# Task 39: Polymeric Materials for Solar Thermal Applications

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## NEWS

### *April 27-29, 2009*

The 6th IEA-SHC Task 39 Experts Meeting was hosted by the Institute for Solar Technology (SPF) and took place at the University of Applied Science HSR in Rapperswil, Switzerland from April 27-29, 2009. 39 experts were present at the meeting. 10 participants were industry partners. Most of the presentations and the results from group work at the Experts Meeting are summarised in this newsletter. The Experts Meeting included excursions to the HSR's Institute for Materials Technology and Plastics Processing and to the solar collector test centre at SPF. The evening lunch excursion to a bakery museum on April 28 was sponsored by HSR.


(a) Prototype of an all-polymeric collector developed by SPF and EMS-Chemie. (b) Excursion to the solar collector test centre at SPF. (c) Prof. Ehrig from the Institute for Materials Technology and Plastics Processing at HSR demonstrates new developments of decorative metallic surfaces on plastics. (d)Task 39 Experts meeting at HSR, Rapperswil.

### *TASK 39 – Participant status by May 2009*

The experts in Task 39 are represented by 17 research institutions and 12 industrial companies from 11 countries worldwide. Six industrial companies are Active Supporters of Task 39: BASF, Bosch Thermotechnik, EDF-Électricité de France, EMS-Chemie, Roth Werke GmbH and Söhner Kunststofftechnik GmbH. Operating agent of Task 39 is Michael Köhl, Fraunhofer Institute for Solar Energy Systems, e-mail: michael.koehl@ise.fraunhofer.de.

### *October 2009*

The 7th Task 39 experts meeting is planned to take place in Golden, Denver, USA in Oct. 2009. NREL will host the meeting. See: http://www.iea-shc.org/task39/meetings

### *Task 39-related Master and PhD degrees*

Very central contributions to the work in Task 39 were made in the frame of PhD- and master projects, in collaboration with our Task 39 research- and industry partners.

**Maria Cristina Munari-Probst**, Architectural integration and design of solar thermal systems. PhD thesis, École Polytechnique Fédérale de Lausanne EPFL, Switzerland, Dec. 2008.

**Katharina Resch**, Polymeric Thermotropic Materials for Overheating Protection of Solar Collectors. PhD thesis, University of Leoben, Austria, Nov. 2008 (in co-operation with PCCL).

**Andres L. Olivares**, Service life estimation of a polymeric solar absorber. PhD thesis, University of Oslo, Norway, April 2008;

**Julien Dumas**, Étude de conception d'un capteur solaire thermique en matériaux polymères. Diploma thesis, Université de Technologie de Compiègne, France, Febr. 2009 (in co-operation with CEA-INES).

**Steffen Jack**, Simulationsgestützte Qualifizierung neuer Konzepte zur Gestaltung von thermischen Solarkollektoren auf Polymerbasis. Master thesis, FHTW Berlin, Sept. 2008 (in co-operation with ISE).

**Eva Stricker**, Untersuchung der Machbarkeit polymerbasierter Solarthermiekollektoren mit wirtschaftlicher Bewertung. Master thesis, University of Flensburg, Germany, Aug. 2007 (in co-operation with ISE).

**Hannes Franke**, Konzeptstudie zur Optimierung von Temperaturverteilung und Wärmeübergang in polymeren Solarabsorbern mittels FEM-Simulation. Diploma thesis, June 2007, ISE and FH Konstanz.

## The compelling facts about plastics

The plastics industry consists of three sectors: plastics manufacturers, plastics converters and plastics machinery manufacturers. For the whole of the plastics industry (around 50,000 companies) the overall turnover in EU27+NO/CH was in excess of 300 billion EURO for 2007. The industry employs more than 1.6 million people. 2007 260 million tonnes of plastics were produced worldwide. From 1950 to 2007 the annual average growth rate of the world plastics production has been about 9% (see Fig. 1).

