION BROCHURE JANUARY 2001

GEOLA

Geola is the international coordination office for the distribution of Holography films and plates.

Geola actively participates in the origination of new products and in primary product testing.

Geola certifies holography materials through its own in-house quality control programme.

Geola's network for the sale, wholesale and distribution of holography materials is currently the largest such distribution network worldwide.

PRODUCTS

Geola currently supplies both Silver Halide and Dichromated Gelatine emulsions for holography applications. Table 1 summarises all materials presently available from Geola.

The fine grain, green-sensitive VRP-M emulsions are very close analogues to the old Agfa 8E56 products and can be used for both Pulsed and CW laser recording of holograms.

The fine grain, red sensitive PFG-01 material gives equivalent performance to Agfa 8E75 for CW recording.

The PFG-03M (red sensitive) and PFG-03C (panchromatic) materials are super-fine grain emulsions.

Finally PFG-04 is a long-life Dichromated Gelatine emulsion for recording in the blue and green sprectral ranges.

All of the Silver Halide materials are available coated onto glass or TAC film substrate and cover a wide range of sizes.

Name of Material	Description
VRP-M	Fine-grained green sensitive holographic plates and film designed for reflection or transmission hologram recording. Average grain size is 35-40nm, resolving power is more than 3000 lines/mm, spectral sensitivity range includes 488nm, 514nm, 526nm, 532nm.
PFG-01	Fine-grained red sensitive holographic plates and film designed for reflection or transmission hologram recording. Average grain size is 40nm, resolving power more than 3000 lines/mm, spectral sensitivity range 600-680nm (including 633nm, 647nm).
PFG-03M	Ultra fine-grained red sensitive plates and film designed for reflection hologram recording. Average grain size is 8-12nm, resolving power more than 5000 lines/mm, spectral sensitivity range includes 633nm, 647nm.
PFG-03C	Ultra fine-grained panchromatic (full colour) holographic plates and film designed for colour reflection hologram recording. Average grain size is 8nm, resolving power more than 5000 lines/mm, spectral sensitivity range up to 700nm (457nm, 514nm, 633nm).
PFG-04	Dichromated Gelatine holographic plates designed for phase reflection hologram recording. Resolving power greater than 5000 lines/mm, spectral sensitivity range up to 514nm (457nm, 488nm, 514nm).

Table 1: List of Available Holographic Materials

Acknowledgements

Geola is grateful to Sergey Vorobyov for the technique of latensification. We would also like to acknowledge the work of Hans Bjelkhagen and Nicholas Phillips, on which much of the chemistry listed in this brochure is based, as well as that of Bernadette and Ron Olson for the technique of colour-shifting by D-Sorbitol.

FINE GRAIN SILVER HALIDE MATERIALS

VRP-M (GREEN SENSITIVE) AND PFG-01 (RED SENSITIVE)

Characteristic curves of fine-grain red (PFG-01) and green (VRP-M) emulsions, showing spectral sensitivity versus wavelength, are shown in Fig.1. The VRP-M optical sensitivity (to CW radiation) is seen to peak at aproximately 75 $\mu J/cm^2$ and that of the improved PFG-01 (to CW radiation) at approximately 80 $\mu J/cm^2$. (This improved batch will be comercially available in the second quarter of 2001). Fig.2 shows the optical density after exposure by CW radiation and after development versus energy. Grain size characteristics for the VRP-M and PFG-01 emulsions are shown in Fig.3.The diffraction efficiency versus exposure for reflection holograms recorded on PFG-01 (using a CW laser) and on VRP-M (using a pulsed laser) is presented in Fig.4. The maximum diffraction efficiency is seen to be >45% for both emulsions. Material lifetime is more than two years.

The VRP-M and PFG-01 emulsions may be used equally well with pulsed lasers and with CW radiation. In the pulsed laser radiation case the emulsion should be post-sensitized with the technique of latensification. The latensification technique is described below.

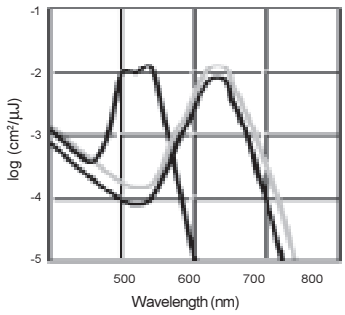

Figure1: Spectral Sensitivity curves for VRP-M (left) and PFG-01 (right). In grey we show a new PFG-01 sensitivity curve (commercially awailable in the second quarter of 2001).

