

FONDAZIONE ISTITUTO ITALIANO DI TECNOLOGIA

A TECHNOLOGY TEASER

PMMA DOPED BY TITANIUM DIOXIDE



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NEW MATERIALS

Istituto Italiano di Tecnologia – Mission and History

The Foundation is intended to promote Italy's technological development and advanced education, consistent with national policies for scientific and technological development, thus strengthening the national production system.

For this purpose the Foundation:

- helps and accelerates the development, within the national research system, of scientific and technological skills able to facilitate state of the art technological advancements of the national production system;*
- develops innovative methods and know-how, in order to facilitate new high-level practices and positive competitive mechanisms in the field of national research;*
- promotes and develops scientific and technological excellence, both directly, through its multi-disciplinary research laboratories, and indirectly, through a wide collaboration with national and international laboratories and research teams;*
- carries out advanced training programmes as a part of wider multi-disciplinary projects and programmes;*
- fosters a culture based on sharing and valuing results, to be used in order to improve production and for welfare-related purposes, both internally and in relation to the entire national research system;*
- creates technological understanding about components, methods, processes and techniques to be used for the implementation and interconnection of innovative products and services, in strategic areas for the competitiveness of the national production system;*
- pools research scientists operating in various research institutes and establishes cooperation agreements with high-level, specialized centres;*
- promotes interactions between basic research and applied research facilities, encouraging experimental development;*
- spreads transparent, merit-based selection mechanisms for research scientists and projects, in compliance with globally approved and established criteria.*

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EXECUTIVE SUMMARY

PMMA doped by TiO₂ technology developed at IIT allows to stabilize and homogenize a colloidal solution of titanium dioxide nanoparticles in acrylic polymers (particularly, PMMA) with complete dispersion of the nanoparticles in the polymeric matrix from which it is possible to obtain thin films by spin-coating or thick plates by easy solvent evaporation, while maintaining transparency properties of the polymer in the visible band or increasing the absorption in the UV band. The composite nanomaterial so obtained shows optical (refractive index, reflectivity, UV absorption) and physical (wettability index, glass transition temperature T_g, hardness) properties that are finely tunable on the basis of the weight ratio between nanoparticles and polymer.

The advantage of IIT technology is the lack of any chemical treatment of the polymer or nanoparticles, thus avoiding increasing the production costs, and the capacity to obtain thick films while maintaining high transparency properties of the polymer. By mean of this technology it is possible to combine in different grades the physico-chemical properties of the polymer and the inorganic nanoparticles, simply by varying their concentration ratio and the laser radiation used for stabilizing the composite nanomaterial. The homogeneous dispersion of the nanoparticles obtained by this technique is able to guarantee ideal transparency properties of the composite nanomaterial.

IIT PMMA has several industrial applications; the material is capable to satisfy a large range of industrial applications in different market segments, such as the production of optical devices and opto-electronics (for example in making waveguides, thanks to the control of the refractive index), the production of rigid, protective, transparent and thermo-resistant shields useful in the automotive and aerospace industry, in the architecture and construction industry, in the photovoltaic industry (transparent and anti-reflecting coating), in the chemical sensors applications and medical & healthcare industry and more in general in the plastic material industry.

The IIT PMMA technology represent a unique opportunity for a company active in one of cited sectors to boost and extend its pipeline or to enter a new market segment. Accordingly, IIT assets appear well positioned for an out-licensing strategy, providing the licensee partner with the ability to take care of the late stage development, CE certification, scale-up and production process. The licensee should guarantee a high probability of market success based on consolidated marketing & distribution organization. A typical licensing strategy based on entry fee and subsequent royalties on net sales can be envisaged.

INTELLECTUAL PROPERTY

IIT Technology Transfer is ensuring proper protection of the technology. Follow details on the PCT filing and application.

