# Task 39: Polymeric Materials in Solar Thermal Applications

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## NEWS

*September 24 - 25, 2007*

The **3rd IEA-SHC Task 39 Experts Meeting** was arranged by the Polymer Competence Center Leoben (PCCL) and the University of Leoben Austria. The meeting took place in Blumau, Austria from September 24-25, 2007.

37 experts from 27 institutions from 10 countries were present. 16 participants came from the solar thermal or polymer industry. The present newsletter summarises topics, which were presented and discussed at the experts meeting in Blumau. A major focus of the meeting were the brainstorming sessions on so-called 'dream' collectors and 'dream' heating systems of polymeric materials.

For more information on Task 39 vistit the official website http://www.iea-shc.org/task39. Task 39 experts have access to the password-protected site under 'Task Work Area'.

## FUTURE EVENTS

*February 07 - 08, 2008*

The symposium **Polymeric Solar Materials 2008** will be arranged by PCCL, the University in Leoben and AEE INTEC, Austria on February 7-8, 2008. The focus will be on polymeric materials in solar thermal and in photovoltaic system applications. Contact person and more information: Gernot Wallner, gernot.wallner@mu-leoben.at; website: http://www.pccl.at

*April 28 - 30, 2008*

The **4th Task 39 experts meeting** will take place in Oslo, Norway from April 28-30, 2008. New task force groups on 'Collector/material test standards' and on 'Marketing' are planned for the Oslo meeting. Contact persons for the next meeting are the Operating Agent Michael Köhl, michael.koehl@ise.fraunhofer.de, and Michaela Meir, mmeir@fys.uio.no.

*October 13-15, 2008*

The **5th Task 39 experts meeting** will take place in Switzerland, arranged by EMS-Chemie or SPF Rappertsvil from October 13-15, 2008.

The contributions of this newsletter were presented and discussed at the 3rd IEA-SHC Task 39 experts meeting in Blumau, Austria, 24.-25.09.2007. The authors are responsible for the content of their contributions.
The newsletter is available as pdf-file under http://www.iea-shc.org/task39/whatsnew.htm

## Solar thermal markets: General overview, actors and statistics

The average annual growth rate of the most relevant solar thermal markets in the years 1999-2005 reached 15 % for Europe and 22% for China and Taiwan. Extreme values have been reached in Tunisia in 2005 (328%) and India (250%). China is the biggest market with a share of more than 63 % of the total installed 106 GWth, followed by the EU with 12.7%. In the 2005 added capacity, the Chinese dominance is even stronger with 77.3%, followed again by the EU with 10.3%. In Europe, the most important markets are Germany with a share of approximately 50%, Austria (10%) and Greece (8%).
Although a $CO_2$ reduction of almost 30,000,000 t/a is reached and the forecasts are very promising, great efforts are necessary to reach the defined targets. To reach the goal of 1 m² installed solar thermal capacity per capita all over Europe in 2020, at least an increase by the factor of 30 is necessary. For this purpose, new and cost-*effective* technologies are required, including new materials for collectors and systems, new system designs and new and production technologies

| | $GW_{th}$ capacity | Tonnes of oil equivalent (toe) | Number of heating oil lorries | Distance of lorries on highway (km) |
|---|---|---|---|---|
| 1990 | 2,2 | 137.897 | 7.000 | 125 |
| 2005 | 11,2 | 686.493 | 34.000 | 600 |
| 2020 Minimal Target (Austria) | 91 | 5.600.000 | 278.000 | 5.000 |
| 2020 Ambitious Target (1m² per capita) | 320 | 19.650.000 | 982.000 | 17.500 |
| Long term Technical Target | 1.200 | 73.100.000 | 3.655.000 | 65.500 |

Source: ESTIF

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## Standards regarding polymeric materials in solar thermal applications

The current European Standards for testing of solar thermal collectors (EN12975) and systems (EN12975) are discussed with regards to testing conditions that are unfavourable or testing methods that are not appropriate for the use of polymeric materials. Further actual proposals of requirements and test methods for testing of collector components are presented. These proposals include procedures for material and aging tests of components, quality test of solar absorbers, durability testing of polymeric materials in collectors, and quality testing of reflector materials and anti-reflective coatings. The major parameters used for lifetime analysis are mechanical characteristics, absorption, emission and/or transmittance.
This is part of a pre standardisation work with the purpose to ensure a certain lifetime of the components and hence ensure a high quality and durability of future polymer based products.