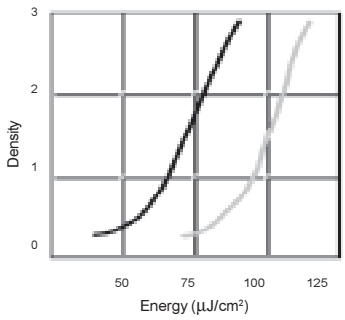

Figure 2: Characteristic Curves for VRP-M (left) and PFG-01 (right).

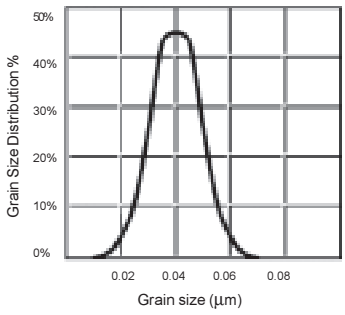

Figure 3: Grain Size Distribution Curve for VRP-M and PFG-01.

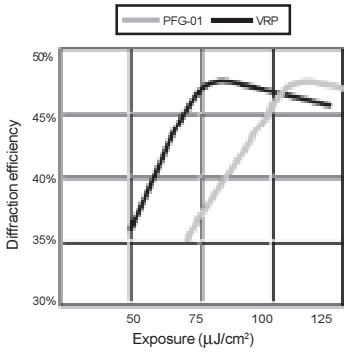

Figure 4: Diffraction Efficiency Curves for VRP-M and PFG-01.

VRP-M PFG-01	Mastering and Copying with Pulsed Radiation	Mastering and Copying with CW Radiation.
Exposure:		
MASTERING	20-40 µJ/cm²	60-80 µJ/cm²
COPYING	30-60 µJ/cm²	70-90 µJ/cm²
Latensification	**Yes**	**If needed**
Development	**SM-6,** 2min	**CW-C2,** 2min
Wash	Water, 1-2min	Water, 1-2min
Bleach	**PBU-Amidol** until clear (~2-3 min)	**PBU-Amidol** until clear (~2-3 min)
Wash	Water 5 mins	Water 5 mins
Final Wash	Water with wetting agent (Agepon) 1min	Water with wetting agent (Agepon) 1min
Drying	Slow Air	Slow Air

Table 2: Recommended Processing for VRP-M and PFG-01

RECOMMENDED CHEMISTRY FOR VRP-M and PFG-01

Table 2 shows a summary of recommended processing schemes for use with VRP-M when exposed by pulsed Neodymium lasers (526.5nm, 532nm) and for use with VRP-M and PFG-01 when exposed by CW Argon or by HeNe lasers. In the case of exposure by CW radiation latensification is usually not necessary.

White-light holograms made on VRP-M have a natural green reconstruction colour that can be easily changed by the technique of colour -shifting using D-Sorbitol (described below). White-light holograms made on PFG-01 have a natural yellow/orange reconstruction colour when using a HeHe laser and the recommended chemistry.

All chemicals necessary for the preparation of the recomended solutions can be obtained from the following companies -
(i) Photographer's Formulary Inc. (www.photoformulary.com),
(ii) Sigma-Aldrich www.sigma-aldrich.com),
(iii) Prolabo (www.Prolabo.fr).

For pulsed work one may also use the standard D-19 Kodak developer if 6-8g of Methyl Phenidone is added into the final solution.

The temperature of all solutions described in this brochure is 20 °C.

SM-6 Developer	
Sodium Hydroxide	12.0g
Methyl Phenidone	6.0g
Ascorbic Acid	18g
Sodium Phosphate (dibasic)	28.4g
Water	to 1.0L
CW-C2 Developer	
1 part A + 1 part B	
Part A	
Catechol	20.0g
Ascorbic Acid	10.0g
Sodium Sulphite (anhydrous)	10.0g
Urea	100.0g
Water	to 1.0L
Part B	
Sodium Carbonate	60.0g
Water	to 1.0L
PBU-Amidol Bleach	
Potassium Persulphate	10.0g
Citric Acid	50.0g
Cupric Bromide	1.0g
Potassium Bromide	20.0g
Amidol	1.0g
Water	to 1.0L
Potassium Iodide Bath	
Potassium Iodide	18.0g
Water	to 1.0L

Table 3:VRP-M and PFG-01 Developers, Bleach and Colour-shift bath.