Source: Plastics Europe; www.plasticseurope.org

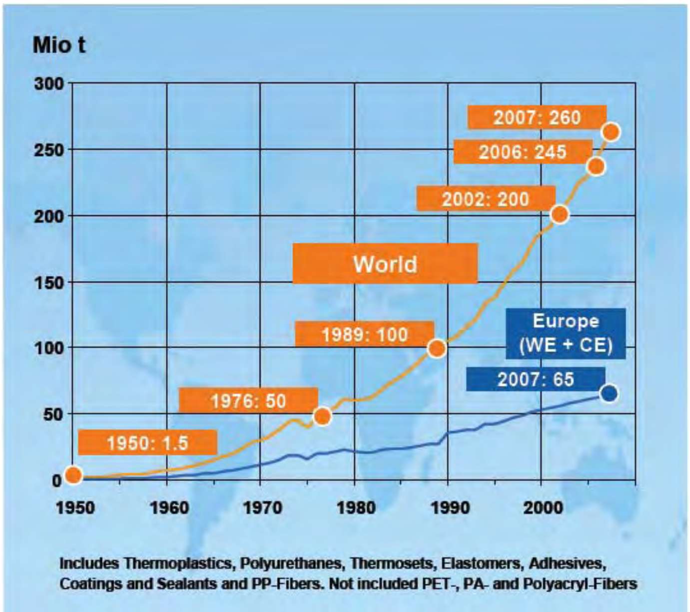


Fig. 1. World Plastics Production 1950-2007 (Source: Plastics Europe).

## Classification of plastics

Plastics are subdivided into thermoplastics, thermosets and elastomers. Thermoplastics count for 65% of the market and are the most important plastic materials. Thermoplastics are commonly subdivided into three main groups: the standard thermoplastics, the engineering thermoplastics and the high performance polymers. The standard thermoplastics are the basic materials and include PE, PP, PS, PVC and PET (bottle-grade). These types exhibit maximum operating temperatures around 100 °C and are available at prizes below 2 € per kg. In total, standard plastics count for approximately 90% of the total plastic material demand. The group of engineering plastics represents grades with improved performance (maximum operating temperatures up to 150°C) but also at higher costs (up to 4 € per kg). Examples are PC, PMMA, PA, PBT or POM. The engineering plastics are a small but valuable part of the market (~10%). High performance plastics are specialized for very demanding applications. They are permitting exceptional end-use-applications and specialized niche products with maximum temperatures above 150°C at costs exceeding 4 to 10 €/kg. Examples are high temperature polymers such PPS, PEEK, PSU, PES or PEI. Their market share is below 1%.

Source: Plastics Europe; www.plasticseurope.org

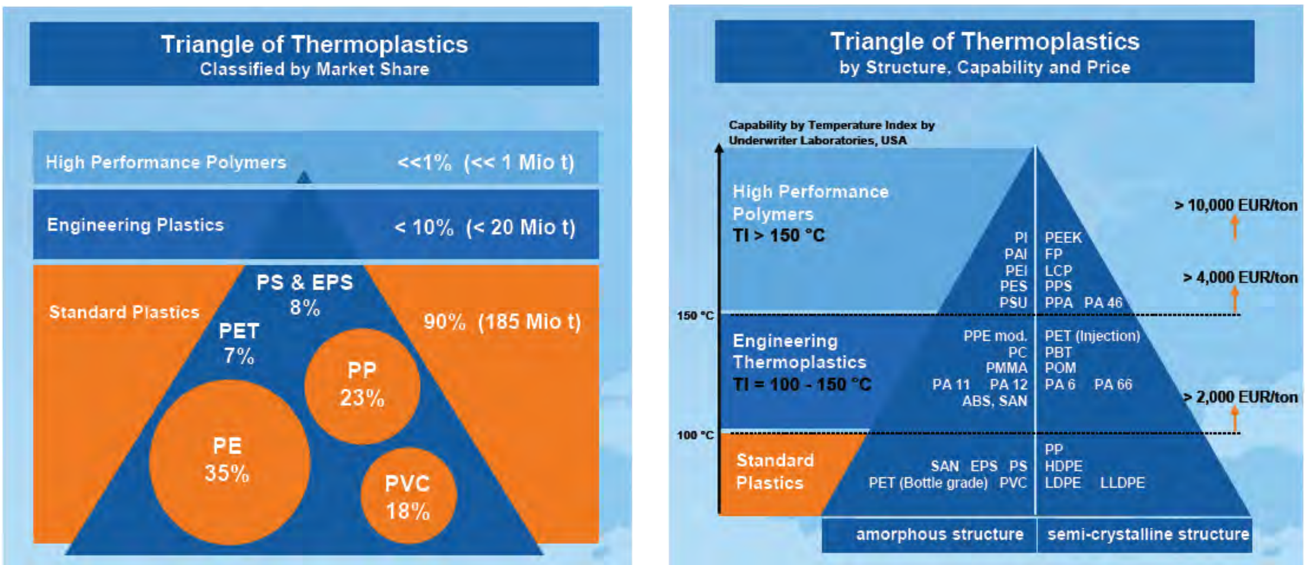


Fig. 2 Classification of plastics by structure, capability and prize (right) and by market share (right) (Source: Plastics Europe).