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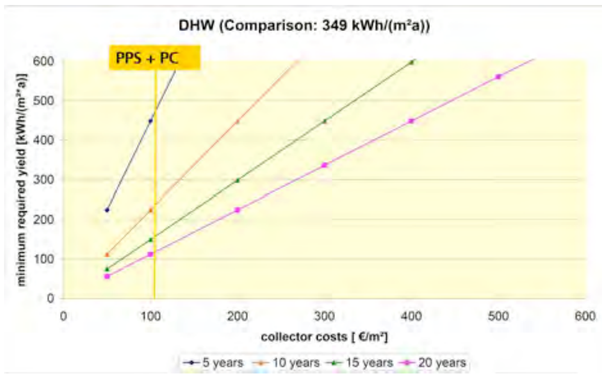
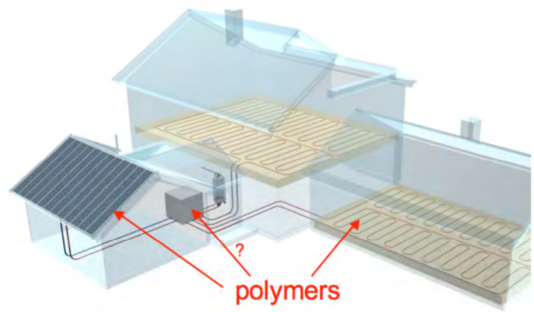
## Feasibility study of polymeric solar thermal collectors with economical valuation

In order to examine the feasibility of polymeric collectors, first some requirements have to be defined. As requirements for the process, a collector area of approximately 2m² has to be manufacturable, furthermore fluid leading channels and ideally also fittings and pipes. In addition, the contact area between absorber and heat transfer fluid should be rather larger to compensate for the lower heat conductivity ($\lambda_{Cu}$ ca. 390 W/mK, $\lambda_{Polymer}$ ca. 0.15-0.3 W/mK). After examining polymer manufacturing processes, the most promising ones are extrusion, injection moulding or thermoforming; However, none of the processes can fulfil all requirements, thus a combination is necessary. The requirements for the material are very diverse, but the most important ones are probably the chemical resistance against the heat transfer fluid, thermal and UV-stability and, for the absorber material, stability against hydrolysis. Taking into account these requirements, some polymers could be excluded and so the variety of possible materials was narrowed. For the economical valuation, two approaches were taken: on the one hand, the price limit for polymeric collectors was determined, using the simulation of the annual yield of an assumed polymeric and an average conventional collector. On the other hand, the required minimum yield was estimated in relation to the lifetime and costs of the collector. It could be shown that, under certain assumptions, polymeric collectors can economically compete with conventional ones.




*Eva Stricker, Fraunhofer ISE, Germany; eva.stricker@ise.fraunhofer.de*

## Polymers from a market perspective - Ideas for future development




Heat at moderate temperatures represents approximately 40% of the energy consumption by the end user in EU25. Trends for future development reveal an increasing energy demand, especially an increased fraction of electric power demand. Further the fraction of urban citizens and industrialised B&C increases, which reduces influence of the end-user. The energy policy is strongly influenced by energy companies/industries, favouring energy as a commercial product, which can be distributed and taxed. Solar thermal energy, normally produced at the end-user level, fits badly into this scenario and has few alliances among the most powerful players on the energy policy scene. Can polymer technology improve this situation? Partnerships with the building industry are important. Polymers have large potential for a better cost-performance ratio, advantages for large-scale building integration and replacement of conventional building covers. Global warming creates increased demand for cooling; hence new designs should aim to cover both the heating demand during winter and cooling during summer.

