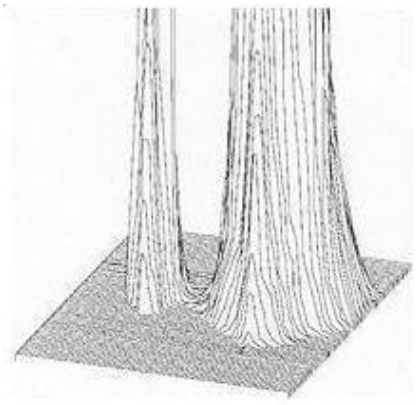
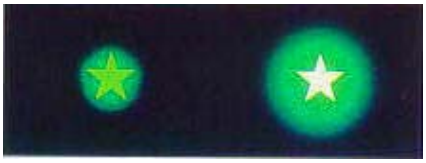
# *LumiNova*®

## LIGHT FAST - SUPER BRIGHT
## LONG AFTERGLOW
## PHOSPHORESCENT PIGMENTS

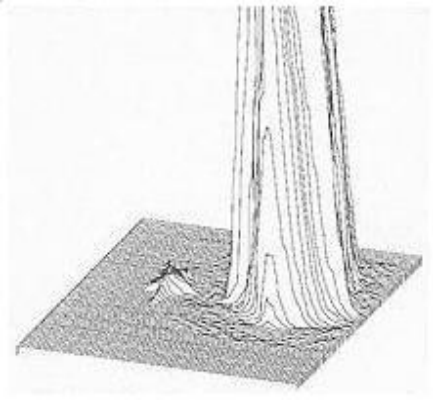
**Afterglow after 5 minutes**



Conventional Pigment ***LumiNova***

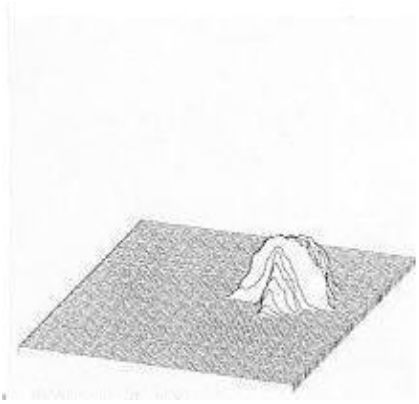


**Afterglow after 60 minutes**



Conventional Pigment ***LumiNova***

**Afterglow after 500 minutes**



Conventional Pigment ***LumiNova***

# *LumiNova®*

# LIGHT FAST - SUPER BRIGHT LONG AFTERGLOW PHOSPHORESCENT PIGMENTS

## *1. What is LumiNova®?*

***LumiNova®*** is a class of newly developed phosphorescent (glow-in-the-dark) pigments which are based on Strontium Oxide Aluminate chemistry. They are drastically different from conventional phosphorescent pigments which are either based on Zinc Sulfide or on radioisotopes for their self-luminous properties. ***LumiNova®*** Pigments are in the TSCA and EINECS inventory and Nemoto & Co., Ltd. was granted the **U.S. Patent in 1995** and since then in many other countries worldwide.

***LumiNova®*** was invented and developed by **NEMOTO & CO. LTD.**, of Tokyo, Japan. Nemoto has been in the luminous pigments business since 1941 and is currently the leading phosphorescent pigment manufacturer in the world. The development of ***LumiNova®*** resulted from the demands placed upon **NEMOTO & CO. LTD.,** by the Japanese watch and clock manufacturers which did not want to use radioactive luminous dials in their products. This challenge created ***LumiNova®***!

***LumiNova®*** which glows practically all night long without the aid of any radioactive substances was chosen as Most Innovative Product in Japan in 1993!

## *2. Features of LumiNova®*

Some of the advantages and distinguishing features of ***LumiNova®*** pigments are:

- Afterglow period of ten times current ZnS based phosphorescent pigments;
- Activation by a wide wavelength band (200-450 nm) but best results are obtained with an activation energy under 365 nm;
- Initial afterglow brightness of up to ten times of current radio luminescent and photo luminescent pigments;
- Increase in luminescence and afterglow with longer activation time;
- Excellent weather and light fastness;
- Free of hazardous and radioactive substances.