LATENSIFICATION

PFG-01 and VRP-M emulsions have peak sensitivities to exposures in the millisecond regime. In order to obtain optimal sensitivity to exposures different from this regime the technique of latensification must be used.

Latensification is usually done directly after the holographic exposure. Before applying the process a latensification time appropriate for your system must be worked out. This procedure is as follows: Place a 25W white lamp at a distance of 1m from a test holoplate or film such that its light uniformly illuminates the emulsion. You will need to try several exposure times.

First of all you will need to develop the unexposed emulsion under normal safelight conditions. The plate will darken a little. This is called the "fog" level. After development wash this control plate, dry and keep it handy. Now a series of exposures with small test plates must be made. Start at about 2 secs and go up to around 10 secs. After each exposure develop your plate and match the darkening of this plate to your control plate. If it is the same, more exposure is needed so go back and repeat the process. Stop when a result that is just marginally darker than the fog level is obtained. This is then the correct latensification exposure for your geometry.

Now that the proper latensification time has been discovered, after every proper holoplate exposure you must take your plate and illuminate it exactly as described above for the time that you have worked out. Then all processing is as normal.

Latensification stabilizes and enhances the latent image formed by the holographic exposure. If required, chemical processing may be done with significant delay after latensification (~8 hours).

COLOUR CONTROL

For the VRP-M emulsion we recomend two colour shifting techniques. One produces a fixed colour-shift towards the red of approximately 50 nm. The other produces an adjustable colour shift.

The fixed colour shifting is accomplished by soaking the final hologram for 1 minute in a bath of Potassium Iodide solution (Table 3). Adjustable colour shifting is accomplished by soaking the hologram for 1 minute in an aqueous solution of D-Sorbitol (sugar substitute - $C_6H_{14}O_6$) with added wetting agent. The colour of the final hologram depends on the solution concentration (Fig.5). After soaking, the film must be taken out and put onto a flat surface. Water drops must be removed using a rubber wiper such as a windscreen wiper. Here one must be delicate - if too much force is employed you may obtain a somewhat different colour than that predicted by Fig. 5. If, after drying of the hologram, the replay colour achieved is not satisfactory, the film or plate may be washed in warm water and then soaked anew in another D-Sorbitol solution of different concentration.

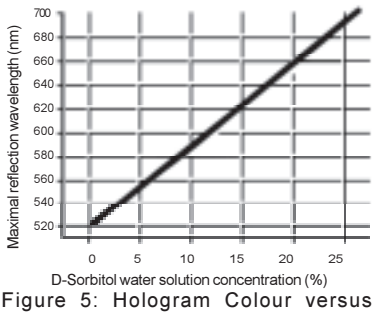

Figure 5: Hologram Colour versus D-Sorbitol Solution Concentration for exposure @ 526 nm.

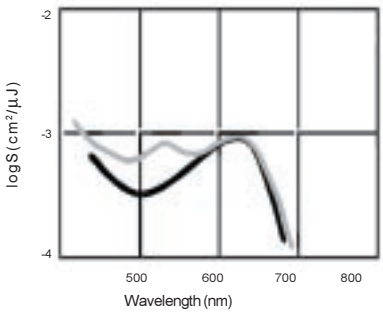

Figure 6: Spectral Sensitivity curves for PFG-03C (grey) and PFG-03M (black).

ULTRA-FINE GRAIN SILVER-HALIDE MATERIALS

PFG-03M

RED SENSITIVE EMULSION

This material is designed for reflection hologram recording using CW radiation in the red spectral range (633nm - HeNe laser and 647nm - Krypton laser). The spectral sensitivity curve of the material is shown in Fig.6.

Peak emulsion sensitivity is around 1.5-2mJ/cm^2. The grain size distribution curves for both PFG-03M and PFG-03C are shown in Fig.7. Recomended processing is given in table 4.

PFG-03C

PANCHROMATIC EMULSION

This material is designed for the production of full-colour reflection holograms using CW laser radiation in the blue (457nm - Argon laser), green (514nm - Argon laser) and red (633nm - HeNe laser).