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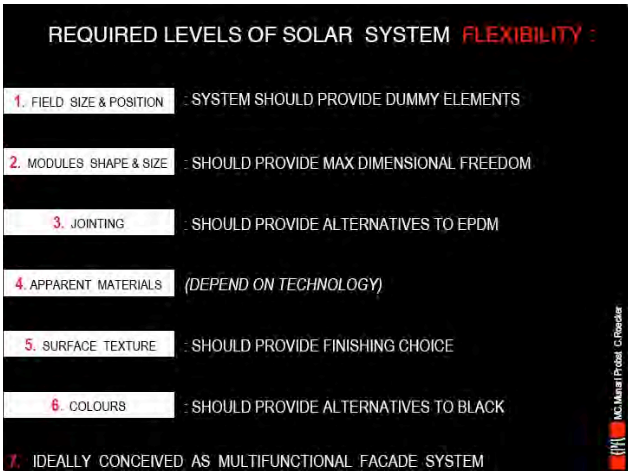
## Building integrated solar thermal systems: Architectural integration issues




New collectors should answer to the technical constraints of their specific solar thermal technology, but should also become architectural elements, conceived to be integrated into the building skin. They should provide an adequate level of flexibility in all the system characteristics affecting the building appearance (i.e. collector material and surface texture, absorber colour, shape and size of the modules, type of jointing). To ease the designer integration efforts and reduce overall costs, they should become multifunctional construction elements, facade cladding being the most relevant added function for glazed and unglazed flat plate collectors. Within this application mode, the use of dummy elements (non-active elements with a similar appearance, fulfilling only the construction function) is a key tool manufacturers should provide to make the geometric/architectural dimensioning of the system independent from the sole energetic sizing.

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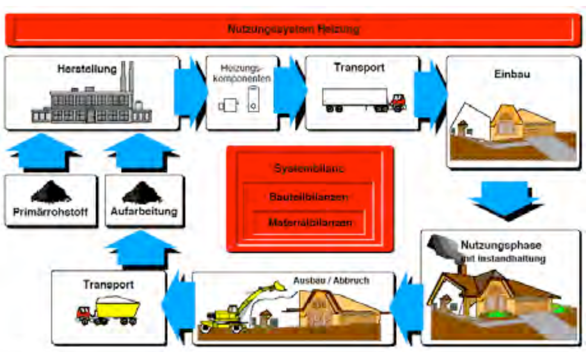
## LCA of polymeric collectors compared to conventional collectors




A life-cycle assessment (LCA) study compared a polymeric collector with a conventional metal-based flat plate collector (PE Product Engineering, 1999). The polymeric collector consisted of a PPE/PS absorber filled with clay granulates, a PC twin-wall sheet as collector cover and aluminium framing. The primary energy consumption for the production and recycling of the collectors, the emission of among others $CO_2$, $NO_x$, $SO_2$ were compared. Most figures were in favour of the polymeric collector: During production 23% less primary energy consumption, 40% less $CO_2$, 94% less $SO_2$ and 114% less $NO_x$ emissions. The primary energy consumption for recycling was 92% lower. A lack of the study was that the design of the solar heating system was not realistic for the case of the polymeric collector, and very likely not either the figures, which compared the energy performance of the collectors during their service-life.

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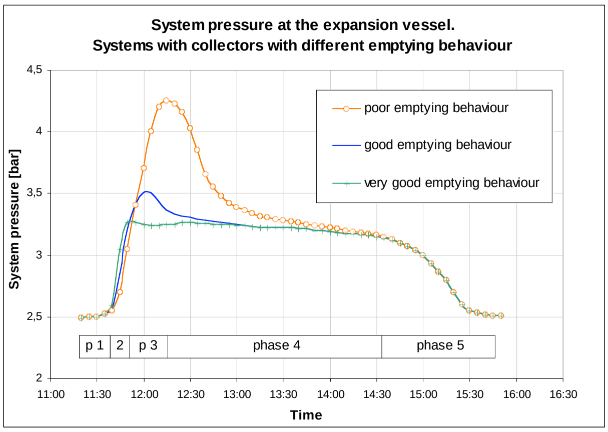
## Stagnation of solar heating systems a challenge for polymer materials