## Taskforce: Testing/Standardization/Certification

The existing European Standard EN 12975:2006 does not reflect with all test procedures the requirements for testing polymeric collectors. In order to include appropriate test procedures within the Standard during the ongoing revision of EN 12975 four tests were identified where changes are needed.

- Internal pressure test
- Exposure test
- Stagnation test
- Thermal performance test (in case the thermal performance depends on absolute temperature and not only on temperature difference between collector and ambient)

After the review of existing test methods within the current Standards (EN 12975, ISO 9806, AS/NZS 2712, SANS 6210, …) alternative test methods suitable for polymeric collectors will be proposed. The alternative test methods will be sent to the national mirror committees in order to be submitted to the CEN TC 312, which is in charge of the revision.

The revised Standard EN 12975 is must be harmonised with the European Construction Products Directive (CPD) according to mandate M369. The corresponding changes within the Standard will be followed closely by the participants of the Taskforce in order to prevent any changes that would penalise polymeric collectors within the Standard.

*Stephan Fischer, ITW University of Stuttgart, Germany; fischer@itw.uni-stuttgart.de*

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## Improving durability of polymers with nano-fillers

The harsh operating conditions of solar thermal systems with high temperatures, UV-irradiation and contact to hot water are very challenging for polymeric materials. High-performance polymers are usually the only polymers, which can fulfil the requirements, but these materials are expensive and not easy to process. Therefore Fraunhofer ISE tests the durability of newly developed types of technical polymers or cheaper commodity plastics, which are stabilized by glass-fibre and Carbon-Nanotubes (CNT).

The tests include the irradiation with high dosed UV-irradiation and the exposition to damp heat conditions (85°C, 85% r.h.). Materials are analyzed with different optical technologies like microscopy, FT-IR spectroscopy, Raman-microscopy and surface sensitive technologies like AFM or FT-IR in ATR mode before and after the exposition. The materials already show a promising durability but further improvement is necessary as the change of the surface after 500 h in damp-heat shows (Fig. 3).

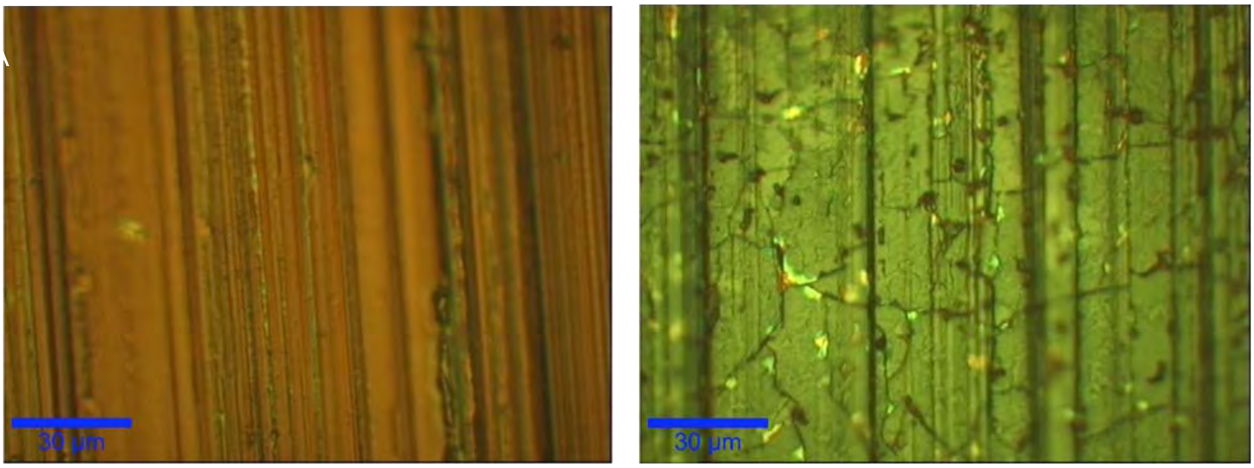



*Fig. 3. Surface of PA-sample with glass-fibre and CNT: virgin (A) and after 500 h in damp-heat conditions (B).*

*K.-A. Weiß, Fraunhofer ISE, Freiburg, Germany; karl-anders.weiss@ise.fraunhofer.de*

## Improvement of thermal conductivity realized

When analyzing thermal processes, the thermal conductivity $k_c$ is the most commonly used property that helps quantify the transport of heat through a material.