## *3. Applications of LumiNova®*

***LumiNova®*** was originally developed to satisfy the current and future needs of the clock, watch and the instrument dial industries, but soon it was found out that like many other new products, that its application possibilities are almost limitless.

The following applications are those that it is being and has been used for:

- Clock & Watch dials;
- Electronic instrument dial pads;
- Home appliances;
- Remote control keypads;
- Lighting apparatus and switches;
- Exit sign boards;
- Emergency signage and low level lighting escape (egress) systems;
- Aircraft and automobile dials and instrument panels;
- Firemen's equipment;
- Traffic signs & high visibility signs;
- Fishing equipment;
- Military applications (e.g. gun sights);
- Outdoor path marking;
- Camping equipment;
- Textile printing and textile fibers;
- Writing & printing inks (gravure, flexo, litho);
- Paints & coatings (including water based systems when the PS-2 types are used).

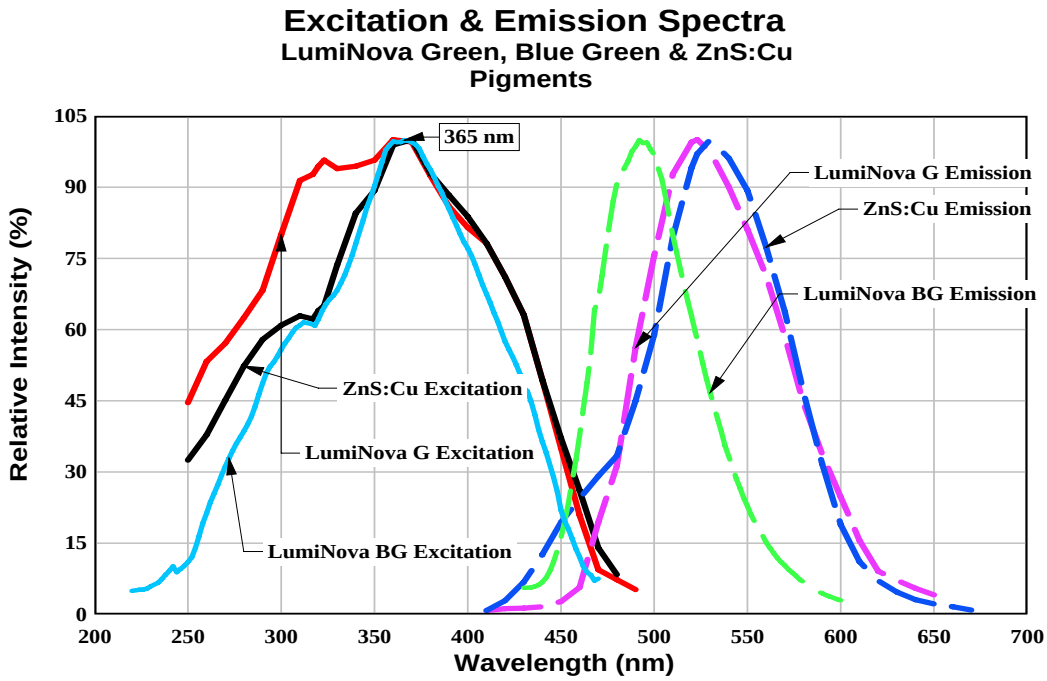
Many other applications where a long afterglow and/or light fastness is needed.

## 4. Comparison between *LumiNova®* types and Conventional Phosphorescent Pigments

| | *LumiNova® Green (G)* | *LumiNova® Blue Green (BG)* | Conventional Phosphorescent Pigment |
|---|---|---|---|
| **Chemical Identity** | Strontium Oxide Aluminate | Strontium Oxide Aluminate | ZnS:Cu |
| **Body Color** | Light Yellowish Green | Light Yellowish Green | Yellowish Green |
| **Av. Particle Size** | 10-40 µm (7) | 10-40 µm (7) | 20-40 µm(7) |
| **Excitation Energy** | 200-450 nm | 200-450 nm | 200-450 nm |
| **Emission Wave Length (Peak)** | 520 nm | 490 nm | 530 nm |
| **Afterglow Brightness (1)** | ≈ 300 mcd/m$^2$ | ≈ 300 mcd/m$^2$ | 20-30 mcd/m$^2$ |
| **Afterglow Extinction (2)** | > 2,000 min. | > 2,000 min. | 200 min. |
| **Excitation Time (3)** | ~ 30 min. | ~ 30 min. | ≈ 4 min. |
| **Light Fastness (4)** | > 1,000 hours | > 1,000 hours | 10-24 hours |
| **Chemical Stability** | Very Good except water (6) | Very Good | Poor to good |
| **Specific Gravity (5)** | 3.6 | 3.9 | 4.1 |