Stagnation of solar water heating systems might be a serious problem. Stagnation describes the state of the system, in which the flow in the collector loop is interrupted and solar radiation is still absorbed by the stagnating collector. High temperatures up to 200 °C and more and, depending on the type of system, high pressures may occur and can stress system components. Nowadays for conventional systems procedures during stagnation are understood and measures to handle this operating state in a safe and, fore the end-user, in an inconspicuous way can be easy taken.
Nevertheless for polymer collectors stagnation will be a considerable challenge. Economically priced polymer materials are overstrained with the temperature and pressure stresses during the standstill of a solar heating system. Therefore measures to overcome this disadvantage are in great demand. PCCL and AEE INTEC are working on a project for overheating protection of polymer collectors. Especially thermotropic layers are among other measures considered to limit the maximum collector temperatures.




In the last meeting of Task 39 stagnation procedures and experiences regarding conventional systems were considered and conclusions for polymer collectors were discussed.

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## Experiences with development of Solartwin system

Although solar panel standard EN 12975 is of limited scope for polymeric innovations, it is a gateway to membership of trade bodies, state subsidies, building codes and Solar Keymark. Its inflexible application may be market limiting, causing polymer based innovations may be forced out of the European market.
Five possible limitations of EN 12975 regarding polymer innovations follow. (1) In the performance test, the quadratic performance equation fails to represent thermal step change panels using thermochromics or thermostatic air vents. In the durability test, the limitations were: (2) description of polymers as organic, thus excluding silicone rubber which is inorganic; (3) use of absolute instead of functional pass-fail criteria, overlooking the flexibility of polymers; (4) incorrect test assumption that that peak pressures in water filled freeze tolerant collectors coincide with high temperature stagnation, when instead peak pressures may occur under freezing conditions; (5) the exposure test requires dry panels to stagnate for 30 days. But some polymer panels are continually pumped a high temperatures (and they dump heat to prevent boiling at low light levels). They do not dry out or stagnate in normal use. Solartwin, a flexible silicone piped, polymer glazed, water filled, freeze tolerant, PV pumped, low pressure, open vented system is continuously pumped at high temperatures. The system includes a panel, PV and pump, all specified only to work together. It has been on the UK and Irish markets for seven years. All four areas of the durability test were problematic. Examining the exposure test, a revised test from arsenal research applied the same 30 days of warm and sunny climate conditions, but to a hot water filled (instead of dry and stagnating) Solartwin panel. This represented normal operation, while stagnation did not. A pass under this revised test, leading to conditional approval under EN 12975 was granted by arsenal research, provided the panel was used precisely as the supplier specified.
On the regulatory impact of arsenal research's report, its has been (1) accepted for Irish Grants, (2) rejected by UK's Solar Trade Association, who expelled the company and (3) after 15 weeks delay is still neither accepted nor rejected by the UK's grant awarding body. Solar Twin Ltd is considering whether to apply the arsenal research report for Solar Keymark.
The question for innovators in the areas of solar thermal polymers is: why is an outdated, limited scope standard containing inappropriate tests and pass/fail criteria being used as a gateway to major European solar thermal markets? Legal consequences of market limitation by misapplication of standards were raised.

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## Polymeric components for solar applications

The French company CLIPSOL has experienced since 2003 the use of polymeric components for solar combisystems.
The Blocsol Combi, for solar combisystems, includes several components made of polymeric materials. The most important one is the hydraulic part of the application: the hydraulic board (like a printed circuit board), made by injection moulding, see left. This board includes all the piping, pumps, valves; it simplifies the mounting, the maintenance (all the components are easily accessible) and reduces drastically the weight, the dimensions, and the cost with regard to a traditional process with copper, brazing, fittings, etc. Polymers are also used for the thermal insulation jacket of the heat storage tank (rotomoulding), and the radio remote control (injection moulding).