The thermal conductivity of different materials spread over a wide range. The conductivity of polymers is 2 orders of magnitude lower than steel and 3 orders lower than aluminium or copper. All the polymers have $k_c$ values between 0.15 to 0.55 W/(m K).

The higher thermal conductivity of inorganic fillers increases of the conductivity of compounds. With a high filler loading of about 40 to 50 Vol% an increase in thermal conductivity 10 times higher can be realized.

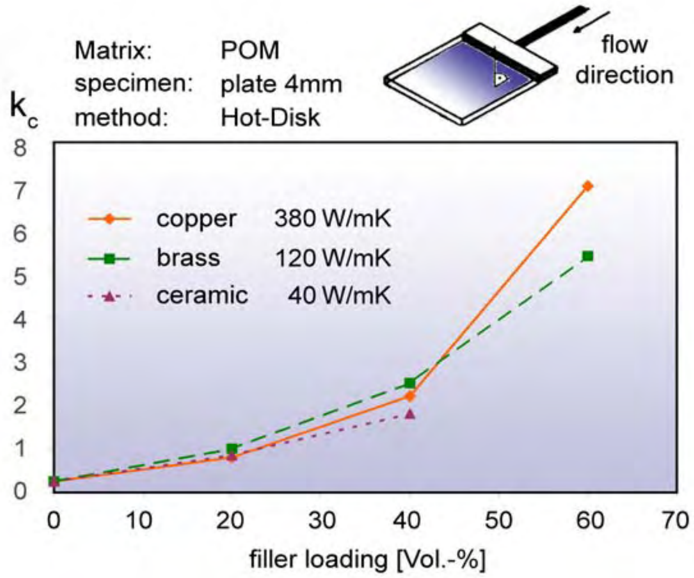



*Figure right: Improvement of thermal conductivity*

*H. Vogel, Germany;* hvogel@fh-osnabrueck.de

## Overheating Protection Properties of Thermotropic Polyamide

In thermotropic polyamide provided by EMS-CHEMIE AG (Switzerland) core shell polymer particles are embedded statically in a thermoplastic matrix material. The performance properties of this material type for overheating protection purposes of solar collectors were investigated. Solar optical properties were determined as a function of temperature applying UV/Vis/NIR spectroscopy and correlated to thermal transitions within the polymer determined by Differential Scanning Calorimetry (DSC). Furthermore the scattering domain size was characterized using Atomic Force Microscopy phase imaging.

The 2 mm thermotropic layer showed a hemispheric solar transmittance of 82% in clear state at temperatures of 25 °C and of 57% in the scattering state at temperatures of 95 °C.

A broad transition temperature range from 35 to 95 °C was detected. The comparison of the thermal transitions within the layer to the switching characteristics revealed a moderate correlation. AFM phase imaging clearly indicated particles exhibiting a soft shell with a diameter smaller than 150 nm and a hard core, with a maximum diameter of 50 nm. To provide excellent overheating protection and to maximize collector efficiency the switching temperature of the thermotropic polyamide should be adapted to values either between 55 and 60 °C or between 75 and 80 °C for application in the glazing or on the absorber, respectively. Furthermore a steeper transition from the clear to the opaque state within a small temperature range is desirable.