PCT International Publication #	WO 2011/121519A1 - 06 October 2011
Priority Application #	IT TO2010A000240 - 29 March 2010
Regional Patent Applications filed	EP 11731085.4, US 13/636990, CN 201180017053.9
Applicant	Fondazione Istituto Italiano di Tecnologia
Inventors	Riccardo Carzino, Francesca Pignatelli, Marco Scotto, Bruno Torre, Gianvito Caputo, Pantaleo Cozzoli, Athanasia Athanasiou, Roberto Cingolani
Title	A technique for stabilizing solutions of titanium dioxide nanoparticles in acrylate polymers by means of short-pulsed UV laser irradiation

Short Description

The technique is based on UV pulsed laser irradiation of acrylate polymers based solutions, that generates in a single step the separation of the initial clusters of colloidal TiO₂ nanorods into clearly separated units, exploiting the intrinsic photosensitivity of the semiconductor nanoparticles. From the irradiated solutions, optically clear nanocomposite films are obtained that exhibit increased UV absorption, refractive index, antireflection properties, as well as tunable wettability; properties not possible otherwise that establish that the photocatalytic property of TiO₂ nanocrystals together with the irradiation process solve the crucial dispersion enigma of their nanocomposites. The obtained good dispersion shows that the larger active surface area of nanocrystals reacting with the incoming light increases the optical properties of the nanocomposites as never seen before. In summary, this is a simple but powerful tool to control the mixing between polymers and semiconductor nanocrystals, using their photocatalytic ability, without chemicals treatment.

IIT TECHNOLOGY

The IIT technology consists in a method for preparing a colloidal solution of titanium dioxide nanoparticles dispersed in a solution of acrylic resin (in particular, polymethyl methacrylate - PMMA) in organic solvent. The colloidal solution so formed is subjected to a stabilization treatment suitable for preventing or reducing nanoparticles aggregation, the treatment comprising irradiation of the colloidal solution with pulse coherent light having a wavelength substantially comprised in the ultraviolet absorption band of the titanium dioxide nanoparticles.

Due to the low affinity between acrylic polymers and synthetically-produced titanium dioxide nanoparticles, a distinct phase separation of the two environments is normally observed, leading to particle aggregation. Therefore, any production of various thickness films is affected by the particle aggregation phenomena that leads titanium dioxide nanoparticles to aggregate, in a dis-homogenous manner, on the surface.

IIT technology, instead, allows to stabilize and homogenize a colloidal solution of titanium dioxide nanoparticles in acrylic polymers (particularly, PMMA) with complete dispersion of the nanoparticles in the polymeric matrix from which it is possible to obtain thin films by spin-coating or thick plates by easy solvent evaporation, while maintaining transparency properties of the polymer in the visible band or increasing the absorption in the UV band. The composite nanomaterial so obtained shows optical (refractive index, reflectivity, UV absorption) and physical (wettability index, glass transition temperature T_g , hardness) properties that are finely tunable on the basis of the weight ratio between nanoparticles and polymer.

The advantage of IIT technology is the lack of any chemical treatment of the polymer or nanoparticles, thus avoiding increasing the production costs, and the capacity to obtain thick films while maintaining high transparency properties of the polymer. By mean of this technology it is possible to combine in different grades the physico-chemical properties of the polymer and the inorganic nanoparticles, simply by varying their concentration ratio and the laser radiation used for stabilizing the composite nanomaterial. The homogeneous dispersion of the nanoparticles obtained by this technique is able to guarantee ideal transparency properties of the composite nanomaterial.

As such, the material is capable to satisfy a large range of industrial applications in different market segments, such as the production of optical devices and opto-electronics (for example in making waveguides, thanks to the control of the refractive index), the production of rigid, protective, transparent and thermo-resistant shields, useful in the automotive and aerospace industry, in the architecture and construction industry, in the photovoltaic industry (transparent and anti-reflecting coating), in the chemical sensors applications and medical & healthcare industry, and more in general in the plastic material industry.

MARKET ANALYSIS

Based on the technology described in WO 2011/121519A1, IIT internal documentation on the technology and related literature publications by the inventors and competitors, the polymethyl methacrylate (PMMA) market has been deeply analyzed along with its industrial applications, including coating.