***Footnotes:***

(1) Brightness after 10 minutes excitation with a $D_{65}$ illuminant of 200 lux for 4 minutes.
(2) Time necessary for afterglow brightness to diminish to 0.32 mcd/m$^2$ (100 times the human perception limit).
(3) Time required for saturation with standard $D_{65}$ illuminant at 200 lux.
(4) Time required for initial afterglow to drop by 20% after irradiation with 300 W high pressure mercury lamp (accelerated light fastness test).
(5) In powder form.
(6) Use PS-2 type for water stability
(7) Depends on type (based on particle size) of ***LumiNova®*.**



## 5. Features & Properties of *LumiNova*®

### *Grades of LumiNova*®

Currently ***LumiNova***® is offered in three main types. Differentiation is based on the particle size of the pigment and their afterglow characteristics. As a rule of thumb, the coarser particles will have better brightness and afterglow, and the finer particles are preferred where particle size is the limiting factor due to application needs.

We also have EXTRA LARGE (for stronger afterglow) and EXTRA FINE (for printing and fibers) types available. Please contact UMC for obtaining details.

### *Typical Particle Sizes*

| *GRADE* | *Typical Particle Size (µm)* | |
|---|---|---|
| | $D_{50}$ | $D_{90}$ |
| **300 C** | 60 ± 5 | ≤ 136 |
| **300 M** | 30 ± 5 | ≤ 92 |
| **300 F** | 17 ± 3 | ≤ 54 |

1) Measured with Shimadzu SALD-2100.
2) For smaller particle size contact UMC and ask for FF or FF-S types

### *Effect of Light Source on Brightness*

| *Light Source* | *Luminous Intensity (Lux)* | *Excitation Time to Saturation (Min)* |
|---|---|---|
| **Sunlight, Clear** | > 50,000 | 5 |
| **Sunlight, Cloudy** | 3,000 - 50,000 | 5 |
| **Dusk** | 1,000 | 8 |
| **Fluorescent Lamp (Office)** | 500 | 10 |
| **Fluorescent Lamp (Home)** | 200 | 30 |
| **Tungsten Lamp (60 W)** | 30-50 at 3 ft | 40 |
| **Headlights (Yellow tint)** | Not effective (exposure time too short) | - |

### *Brightness, Afterglow and Emission Color:*

The most effective energy saturation can be obtained when the pigment is exposed under direct ultra violet rays (UV) from the sun, black lamps, halogen lamps, discharge lamps, and other light sources which are rich in UV light (this can be seen also from the Excitation Emission curves). Tungsten lamps are not very effective exciters as their light output is weak in UV. With fluorescent lamps, which are rich in UV, even faster excitation is possible when the pigment is placed close to the source. Afterglow brightness is also proportional to the intensity of UV contained in the excitation light.