A spectral sensitivity curve of the PFG-03C material is shown in Fig.6. Diffraction efficiency versus exposure is shown in Fig.8. The maximum diffraction efficiency in the blue region is >25% and in the green and red regions >45%.

Typical sensitivity values for PFG-03C are 2mJ/cm^2 and 3mJ/cm^2 for the blue and red/green regions respectively.

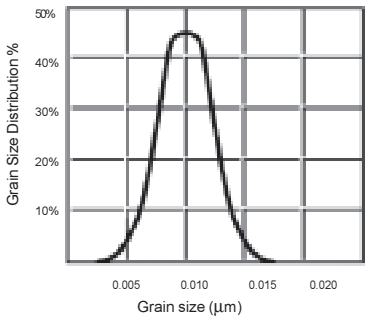

Figure 7: Grain Size distribution curve for PFG-03C and PFG-03M.

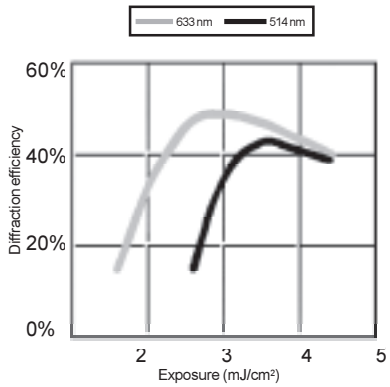

Figure 8: Diffraction Efficiency Curve for PFG03C.

Reflection holograms	PFG-03M	PFG-03C
Exposure	**1500 - 2000 μJ/cm²**	**2500 - 3000 μJ/cm²**
Hardening	**Hardener, 2-3 min**	**Hardener, 6 min**
Wash	Water, 1-2 min	Water, 1-2 min
Development	**GP-2,** 10 - 15min	**VRP,** 4 - 5min
Wash	Water, 1-2 min	Water, 1-2 min
Fixing	**Fixer**, 2 min	**No**
Bleach	**No**	**PBU-Amidol**, 5-8 min
Wash	Water, 1-2 min	Water, 1-2 min
Stop bath	**No**	**Stop bath**, 2 min
Wash	No	Water, 1-2 min
Bathing	**No**	**Water with wetting agent,** 1min
Drying	**50%,75% and 96% Ethyl Alcohol**, 2mins each bath	**Slow Air Drying**

Table 4: Recommended Processing for PFG-03M and PFG-03C

Hardener

Formalin 37%	10ml
Potassium Bromide	2g
Sodium Carbonate	5g
Water	to 1L

GP-2 Developer

Concentrated solution:

Methyl Phenidone	0.2g
Hydroquinone	5g
Sodium Sulphite(Anhyd.)	100g
Potassium Hydroxide	5g
Ammonium Thiocyanate	12g
Water	to 1L

Working solution:

40ml GP-2+1L H_20

VRP Developer

Concentrated solution:

Sodium Sulphite (Andydrous)	194g
Hydoquinone	25g
Potassium Hydroxide	22g
Methyl Phenidone	1.5g
Potassium Bromide	20g
Potassium Metaborate	140g
1,2,3-Benzotriazole	0.1g
Distilled Water	to 1L

Working solution:

1 part of developer + 6 parts water.

Fixer

Sodium Thiosulphate (cryst.)	160 g
Potassium Metabisulphite	40 g
Water	to 1L

Stop Bath

Acetic Acid	20g
Water	to 1L

Table 5: Recommended Chemistry for PFG-03C and PFG-03M.

DICHROMATED GELATINE PFG-04

This material is designed for the recording of reflection Denisyuk type holograms using CW laser radiation (e.g. 488nm, 514nm - Argon laser). The material spectral sensitivity curve is shown in Fig.9. The sensitivity reaches 100mJ/cm² in the blue spectral region and 250mJ/cm² in the green. Due to its grainless structure, this material has a very high resolving power and a diffraction efficiency of >75%.

The recommended processing technique for PFG-04 is as follows:

1).Thermal Hardening after exposure (100°C) - Depending on the layer freshness. See Fig.10.

2).Cooling to room temperature.

3).Bathing in running filtered water - 3mins.