Although IIT technology is applicable on various methyl, ethyl, butyl, or 2-ethylhexyl acrylate- or methacrylate-based polymers, by far the main product used in industrial and household applications is PMMA, and therefore the following market analysis has been focused to this market. The market has been analyzed for its current dimension and future trends through a web search-based retrieval of free-of-charge specific information. Key players have been identified, and their websites have been reported; particular focus has been put on European key players, as potential source of industrial partners to get in touch with in order to touch basis of their potential interest in the IIT technology; their size, specific products, core skills and market strategies have been briefly documented.

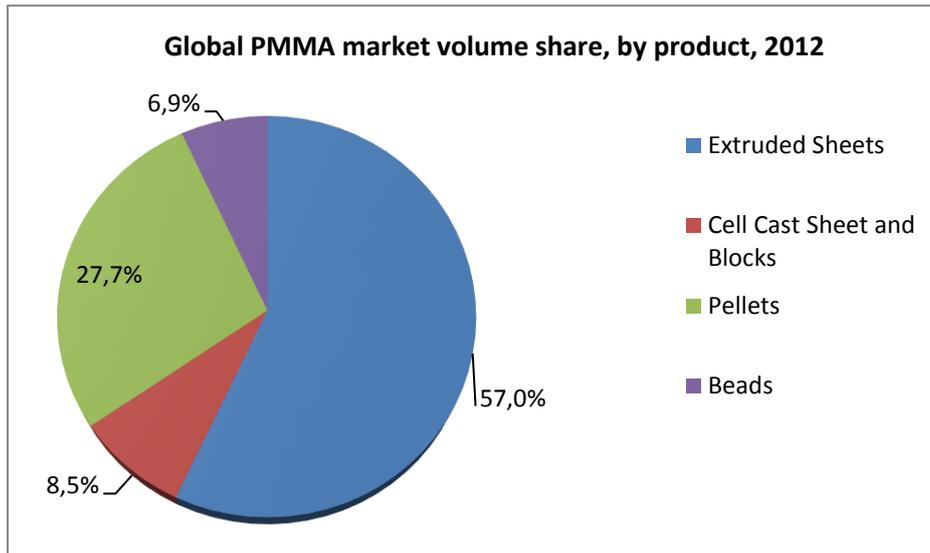
PMMA, obtained by polymerization of methyl methacrylate (MMA) monomer, constitutes about 50% of the downstream market of MMA. PMMA is widely used in various applications for its many advantageous properties. Perhaps the most well-known of these properties is light transmission; typical PMMA grades allow 92% of light to pass through it, which is more than glass or any other plastics. This outstanding transparency enables the use of PMMA in many different optical and related applications. Because it is inherently stable to UV light, PMMA is used for many outdoor applications, in which it maintains its original color and finishes for many years. PMMA also has excellent scratch resistance and is able to be processed to a very high gloss finish. These properties, combined with PMMA's dimensional stability, enables its use in many different applications where lasting beautiful appearances are important, such as on furniture or kitchen or bath walls or cabinet facades.

PMMA can be further modified by incorporating different additives (in the case of IIT technology it is doped by TiO₂ nanoparticles). These modifications are typically performed to improve specific properties of the polymer, usually targeted toward highly specific and more sophisticated industrial applications. Examples of properties that can be adjusted in this way are impact resistance, chemical resistance, flame retardancy, light diffusion, UV light filtering, and optical effects.

Market Size

From data published in June 2014 by the Transparency Market Research Group in the report: "Polymethyl Methacrylate (PMMA) Market: Global Analysis, Size, Share, Growth, Trends and Forecast 2013 - 2019", global PMMA market was valued at USD 5.74 billion in 2012 and is expected to reach USD 10.53 billion by 2019, growing at a compounded annual growth rate (CAGR) of 7.9% over the forecast period from 2013 to 2019.

Based on the grade, the global PMMA market is segmented into general purpose (GP) and optical grade. GP-grade PMMA is a material widely used in many industries and a large number of everyday household applications, such as souvenirs, illuminated signs and bathtubs. In 2013, GP-grade PMMA accounted for 59.1% of the global PMMA market by consumption, while the rest of PMMA market is covered by optical grade PMMA.