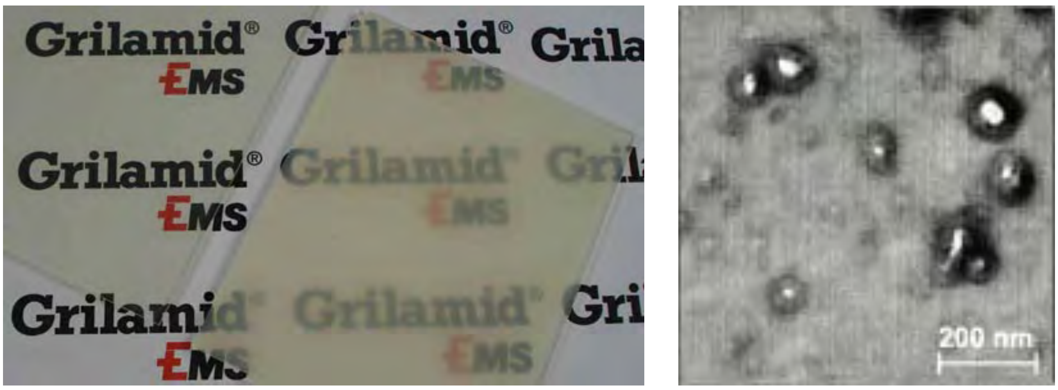
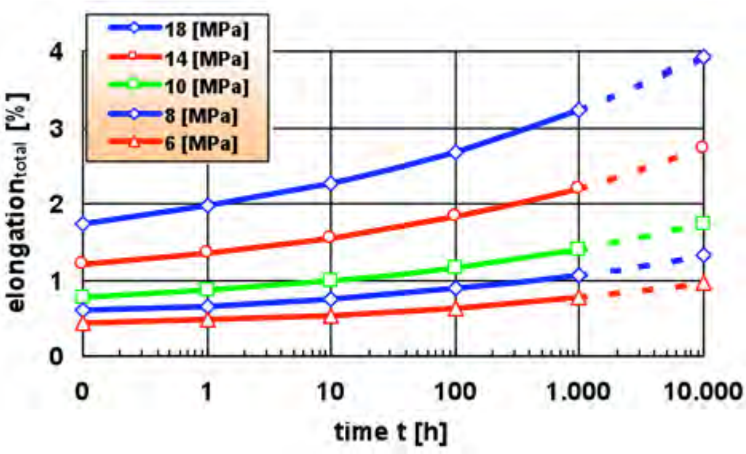



*Fig. 4. Thermotropic polyamide in clear and scattering state (left) and AFM phase image representing layer morphology (right).*

*Katharina Resch, Polymer Competence Center Leoben GmbH, Austria;* resch@pccl.at

## Ultrason® P (PPSU): A polymer with excellent hydrolysis resistance

Without special equipment like thermo tropic layers or other technical measures, the absorber material has to withstand high peak temperatures. Together with long lifetime requirements high-temperature polymeric materials with excellent hot water resistance are a possible solution. PPSU is an amorphous high temperature material with outstanding impact behaviour. For processing all standard technologies like injection moulding or extrusion are suitable. Post-processing like welding or thermoforming of semi-finished products are further possible processing stages.




The excellent hydrolysis resistance even under load can be shown by tensile creep tests. Even in contact with hot water (95 °C) the material can withstand under long-term conditions stresses up to 18 MPa. During this test tensile bars are immersed into hot water plus mechanical load during the entire test duration.

*Rüdiger Bluhm, BASF, Germany; ruediger.bluhm@basf.com*

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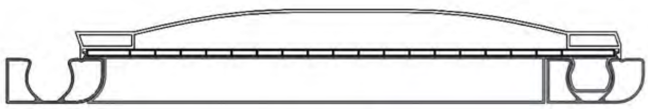
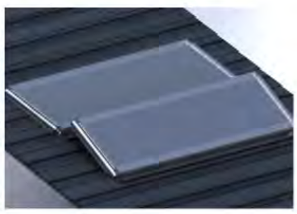
## Performance and competitiveness for polymeric collectors

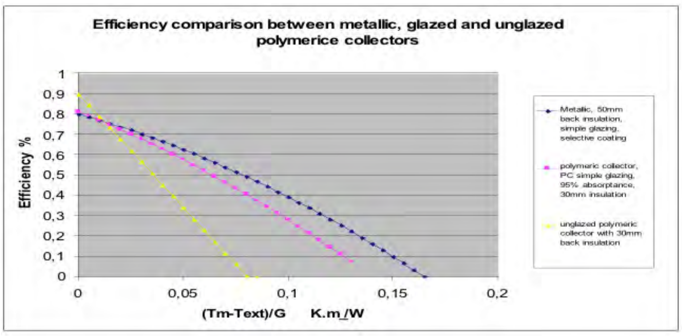
There are few polymeric materials that can fit the requirement of high temperature, hydrolysis and UV exposure for high performance collectors and at a reasonable price. PPS, PPA, PA12 for the absorber, and PC with UV protection or PA12 for the glazing seem to be the materials that can endure these constraints. Longer durability tests to hydrolysis are needed to confirm these results, particularly for PA12 and PPA. These materials are engineering polymers and are very expensive. In consequence, the design of the collectors has to be improved in order to optimize the quantity of material used and the ratio performance/price. Different concepts have been imagined based on different plastic processes and the analysis of these concepts shows important results:

- Double glazing designs and insulation above 30 mm provide too high stagnation temperatures.
- Thermoformed concepts seem to be more expensive for massive production than extruded ones. Thermoformed concepts allow geometric possibilities for roof tile integration while extruded concepts allow modular connectivity and flexibility in the size of the collector.
- The performance/cost ratio of concepts using transparent PA12 or high temperature PC for the glazing seems not to be competitive with metallic solutions.
- The stagnation temperatures reached by these concepts show that a drain back system, a cooling system or decrease the performance of the collectors at high temperature are necessary solutions in order to endure hydrolysis with all polymer concerned.
- Extruded concepts with simple glazing, 30 mm back insulation, injected end-caps, and absorber efficiency factor close to 1 are concepts that can have a better performance/price ratio than good metallic collectors.