More information available at http://www.clipsol.com

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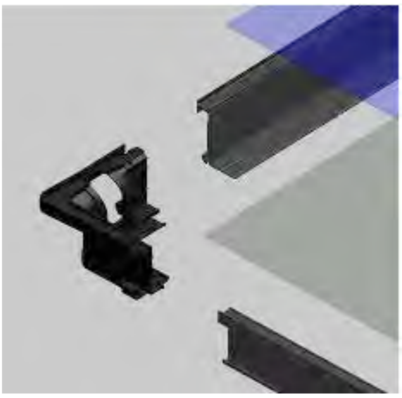
## Experiences with development of BBT polymeric components



The company Solar Diamant Systemtechnik GmbH, a sub company of the BBT Thermotechnik, was founded in 1978. We can look back on nearly 30 years of experience in developing of solar thermal systems. Polymeric materials were always part of our systems, e.g. collector frames. It is very important to choose the right material for the specific applications. You have to consider issues like static, dynamic and thermal stress, quantities and material usage and the robustness against aggressive ambience. At last polymeric materials are very useful, but they are not the solution for every problem and application. Regarding the calculation of profitability, polymeric material should only be used, when there is an absolute advantage.

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## Manufacturing and processing of polymeric materials for geomembranes and sheets in solar-thermal applications


The requirements for the suitability of polymeric materials in solar-thermal applications has been focussed on polyolefin resins typically used in applications for geomembranes by flat die calendering method.
The actual system requirements were given by a project for storage of solar thermal water in large scale. Fabian Ochs from ITW-Stuttgart demanded a barrier liner suitable to cover maximum 80°C for a distribution-temperature curve over the year for the thermal water storage basin accumulated to a life expectancy of 40 years.
Present PE-materials are limited to a permanent temperature of 60 °C. New so called PE-RT materials (High Temperature Stabilized Polyethylene) show creep curves for 90°C according to Arrhenius equation with 10 years resistance to thermal aging as per ON B5159:2007. Accumulated to the "hot period" when the thermal storage tank is in full operation a calculated service life of 40 years can be expected.
As flat die calendering method allows multiple layer systems combined to one geomembrane a second aspect to consider for this project was water vapour transmission through PE which should be blocked at all. For this requirement a thin film alu-foil of 0.15 mm was integrated in between two PE layers so that zero area-transmission can be considered.
A steady development of designed PE-resin types and manufacturing techniques in combination with feasible welding techniques will open new opportunities for the "commodity" plastic-materials as Polyethylene and Polypropilene which shall be an essential consideration to create also economic competitive solutions in thermal solar applications.

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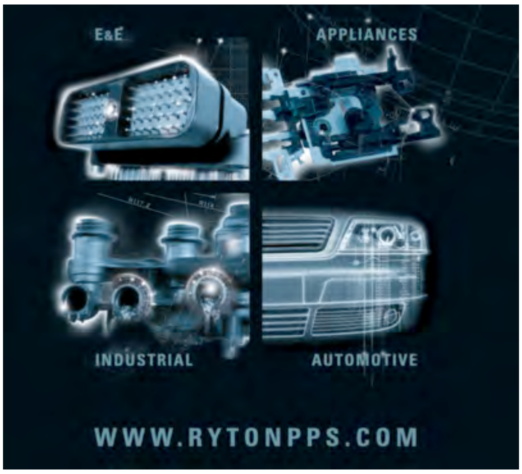
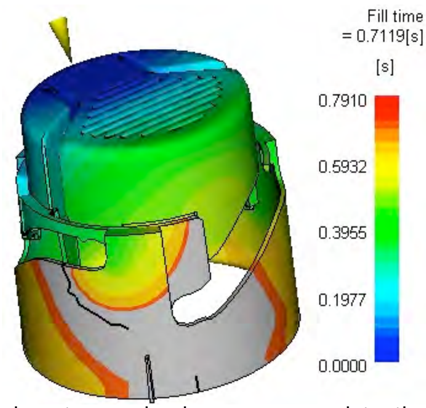