4).Bathing in 50% Isopropyl Alcohol solution for 2 - 3 mins.

5).Bathing in 75% Isopropyl Alcohol solution for 2 - 3 mins.

6).Bathing in 100% Isopropyl Alcohol solution for 2 - 3 mins.

7).Drying in a desiccator. (100°C) for 60 mins.

8).Emulsion layer preservation using optical anhydrous adhesive and protective glass.

Note that the processing solution temperatures must not exceed 20°C for fresh layers. If holograms appear "milky" in colour then the processing solution temperature should be decreased or the thermal hardening period should be prolonged. The material shelf life is 18 months (average observed period).

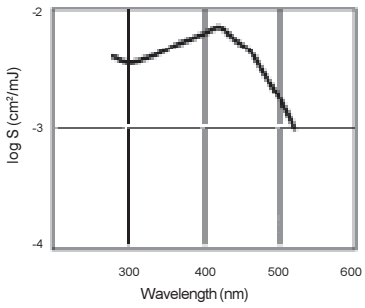

Figure 9: Spectral Sensitivity Curve for PFG-04.

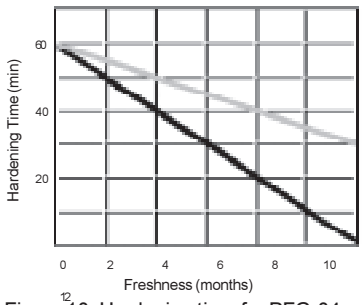

Figure 10. Hardening time for PFG-04 vs Storage Time. The black curve corresponds to a storage temperature of 18 °C and the grey curve to 4 °C.

TEMPORARY LAMINATION

Holography materials certified and distributed by Geola are manufactured on glass and TAC film substrates that are ostensibly identical to those used by Agfa.

The temporary film lamination technique described below is an alternative to the well-known index matching technique and is easier and less time-consuming. The technique is appropriate for film sheets of 20x30cm or larger.

We recomend using an electrostatic transparent film similar to the 5105CL "Penstic" Transparent film from Molco GmbH (www.molco.com), Germany. The procedure is as follows.

1. Clean a glass plate and place it horizontally. The plate should be slightly bigger than the actual film.

2. With a soft brush create an electrostatic charge on the glass plate.

3. Apply the electrostatic film to the glass plate with a (photographic) rubber roller making sure that you eliminate all the air bubbles.

4. Again take a soft brush and create an electrostatic charge on the electrostatic film.

5. Apply the holographic film to the electrostatic film with the rubber roller making sure, once again, that you eliminate all the bubbles.

6. Now use the glass plate as you would a normal holographic plate.

7. After making an exposure (and latensification) simply peel off your photosensitive film and process it as described above.

Another technique useful to achieve the necessary flatness for the recording of film holograms smaller than 20x30cm is to put the film between two glass plates.

FINAL LAMINATION

The emulsion of holograms made on film and glass plates should be protected from humidity and UV light.The diffusion of water into the emulsion leads to the colour of the hologram changing. UV radiation causes hologram brightness degradation (the "print out" effect). In order to protect the hologram from these unwanted effects one may cover and seal the hologram on one or both faces. In the case of glass holograms sealing from the back side is sufficient whereas film holograms should be sealed both from the front and the back.

The best way to protect the back side (the emulsion) of reflection holograms is by lamination of a black self-adhesive film. We recomend "Black Oracal" 641-070M from Orafol GmbH, Germany (www.orafol.de), or a similar product. It is straight-forward to apply this black film to the emulsion side of the hologram using a photographic rubber roller. Alternatively a cold lamination machine may be used. The result is a sandwich consisting of the holographic substrate, the emulsion and the protective film.

For emulsion protection of transmission film holograms we recomend the use of a transparent double-sided self-adhesive film (e.g. Optimount 60238 from Hunt Graphics Europe Ltd.) and a plexiglass sheet (e.g. Plexiglas XT, from Rohm GmbH, Germany, www.roem.de).

One side of the double-sided film is applied to the emulsion side of the hologram and the other side is stuck to the plexiglass. This can be done either by hand (rubber roller) or by using a cold lamination machine. The result is a sandwich consisting of holofilm substrate, emulsion, adhesive and plexiglass.