### *Moisture Sensitivity:*

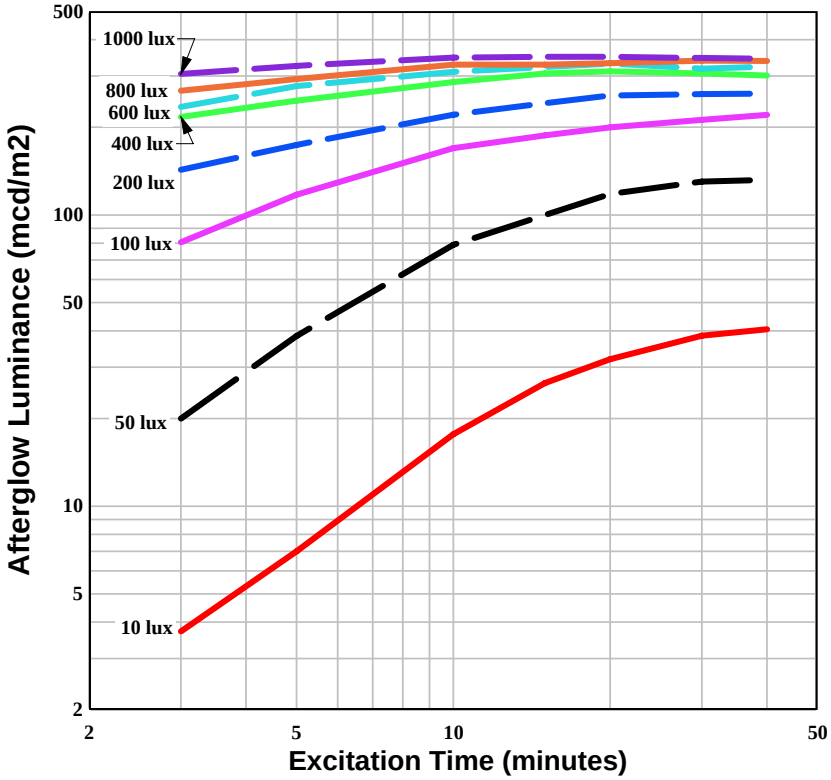
Regular ***LumiNova*® G** pigments are moisture sensitive and cannot be used in water based systems. In most cases the resin component of the coating would protect the pigment from the effects of atmospheric humidity, but for even better results the pigmented layer should be over coated with a clear coat, which would protect the under layer from humidity. In cases where the edges might be exposed to humidity, care should be taken that the edges are sealed properly. Nemoto has recently developed a special grade (patent protected) called PS-2 type which overcomes this problem and makes it possible to use in water based systems. Please contact UMC for details.

### *Light Fastness:*

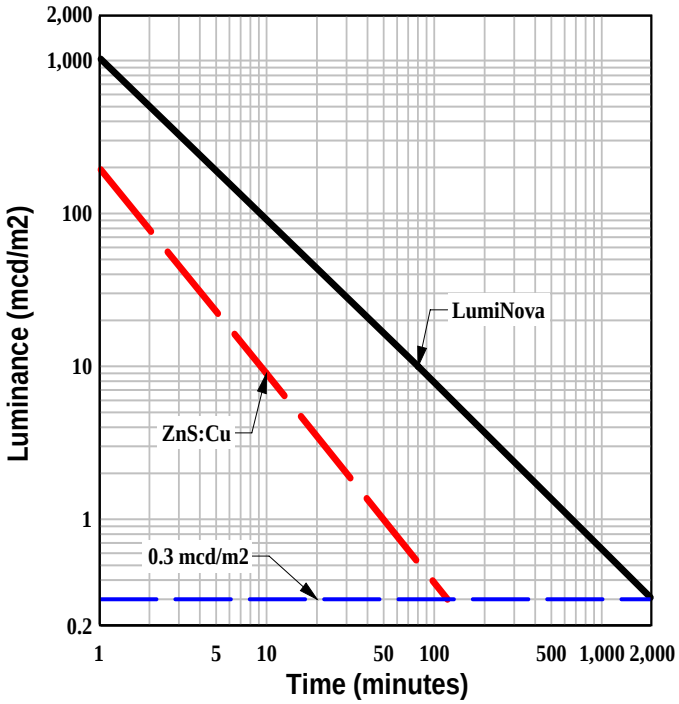
***LumiNova***® pigments also have excellent light fastness compared to conventional phosphorescent pigments. Test samples were irradiated with a 300W High Pressure Mercury lamp for 1,000 hours under a temperature of 38-40°C and humidity of 80% and the results are shown in the following table:

| | *Relative Afterglow (%) After Exposure* | | | | |
|---|---|---|---|---|---|
| ***Pigment*** | **0** | **10 hr** | **100 hr** | **300 hr** | **1000 hr** |
| ***LumiNova***® | 100 | 98 | 98 | 97 | 96 |
| ***ZnS:Cu Pigment*** | 100 | 86 | 35 | 0 | 0 |