PMMA Market segment by product

Global production of PMMA molding compounds and semi-finished products increased to over 1.6 million tons in 2010 as many end-use industries managed to recover from the 2008 global financial crisis more quickly than originally expected.

PMMA is manufactured in four forms including extruded sheet, pellets or resins, beads (powder) and cell cast sheets and blocks. It has wide usage in various industries such as electronics, construction, signs and displays, furniture and interiors, solar panels, sanitary ware, fashion and apparel, lighting and decorative, medical and healthcare, as more extensively described above. Growth in key end-use applications such as signs and displays, electronics and automotive industries is expected to boost the global PMMA demand over the next six years. These industrial sectors have been witnessing rapid growth, especially in emerging markets such as Asia Pacific and Latin America, thus fuelling the PMMA demand. However, volatile raw material prices of petrochemicals are expected to be a key issue for market participants. In order to reduce reliance on conventional (petroleum derived) PMMA, industry has shifted its focus towards developing its bio-based alternatives, which are expected to catch up in the near future owing to their eco friendly characteristics and secure raw material supply.

In another Report by the Grand View Research Inc., published in January 2014, the production of extruded sheets, cell cast sheets and blocks, pellets and beads is analyzed. Extruded sheets emerged as the leading PMMA product consumed worldwide and accounted for over 55% of total PMMA volume in 2012. Extruded PMMA sheets are widely used in manufacturing LED screens for electronic devices, facades in buildings, solar panels, decorative interiors, and signs and displays. Rapid development of the LED screens and the signs and display segment mainly in Asia Pacific is expected to drive the market for PMMA extruded sheets over the next six years. Extruded sheets were followed by pellets which accounted for over 25% of global market volume in 2012. PMMA pellets are the basic form, which can be further processed for a variety of applications. They can be molded for use in signs and display, automotive panels, medical and healthcare, fashion apparels, etc.

Owing to its use in coating and emulsion markets, and as additives to other copolymers, PMMA beads (powder) form is expected to be the fastest growing market at an estimated CAGR of 8.8% from 2013 to 2019. They are added as coloring agents and impart a glossy look to the emulsion. They also act as

strengthening agents in some application. Cell cast sheet and blocks is another PMMA form widely used for construction activities owing to its impact strength and weather resistance.

Below a dedicated focus for different applications is reported.

Industrial & Household Applications

The industrial applications for which PMMA is commonly used are reviewed from <http://www.pmma-online.eu/applications>; the site content is provided by the group representing the manufacturers of methacrylic acid, and its basic esters, and polymethyl methacrylate (PMMA) in Europe.

Of course IIT technology will be best applied to those segments that require high sophisticated composite materials with outstanding optical properties of transparency, reflectivity, refraction, UV light filtering, mechanical resistance and thermo-resistance.

Architecture & Construction

- Door and window profiles: Available in a wide range of colors and different levels of gloss finishes, the co-extruded surfaces provide outstanding impact, chemical and UV resistance as well as excellent performance in all weather conditions.
- Sound barriers: Optical clarity and the highest performance in all weather conditions, make acrylic sheet products the ideal choice for sound barrier installations alongside motorway systems.
- Structural panels: Some of the world's biggest and most impressive aquaria and marine centers feature viewing panels that are made of PMMA. These panels are extremely strong and resistant to abrasive action. Above all, they provide superior, pure optical clarity to ensure the best possible viewing experience. Similar principles and manufacturing techniques can be applied to the creation of structural panels for pavilions and other in- and outdoor buildings.
- Greenhouses: PMMA facilitates light transmissions, which ensures that the plants grow quicker. Good heat insulation enables savings on heating costs.
- Worktops and surfaces: Acrylate is a high performance, extremely hardwearing material that is resistant to UV light and chemicals and easy to mold, thermoform and fabricate into solid sheet and shapes. This makes it a flexible solution for solid surfaces for both domestic and public installations.