In order to insure flatness of film reflection holograms the same technique of mounting to a plexiglass sheet using a doublesided film may be used. The result is a sandwich consisting of the film substrate, the emulsion, a black self-adhesive film, the double-sided self-adhesive film and finally the plexiglass sheet.

Front-side protection of the hologram from UV radiation can be effected by use of the standard UV reflecting films available from Edmond Scientific(www.edsci.com).

Material Sizes

PLATES Emulsion*	Plate Size (nm)	Q-ty per Box	Box Size (nm)	Box Weight (Kg)
VRP-M, PFG-01, -03C,-03M, -04	63x63	30	185x82x90	9.50
VRP-M, PFG-01, -03C,-03M, -04	102x127	25	245x168x220	3.30
VRP-M, PFG-01, -03C,-03M, -04	300x400	6	423x330x43	5.45
FILMS Emulsion**	**Sizes mmxm (Roll)**	**Q-ty of Rolls per Box**	**Box Size (mm)**	**Box Weight (Kg)**
VRP-M,PFG-01,-03C,-03M	35x20m	1	320x300x40	0.3
VRP-M,PFG-01,-03C,-03M	102x20m	1	320x300x110	0.9
VRP-M,PFG-01,-03C,-03M	203x20m	1	320x300x230	1.8
VRP-M,PFG-01,-03C,-03M	304x10m	1	160x150x340	1.3
VRP-M,PFG-01,-03C,-03M	350x10m	1	160x150x390	1.5
VRP-M,PFG-01(on request)	1150x10m	1	160x150x1350	8.9

*bigger sizes on request **cut sheets on request

Table 6: Material sizes available as standard products.

SUMMARY OF TECHNICAL SPECIFICATIONS

Parameters	PFG-01	VRP-M	PFG-03M	PFG-03C	PFG-04
Holographic Sensitivity					
@ 457nm CW $\mu J/cm^2$	.	.	.	2000	80000
@ 488nm CW $\mu J/cm^2$	.	.	.	.	100000
@ 514.5nm CW $\mu J/cm^2$	.	75	.	3000	250000
@ 526.5nm 30ns pulse with latensification - $\mu J/cm^2$	.	75	.	.	.
@ 633nm $\mu J/cm^2$	80	.	1500-2000	3000	.
Maximum Density on Characteristic Curve (D_{max})	<4.0	<4.0	<4.0	<4.0	x
Resolving Power (R), mm^{-1}	3000	3000	>5000	>5000	Grainless
Max. of Spectral Sensitization, nm	633	530	633	457/514/633	415
Swollen Emulsion Layer Strength after Chemical Processing, H (gm force)	900	900	>50	>50	x
Deformation Temperature of Emulsion Layer in Water (T_{def}), °C	>90°C	>90°C	>35°C	>35°C	x
Emulsion Layer Thickness (microns)	7 to 8	6 to 7	6 to 7	9 to 10	16 to 17
Normal Diffraction Efficiency for Reflection					
@ 457nm, %	.	.	.	>25%	>75%
@ 488nm, %	.	.	.	.	>75%
@ 514.5nm, %	.	45%	.	>45%	>75%
@ 526.5nm, %	.	45%	.	.	.
@ 633nm, %	>45%	.	>45%	>45%	.
Observed Storage Period for the holographic materials certified by Geola: At 4° Celsius, 30% Humidity.					
Film Roll (months)	18	18	18	x	x
Cut Sheets (months)	12	12	6	x	x
Plates (months)	18	18	12	12	12

Sales & Purchasing Information

International Sales Centre

UAB Geola is the International Sales Coordination office and International Stockhouse for all Holographic consumable products.

Distribution Network

In order to increase customer service, product quality and the processing speed of commercial orders, Geola has created a large International network of distributors and sales offices for holography materials. Please see below in order to find out which is your nearest and most convenient Holographic materials distributor.

Service

The Geola International Sales Coordination Office was formed in order to ensure that end-users obtain the highest quality materials available. All batches of holographic materials are tested in our modern laboratories and certified. The best processing techniques for each material are continuously reviewed by our highly skilled team of experienced photonic engineers and chemists.

Guarantee

In the unlikely event that any certified holographic product is found to be defective due to manufacture and this product has been sold through the Geola Distribution Network, this product will be replaced free of charge in the shortest possible time.

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