Extruded concepts with good ratio performance/price
*Cost <80 €/m² (material and process for 50.000 units/ year)*



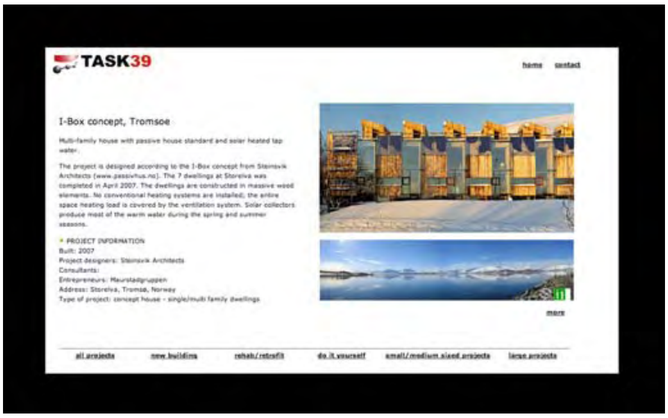

*Julien Dumas, CEA-INES, France; julien.dumas@cea.fr*

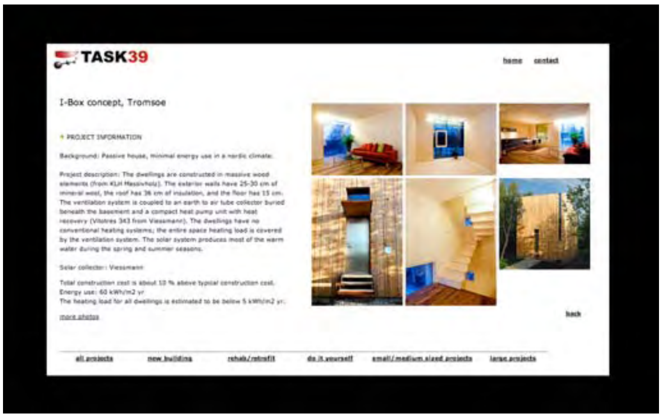
## Taskforce: New database containing appealing and inspiring show cases; Architectural integration of solar thermal energy systems

This database is a part of the outcome from Task 39 - Polymeric Materials for Solar Thermal Applications. The objective is to show projects where -not only function- but also aesthetics and architectural integration, have been in focus when designing and installing solar thermal systems. The idea is to make solar thermal more desirable by showing *visually appealing* solar systems – something people would want to put on their houses, something architects would want to implement when working on buildings.

A variety of showcases will be available in the database, and technical as well as financial information will be accessible.

*If you know of a project that could be of inspiration – please e-mail to is@aventa.no.*





*Ingvild Skjelland, AVENTA, Norway; is@aventa.no*

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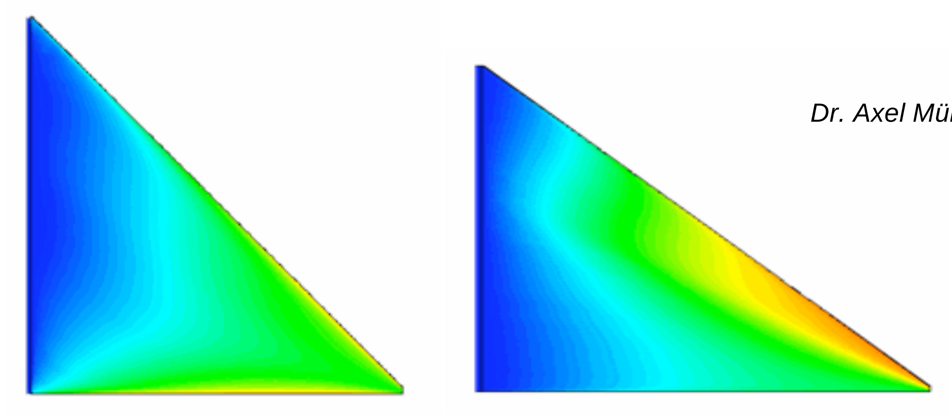
## New Shapes of Thermal Collectors