Furniture and Design

- Furniture: In this segment, designers and fabricators know they have the perfect combination of high performing characteristics and beautiful aesthetics in the form of colors, effects and special finishes to choose from. From tables in ultra thick clear acrylic to etched frost consoles and chairs in all shapes and sizes, furniture made from quality acrylic will add style to any interior.
- Gift and tableware: Acrylic sheet products are used for photo frames, occasional storage, table mats and other home-wear, or for injection molding into salt and pepper mills, salad bowls and servers and even chess pieces.

Electronics & Energy

- LCD screens and monitors: All top electronics brands use screens made from PMMA. Its durability and light transmittance makes it the best choice from small to ultra large screens.
- Mobile phone screens: Easy processing, excellent optical clarity, high light transmission, toughness and high scratch and impact resistance make PMMA a suitable material for mobile phone screens.

- TV and video equipment: PMMA is used extensively for the manufacture of electrical equipment display and infra red transmitter/receiver windows.
- Solar Applications: Photovoltaic modules are exposed to extremes of nature. Particularly the sun, which is essential for their purpose, is a constant stress factor that PMMA withstands on a durable basis. The specific properties of the material simultaneously ensure high energy conversion efficiency, thus making solar electricity even more economical.

Lighting

- Lamps and LEDs: PMMA shows its strengths particularly in combination with light. Its unsurpassed transparency and brilliance make PMMA an indispensable material for optical and technical applications. PMMA-based lighting solutions offer a unique combination of illumination and up to 50% reduced energy consumption compared to traditional back lit systems. PMMA is able to maximize the light emitting potential of LEDs.
- Skylights: Innovative PMMA products include reflective acrylic features: an innovative component distributed uniformly throughout the cast sheet, which effectively reduces the heat typically transmitted through windows and skylights. The benefits include lower energy costs, reduced environmental impact and pleasing aesthetics.

Automotive & Transportation

- Caravan windows: Thermoformed acrylic sheet is now used almost exclusively for caravan window glazing where all the necessary requirements for light weight materials that are safe, easy to process and perform in all weathers are met.
- Interior and exterior trim: PMMA is used to create interior and exterior panels, trim, bumpers, fenders and other molded parts. Key qualities include: excellent surface hardness, UV and abrasion resistance; PMMA offers a myriad of coloring options from transparent to deep color, highly gloss or matt.
- Light covers: PMMA is used in exterior, rear and indicator light covers and for interior light covers and fascia. They provide excellent optical clarity, light transmission and color accuracy; they are easy to process and create hard surfaces that withstand continuous exposure to wear and tear.
- Aviation: PMMA is used for windscreens, windows and canopies. It resists high inside cabin pressure, double-digit subzero outside temperatures, and harsh UV radiation. PMMA offers outstanding optical properties, is lightweight, resists to temperature fluctuations and shows high weather resistance.
- Windshields and sun visors: Acrylic sheet products are used for clear and tinted motorcycle, aviation, helicopter, and recreational vehicle windshields. They are much lighter than glass yet they offer double impact resistance, uniform thickness tolerance and low internal stress levels for consistent performance (Plexiglas®).
- Automotive glazing: PMMA glazing is 40 to 50% lighter than conventional glass, which makes it of great interest to car manufacturers. Weight savings apart, the transparency of PMMA as well as its very high weathering resistance, pleasant acoustic properties, and outstanding formability enable entirely new design possibilities.
- Marine Applications: PMMA is extensively used for marine applications such as windshields and windows. PMMA is lightweight and is resistant to salt and cleaning products.

Medical & Health

- Cabinets: Whether they are used inside hospitals, doctors' surgeries, dental practices or research laboratories, cabinets made of PMMA offer high quality storage that is easy to maintain and keep clean.
- Dental: PMMA's biocompatibility, reliability, ease of manipulation makes it the perfect material for dental applications such as cavity fillings.
- Medical: Acrylic resins are used by global leaders in the field of bone cement where consistent and high performance is paramount. Manufacturers and surgeons are continuously improving bespoke formulations to ensure to stay at the cutting edge of this important sector.
- Diagnostics: Excellent transparency and optical clarity, UV resistance and surface hardness coupled with good chemical resistance makes acrylic polymers ideally suited for the manufacture of disposable medical diagnostics. Blood cuvette, drug testing device and laboratory equipment manufacturers benefit from easy processing, purity of material, good dimensional stability and excellent bonding capability with itself and other polymers.