## PPS and PPS alloys: Plastics that take the heat.

Poly(p-phenylene sulfide) (PPS) by Chevron Phillips Chemicals is a highly stable polymer with a remarkable degree of molecular stability toward both thermal degradation and chemical reactivity. When blended with glass fibers and other fillers, PPS produces engineering plastics having a unique combination of properties.
Ryton® PPS competes successfully with metals because it often eliminates expensive secondary operations and because it offers greater design flexibility. This yields parts consolidation and reduces total production time. Part integration lowers weight and cost and also eases manufacturing and assembly. As a result, the use of plastics to replace metals is becoming an essential strategy for many companies. Metals replacement is advantageous mainly due to Ryton®'s long-term predictability of performance properties over a wide range of temperatures and environments.

*Tom Vencken; Chevron Phillips Chemicals, Belgium; venckt@cpchem.com*

## Injection moulding of polymeric components




For the production of polymeric components used in solar collectors, the injection moulding process is an interesting production process. The process runs in several phases: polymer pellets are melted, then the polymer melt is injected into a steel mould, cooled down, the mould is opened and the final part is ejected. The advantages of this process are a high reproducibility of complex geometries, a high level of automatization and the possibility of assembling various functional elements in one process step without further treatment. In order to optimize the process and quality of injection-moulded parts, computer simulation tools are available, which can reduce the production time and costs significantly. Especially for the production of manifolds, there are special variations of the standard injection moulding process like gas or water assisted injection moulding. For the production of polymeric glazing, the injection compression moulding process could be applied, which enables larger panels to be produced with good optical properties. In case of mass production, the production costs of injection-moulded parts can be lower compared to the processing of other materials.

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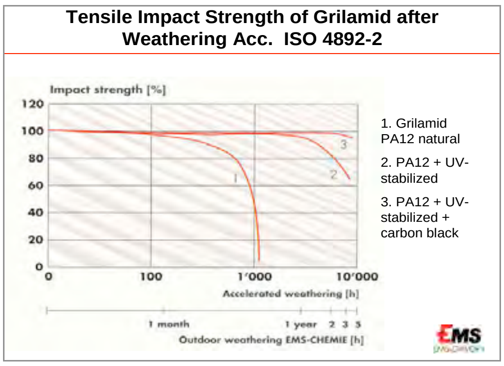
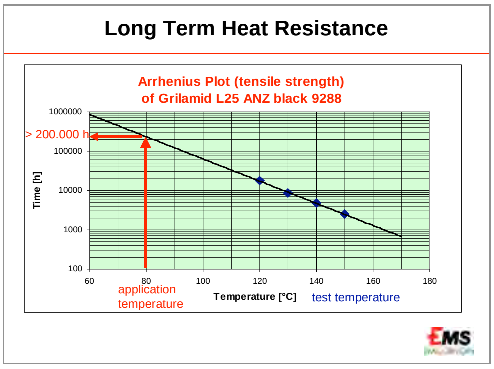
## Polymer degradation under exposure of heat aging, weathering and hydrolysis

In usage polymers in solar-thermal applications the polymers are exposed to thermal-oxidative degradation by heat, light induced degradation (intensive sun rays with UV, moisture, temperature) and hydrolysis degradation at heat exchangers by a water/glycol mixture. With limited working temperatures adapted to polymers and stabilisation there can be given a lifetime estimation by using the Arrhenius equation. Standards and test methods based on this equation are e.g. the thermal endurance, relative temperature index, Xenotest, hydrolysis and creep rupture test. The test criterias are described and examples of material testing and finished part test are given. The presentation closes with a summary.