## *Excitation Light Intensity & Saturation*



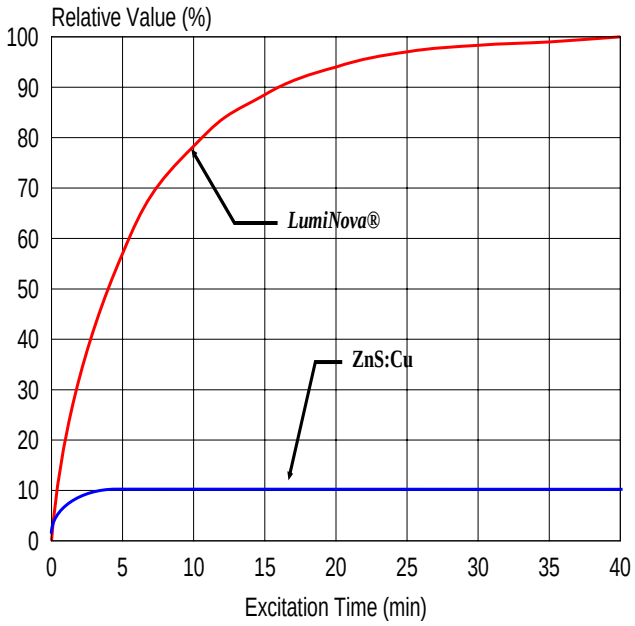

## *Afterglow Characteristics*




This graph shows the afterglow characteristics of ***LumiNova®*** compared to a ZnS:Cu based pigment. The measurements were taken on silk screened surfaces of 100 µm thickness, which were excited with a $D_{65}$ light source at 200 lux for 4 minutes.

As the data indicates, ***LumiNova®*** is TEN TIMES BRIGHTER and has over TEN TIMES THE AFTERGLOW of ZnS:Cu based pigments at equal loadings.

## *Excitation Time on Afterglow Brightness*




***LumiNova®*** shows a much higher capacity for absorbing and storing light energy (i.e. does not easily reach its saturation point) compared to conventional phosphorescent pigments. The above graph shows the results when both types of pigments were excited using a $D_{65}$ light source of 200 lux intensity for different lengths of time.

### *Effect of Weight per Unit Area:*

Under constant lighting conditions, increasing the weight per unit area of pigment increases both initial afterglow brightness and the afterglow duration. The table below shows such a study made by exciting paraffin disks of 2mm thickness, containing different weights per unit area of ***LumiNova®***. The excitation source used was a Xenon lamp at 1000 lux intensity for 5 minutes.

***Afterglow Brightness & Duration Based on Weight per Unit Area of LumiNova®***

| | Pigment Loading | | | | | |
|---|---|---|---|---|---|---|
| **Time** | **10 g/m²** | **25 g/m²** | **50 g/m²** | **100 g/m²** | **200 g/m²** | **400 g/m²** |
| **1 min** | 94.5 | 218.9 | 390.8 | 689.2 | 1,231.0 | 2,610.0 |
| **5 min** | 24.1 | 49.7 | 97.5 | 171.5 | 306.0 | 697.0 |
| **10 min** | 12.4 | 26.0 | 50.5 | 90.1 | 156.1 | 364.0 |
| **30 min** | 4.03 | 8.2 | 16.4 | 29.2 | 50.2 | 118.8 |
| **60 min (1 hr)** | 1.91 | 3.97 | 7.71 | 13.5 | 23.4 | 55.8 |
| **90 min (1.5 hr)** | 1.16 | 2.45 | 4.81 | 8.62 | 14.7 | 34.8 |
| **120 min (2 hr)** | 0.84 | 1.75 | 3.45 | 6.06 | 10.4 | 24.8 |
| **180 min (3 hr)** | 0.53 | 1.13 | 2.14 | 3.62 | 6.38 | 15.4 |
| **240 min (4 hr)** | 0.36 | .79 | 1.5 | 2.66 | 4.57 | 10.9 |
| **300 min (5 hr)** | 0.28 | 0.62 | 1.17 | 2.1 | 3.4 | 8.38 |
| **360 min (6 hr)** | ___ | 0.48 | 0.91 | 1.75 | 2.76 | 6.47 |
| **420 min (7 hr)** | ___ | ___ | 0.78 | 1.4 | 2.23 | 5.62 |
| **480 min (8 hr)** | ___ | ___ | ___ | 1.2 | 1.91 | 4.77 |
| **540 min (9 hr)** | ___ | ___ | ___ | ___ | 1.7 | 3.97 |
| **600 min (10 hr)** | ___ | ___ | ___ | ___ | ___ | 1.05 |
| **Extinction Time (to 0.3 mcd/m²)** | 270 min (4.5 hr) | 480 min (8 hr) | 750 min (12.5 hr) | 1,200 min (20 hr) | 2,400 min (40 hr) | 3,000 min (50 hr) |