Conventional solar collectors have a rectangular shape, due to the advantages of their construction process based on metals (copper or aluminium). However, architects and landscape-designers complain about the fixed and uninteresting shapes, which often do not match their aesthetic concepts. More practical limitations arise from the fixed size and shape of existent roof, for example on older buildings. For these reasons new design concepts are necessary.
For the purpose of developing a new type of highly efficient collectors polymeric materials have the key advantage that they can be formed unconventionally. The key challenge for such types of collectors is however to ensure a uniform flow pattern through the collector.
Dr. Axel Müller - HTCO - a company specialized in the field of fluid dynamics and heat transfer simulation (CFD) – contributes to Task 39 by designing and optimizing the flow through non-rectangular collector shapes.



*Dr. Axel Müller – HTCO, am@cfd-fem.com*

*Fig. 5. Temperature distribution in two triangular thermal collectors*

## Color d.d., selective paints manufacturer

Color d.d., is a paint, resin and powder coatings manufacturer based in Medvode, Slovenia. The company operates under ISO 9001, ISO 14001 and ISO 18001 standards. Its yearly sales are 31 960 tones with operating profit of 63 544 000 € and profit of 4 370 00 € (2008). 330 people are employed at the company (as of December 31, 2008). Since 2004 Color is a part of Helios group that belongs among 20 largest paint manufacturers in Europe.

Color's sales program consists of powder coatings, resins, and paints for metal and wood industry, heavy-duty coatings, car refinishing coatings and decorative paints. A special place belongs to spectrally selective paints for military and solar applications. The later come in two distinctive types, thickness sensitive spectrally selective (TSSS) and thickness insensitive spectrally selective (TISS) paints.

TSSS paints are suitable for metal or metalized substrate absorbers of glazed collectors, offer great value, but no anticorrosion protection. Color's new Suncolor TS S paint is available in black and selected color shades and has a selectivity up to $a_S$=0.91, $e_T$=0.06 (black, thickness dependent).

TISS paints are suitable for metal and non-metal absorbers of glazed or unglazed collectors, offer excellent anticorrosion protection (up to C5m (ISO 12944) in a system). Color's Suncolor PUR (polyurethane binder), Suncolor S (silicone binder) and Suncolor CC (coil-coating product, silicone binder) are available in black and non-black color shades and have selectivity up to $a_S$=0.90, $e_T$=0.35 (Suncolor S black).

*Miha Steinbücher, Color d.d., Slovenia; miha.steinbucher@color.si*

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## Self-cleaning UV protective clear coating for polymer substrates

Development of a clear polymeric multifunctional UV protective coating suitable for spraying is one of the goals of the MATERA MULTIFUNCOAT project. It should offer good UV protection and an antisoiling effect.

As a starting material, high solid, low VOC 2-pack polyurethane containing organic UV-absorbers tested for 20 years use as an automotive topcoat was used. Its adhesion to polycarbonate (PC) and poly(methyl methacrylate) (PMMA) was achieved by use of a commercially available Colomix Plastic Primer from Color d.d.

Low coatings' surface energy and thus an antisoiling effect was achieved by incorporation of a polyhedral olygomeric silsesquioxane provided by National Institute of Chemistry, Ljubljana (SI) into formulation. An addition of 1% of the additive increased static contact angles to 106 ° (water) and 55 ° (n-hexadecane). The same additive increased coatings' hardness (König and Taber tests) and flexibility (Cupping test, Impact resistance test).

The coating is going to be further improved by incomposition of nanofillers and nanotechnology UV-absorbers to achieve good scratch resistance and self-cleaning together with coating service life of 20 years in a solar collector.

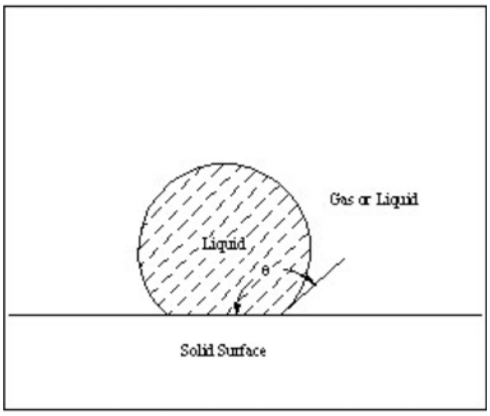


*Fig. 6. Static contact angle (Θ) for a liquid on a solid surface.*

*M. Steinbücher*, Color d.d., Slovenia, I. Jerman, M. Koželj, B. Orel, National Institute of Chemistry, Slovenia; miha.steinbucher@color.si*