Sanitary

- Bathtubs: Available in a wide range of colors and effects, acrylic has a luxurious warm feel and is extremely hard wearing. It is resistant to chemicals, UV and abrasion, and easily formed into an array of shapes and styles.
- Panels and fittings: The use of cast acrylic to create bath panels that complement the tub itself are a natural product extension. The same wide range of colors and effects, luxurious warm touch and hard-wearing qualities combine with easy formability and resistance to chemicals, UV and abrasion to make it an ideal choice for bath manufacturers.
- Shower cabin doors: Perfect for use in high performance washroom areas at leisure complexes, gyms and spas, shower panels made from acrylic are extremely practical and hard wearing. Resisting damage from repeat use and constant exposure to chemicals, they retain their high quality finish for substantial periods of time.

Visual Communications

- Museum casings: PMMA sheet offers maximum protection to precious photographs, artworks and exhibits by filtering out damaging UV light. The sheet is easy to fabricate into high quality casing, which provides excellent optical clarity to museum and gallery visitors.
- Point of Sale & Exhibition Booths: Acrylic is used for displays, signage, display cabinets, leaflet dispensers, window displays, poster holders and many other POS applications.

Acrylic coatings and Cool Roof Systems

- There is increased interest in the energy-saving, improved urban air quality, and longevity benefits of Cool Roof Systems that are based on acrylic coatings. Weatherproofing commercial and industrial buildings with high performance acrylic coating systems are growing and cost effective. TiO₂ is termed a prime pigment in acrylic coating formulations due to its impact on coating durability and reflectivity. TiO₂ comes in different grades at different prices. Various grades can oxidize at different rates and cause different degrees of coating chalking over time. TiO₂ is also opaque to UV radiation and blocks these harmful rays from reaching the substrate. TiO₂ adds whiteness and reflectivity to an acrylic coating system, impacting the overall energy efficiency of a Cool Roof System. A chalky coating installation may signal the use of a coating based on insufficient TiO₂ levels or inferior grades of TiO₂.

COMPETITIVE SCENARIO

The PMMA market is concentrated with top four players holding more than 70% share. Some of the key manufacturers of PMMA include among others:

- Mitsubishi Rayon Company (Korea, <https://www.mrc.co.jp/english/>),
- Evonik Industries AG (Germany, China and Taiwan, <http://corporate.evonik.com/en/Pages/default.aspx>),
- Altuglas International, a subsidiary of Arkema Group (France, <http://www.altuglasint.com/en/>),
- Lucite International, a subsidiary of Mitsubishi (UK and Japan, <http://www.luciteinternational.com/>),
- Chi Mei Corporation (Taiwan, <http://www.chimeicorp.com/en-us/>),
- Sumitomo Chemical Company (Japan and Singapore, <http://www.sumitomo-chem.co.jp/english/>),
- Dow Chemical Company (US, <http://www.dow.com/>),
- LG MMA (South Korea, <http://www.lgmma.com/en/>),
- Quinn Plastics (UK, <http://www.quinn-plastics.com>),
- Kuraray (Japan, <http://www.kuraray.co.jp/en/>),
- Polycasa (B, <http://www.polycasa.com/>),
- Plazit (IL, <http://www.plazit-polygal.com/>).

Recently, Arkema SA (Altuglas Int.), in collaboration with Natureworks has developed a composite material of PMMA doped with 25% Polylactic acid (PLA), a renewable resin. The product will be launched under the brand Plexiglas/Altuglas RNew. This product provides lowered carbon footprint and possesses better impact strength and chemical resistance. In addition, Mitsubishi Rayon Company and Evonik Industries AG., separately, are working towards producing bio-based PMMA using green building blocks like Methacrylic acid and Itaconic acid by fermentation of sugars. These initiatives are at the R&D stage and not yet introduced for commercial production. This process may help reduce dependence from petrochemicals for production of PMMA, thus, reducing the carbon footprint as well. Finally, further investment in new PMMA plants for the middle East has been announced or is at the planning stage, for example the joint venture by Mitsubishi Rayon and Sabic with the objective to erect a new MMA and PMMA production facility in Saudi Arabia.