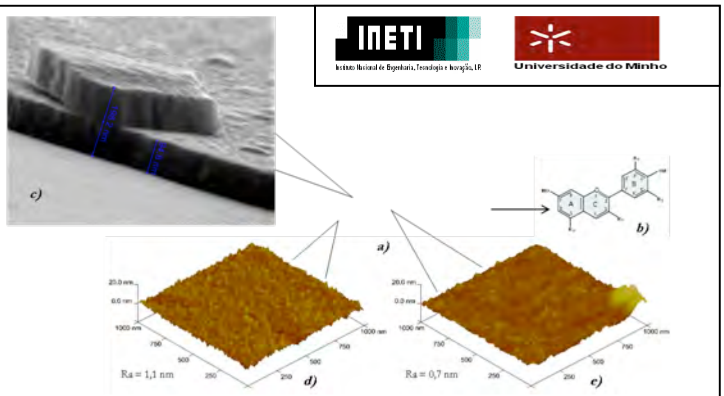



*Dietmar Etzel, EMS-Grivory, a division of EMS-Chemie AG, Switzerland ; dietmar.etzel@emsgrivory.com*

## Novel nanocomposite coating with nanoparticles for solar absorbers

This ongoing research Project funded by the Portuguese Ministry of Science (ref. POCTI/ENR/ 62660/2004) aims at the production of new spectrally selective coatings with organic pigments for solar absorbers, to be applied on thermal solar collectors.
The basic idea is to use photo-sensitive organic pigments so as to develop new products with high photothermal conversion efficiency, low cost, long lifetime, and stable within the high range of the medium operating temperatures (i.e. 120-150 ºC).
The research team, from the Public Research Lab INETI and the University of Minho, expects to achieve this using two pathways. One approach is to devise a paint to be applied on substrates of aluminium, cooper, and stainless steel. This paint would be composed by (i) a binder (possibly an epoxy/silicone resin), (ii) organic and inorganic pigments for photothermal conversion of the solar energy, and (iii) theological additives. The other approach involves a first phase where the substrates are coated with thin layers of TiO2 obtained by cathodic magnetron sputtering deposition, and a second phase where certain organic pigments are deposited by impregnation. The work started in January 1, 2006, and will be finished in December 31, 2008. The results obtained until now are already promising.




**a)** Scheme for study samples (tandem of TiOx, pigment on glass slides) **b)** chemical structure of anthocyanin **c), d)** and **e)** morphology of the sample sputtered in DC mode: **c)** by SEM for sample without pigment **d)** by AFM without pigment and **e)** AFM for sample with pigment.

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## Review on thermotropic polymers

Thermotropic materials change their light transmission behaviour from highly transparent to light diffusing upon reaching a certain threshold temperature. In thermotropic materials that undergo a transition from transparent to light diffusing, the light is scattered from particles, which exhibit an index of refraction, which is different to that of the matrix. In the past various thermotropic systems for active daylight control in transparent facades (required switching temperatures between 20 and 40°C) have been developed and investigated. Whereas in thermotropic hydrogels and polymer blends the switching is involved in a phase separation, in thermotropic resins, the scattering domains are embedded statically in a matrix material.
The advantages of thermotropic hydrogels are a high transparency in the clear state and a high opacity in the scattering state (change in transmittance by 60%), a steep switching gradient, and a high reversibility within a small time frame. Drawbacks are the long term stability and that hydrogels place high demands on sealing due to water as a main component. Currently, a thermotropic hydrogel glazing, a sandwich of two glass panes and the encapsulated hydrogel, is commercialized by Affinity Ltd., Japan.
Thermotropic polymer blends were developed for glazings, but currently no products are available commercially. Polymer blends developed so far exhibit a high transparency in the clear state and a high opacity at elevated temperatures (change in transmittance by 50%), whereas the phase transition is highly reversible within a small time-frame. Disadvantages of thermotropic polymer blends are the gradual switching within a broad temperature range and insufficient long-term stability (sensitivity to UV radiation and humidity).Thermotropic resin systems with fixed domains are characterized by a steep and rapid switching process within a small temperature range, an extraordinary high reversibility at low hysteresis and a high flexibility as to adjustment of the switching temperature (0 to 200°C). The drawback is the moderate change in transmittance (currently by 25%). At the Polymer Competence Center Leoben current developments focus on the systematic investigation and optimization of various thermotropic resin systems with fixed domains.


*Thermotropic layer developed at the PCCL in clear (left) and scattering state (right).*

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