## *6. Applications*

***LumiNova®*** pigments may be used in all types of paint, powder coatings, silk-screen inks, enamels, plastics and even porcelain (up to 500 °C). The regular ***LumiNova®*** G pigments are not stable in water, therefore aqueous systems are not recommended unless special grades are used (please contact UMC and ask for the PS-2 grade). We also have EXTRA SMALL size grades for Flexo, Pad, Gravure and Litho inks (please contact UMC and ask for the FF or FFS grades). For optimum performance the following suggestions should be useful:

### *Paints & Coatings:*

- Use a transparent solvent vehicle with neutral or alkaline pH.
- Do not grind the pigment, just stir. If possible use light colored ceramic or glass lined vessels.
- Plan on using about 10 parts of ***LumiNova®*** to 6 parts of binder (by weight).
- Shelf life depends on the moisture content of the vehicle, if moisture is present, shelf life is diminished. Although solvent based paints do not contain moisture, some of them might absorb ambient moisture. Therefore take precautions to minimize this from happening.
- To minimize settling, use a viscous vehicle and/or anti-settling agents. Stir well prior to application.
- Apply a white base coat under the phosphorescent layer to improve afterglow.
- Apply a clear overcoat to protect the pigment from humidity and to improve gloss.
- All additives should be free of heavy metal compounds.

Nemoto & Co. has recently developed (patented) the PS-2 type for water based systems which makes it possible to use ***LumiNova®*** in water based paints and coatings.

## *Inks: Silk Screen & UV Cured:*

- Viscosity of inks should be about 3,000-5,000 poise. During printing, viscosity should be adjusted by using a diluting agent based on printing speed.
- Apply a white base coat under the phosphorescent layer to improve afterglow.
- Minimum film thickness of the ***LumiNova®*** layer should be 100 µm. In order to achieve maximum afterglow (over 8 hours), a film thickness of 130-150 µm is required. For achieving this thickness two passes may be necessary.
- Ideal screen size would be 80 - 100 mesh. Larger screen openings would give better results. Preferably, use screens manufactured from synthetic resins.
- One pound of dry ***LumiNova®*** pigment can cover a 12 square foot area at a 150 µm film thickness [1 gram covers 25 $cm^2$].
- To minimize settling, use a viscous vehicle and/or anti-settling agents. Also stir well prior to printing.
- It is very important to keep the entire system dry! A yellowing of the resin may indicate the pigment reacting with moisture.

For use in Flexo, Pad, Gravure and Litho inks contact UMC for recommendations.

## *Plastics - General:*

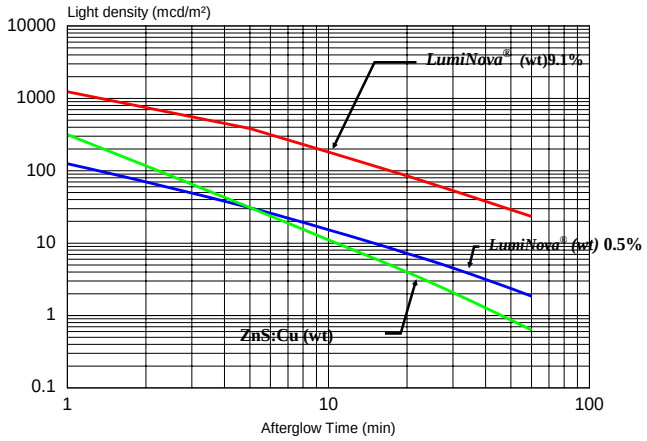
- ***LumiNova®*** is compatible with Acrylic, Polyester, PUR, Epoxy, PVC, Polycarbonate, Polypropylene and Polyethylene (HDPE, LDPE, etc.) polymers.
- Material can be cast, dipped, coated, extruded or molded.
- Plan on using less than conventional phosphorescent pigment loadings. (See following graph)