European Players

Altuglas International (FR) a subsidiary of the Arkema group, is heavily involved in the field of engineered plastic, from MMA monomer to PMMA acrylic glass. Altuglas designs and manufactures highly innovative products tailored to the specific needs of its global customers. They have three areas of business (MMA, Acrylic Sheets and PMMA resins). Its three large professional brands set the standard for the European market: Altuglas®, Oroglas®, Solarkote®.

Evonik Industries (D) is one of the world leaders in specialty chemicals. Its activities focus on four key megatrends health, nutrition, resource efficiency and globalization. Evonik benefits specifically from its innovative prowess and integrated technology platforms. Evonik is active in over 100 countries around the world. In fiscal year 2010 more than 34,000 employees generated sales of around € 13.3 billion and an operating profit (EBITDA) of about € 2.4 billion. The Acrylic Polymers Business Line of Evonik is one of the world's leading suppliers of PMMA molding compounds and sheet products, marketed under the Plexiglas® trademark. Of all solar technologies, concentrating photovoltaic (CPV) technology has been found to be the most efficient. It uses optical elements to concentrate the sunlight onto high-efficiency solar cells (multi-

junction cells). The optical system are usually lens parquet. Evonik Industries has developed a special PMMA grade that meets the requirements for CPV outdoors. Called Plexiglas Solar®, this new PMMA has transmission properties which are specially tailored to the effective range and requirements of solar cells. Concentrator Optics GmbH, Cölbe (D), mass-produces certified lens parquets using extruded sheets of Plexiglas Solar®.

Lucite International (UK) is a global company that focuses on the design, development and manufacture of acrylic-based products. With manufacturing, sales and distribution capabilities they are beyond some of the world's best known branded acrylic products like Lucite®, Perspex®, Diakon®, Elvacite®, Coracryl® and TufCoat®. Lucite International has about 2,000 employees and one of the most diverse asset portfolios, with 22 plants at 14 manufacturing sites worldwide and a base of customers in more than 100 countries worldwide.

Polycasa (B) is a market leader in plastic sheet extrusion. The headquarter is based in Geel, Belgium, and they are manufacturing products in six different plants across Europe. This has resulted in an extensive range of products for many different applications. Acrylic Granulate and Sheet are one of the most important products in the portfolio. As a specialist in plastic sheet products, they respond to the needs of the market by continually enhancing the product range and developing new products to meet customer needs.

Plazit (IL) is part of the Plazit-Polygal group with an increasing presence in the plastic sheets market. The Plazit 2001 headquarters are situated in Kibbutz Gazit in Israel. The group manufactures solid and multiwall plastic sheets. The organization is supported by a staff of more than 550 people, comprising engineers and experts in the field of plastic sheet processing. One of the principal products is acrylic sheets, which include a wide range of qualities, produced either by extrusion or cast processing. Plazit 2001 is an emerging company with more than 35 year of expertise in the field.

Asian PMMA Market & Key Players

The figure aside illustrates Asian PMMA capacity in tons x1000 key players.

ASIA PMMA CAPACITY		
Company	Location	Capacity
Chi Mei	Jen-Te	175
LG MMA	Yeos, South Korea	125
Sumitomo Chemical Singapore	Jurong Island, Singapore	100
Mitsubishi Rayon Polymer Nantong	Nantong, China	60
Sumitomo Chemical	Niihama, Japan	59
Kuraray	Nakajo, Japan	58
Arkema	Chinhae, South Korea	50
Daesan MMA	Yeosu, South Korea	50
Chi Mei	China	50
Asahi Kasei	Chiba, Japan	40
Evonik Forhouse Optical Polymers	Taiwan	40
Evonik Industries	Caojing, China	40

FOR FURTHER READING

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