## *Masterbatch Manufacturing:*

- Preferably use masterbatches or compounds for incorporating ***LumiNova®*** into plastics. As ***LumiNova®*** is a very hard substance (with a hardness similar to alumina) and the particles have a needle like shape (sharp-edged), it is difficult to incorporate them into plastic resins directly (they can be regarded as glass or ceramic powders).
- Prior to starting manufacturing a **masterbatch**, the interior of the extruder should be thoroughly cleaned.
- The processing temperature should be set about 10°C (20° F) higher than usual. The extruder should be cleaned again by running virgin resin until clean resin starts coming out of the machine.
- The recommended machine configuration is one with a distributive screw design and twin hoppers. Use the first to feed the resin and additives and the second to dose ***LumiNova®*** into the polymer melt. This would minimize the chances of ***LumiNova®*** abrading the interior surfaces of the extruder.
- If the above is not possible keep the mixing (interaction) time of pigment and resin as short as possible. Stirring for a longer period may cause darkened products.
- The resin and pigment should be thoroughly dried before the extrusion process.
- Using carrier resins in powder form can also minimize darkening.
- Masterbatches containing up to 50% of ***LumiNova®*** pigment have been manufactured.

## *Extrusion Molding:*

- For **extrusions** a small-bored machine would be preferable as to minimize residence time. Extruders with large inside wall areas or equipped with complicated screw geometries tend to cause darkening of the end product.
- It is recommended to use an extruding temperature as low as possible (only experimentation will give the right temperature level)
- The optimum back pressure should also be determined by experimentation.
- The color of the pellets being produced should be observed, they should be the same color as the pigment itself.
- The best temperature level inside the barrel is closely related to screw geometry and back pressure, these should be determined after repeated experiments.




## *Injection molding:*

- The use of an **injection molding** machine equipped with a small chamber is recommended. For instance, for injection molding a piece of 50 grams per shot with a duration of 3 minutes, do not use a machine with a 5 kg chamber capacity as it will have enough resin for 100 shots. This means a residence time of 300 minutes. In such a case, the final product would probably be darkened. An adequate sized chamber would be the one in which a resin stays at most for 30 minutes or less.
- A test run with a virgin resin is recommended before injection molding with ***LumiNova®***.
- Masterbatches or pellets containing ***LumiNova®*** must be fully dried up before usage.
- The most adequate molding temperature should be determined by running experiments at different temperatures.
- It is difficult to injection mold resins containing a stabilizer or resins which are hygroscopic or contain water. (Unless you use PS-2 types)

## *General Precautions*

Although ***LumiNova®*** is chemically stable, we would like to repeat here a number of things to avoid:

- Do not grind or mill the pigment. Breaking down the crystals will destroy the afterglow.
- Avoid exposing the pigment to strong acids or heavy metal compounds. They will react and destroy the glow. Also keep away from moisture (unless special PS-2 grade is used).
- ***LumiNova®*** is a hard material and this might cause abrasion of extruder internal metal surfaces. In order to avoid this problem either use specially surface hardened barrels and screws, or a wax to wet ***LumiNova®*** prior to extruding, or use a machine with two entry ports.
- Avoid moisture and aqueous systems (unless special PS-2 grade is used). Once the pigment is incorporated into the solvent based resin system or plastic resin, it is not affected by moisture.
- We have tested our products thoroughly but the afterglow properties are depended on the pigment quantity used, film thickness and the manufacturing process in which the pigments are applied. The efficiency of phosphorescent pigment containing articles can only be observed when installed properly and excited under correct lighting conditions as required by proper authorities. Therefore we can not guarantee that the end products containing ***LumiNova®*** conform to the required standards.

## *7. Conclusion:*

***LumiNova®*** is sure to revolutionize the glow-in-the-dark products' field . Its superior light fastness combined with its high initial brightness and long afterglow will create new opportunities for companies that were limited by the restrictions placed upon them by conventional phosphorescent pigments. ***Now the only limit is the designer's imagination!***



***Manufactured by:***

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