## Polymeric Solar Collectors: Field testing of a State-of-the-Art System

In the field of polymeric solar thermal collector development within Task 39, a research project is carried out at Ingolstadt University of Applied Sciences (Germany). Based on a detailed component analysis in existing solar systems, the component as well as the system designs will be adopted to polymer needs. In a field-testing system, a collector operating in the system and a stagnating collector are compared. Especially the distribution of temperature loads for collector parts is essential for the choice of polymeric materials. As Figure 7 shows exemplary for a sunny day, the absorber operating in the system has a temperature higher than 95 °C for almost 7 hours and the stagnating absorber not in the system for nearly 8 hours. The stagnating absorber has a temperature level between 135 °C and 205 °C for the duration of 6.3 hours. The temperature load on the housings of both collectors is on a low level.

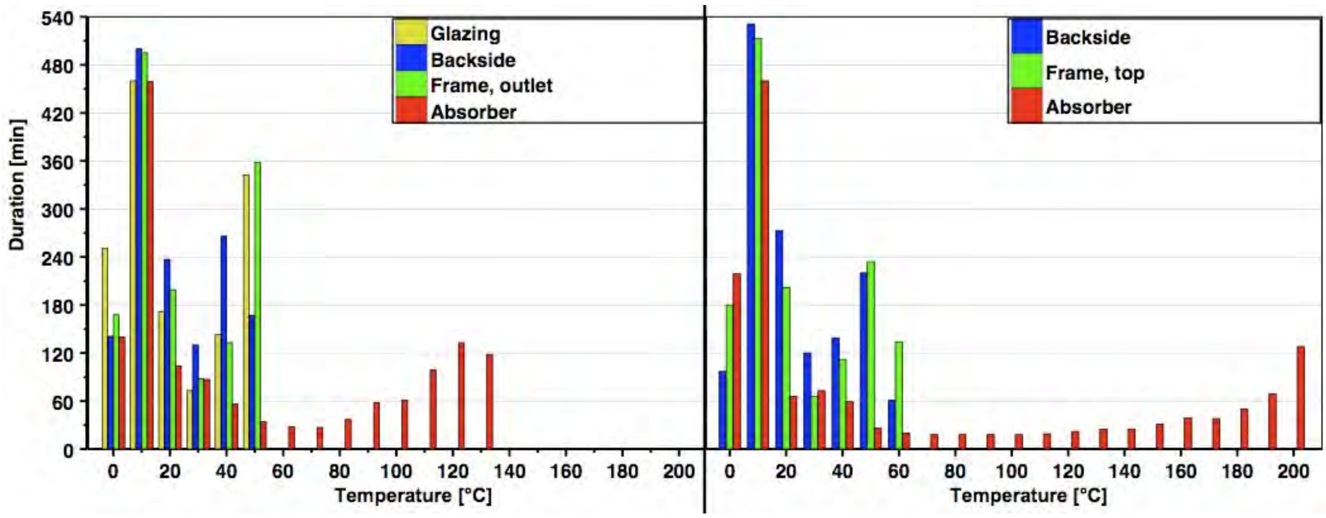


*Fig. 7. Distribution of temperature loads on collector parts in the system (left) and not in the system (right) for a sunny day in April.*

As considerably higher temperature loads are expected for the summer period, the measurements and analyses will be continued in order to provide temperature distribution information for a period of one year.

*Christoph Reiter, Christoph Trinkl, Ingolstadt University of Applied Sciences, Germany, christoph.trinkl@fh-ingolstadt.de*

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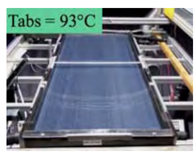
## From polymers to glazed collectors




Updates on the progress with polymeric collector developments were reported by Theo Doll (Söhner Kunststofftechnik), John Rekstad (Aventa) and Stefan Brunold (SPF). The designs vary significantly in materials used, applied production techniques and functional design. The concept presented by Theo Doll is building on Söhner's expertise on thermoforming and PC-based collector casing (Fig. right, top). John Rekstad informed about the all-polymeric collector concept based on extruded PPS absorbers (Fig. right, middle), a collaboration between Aventa and Chevron Phillips Chemicals. Stefan Brunold presented a prototype of an all-polymeric collector (alternatively with glass instead of PA cover) of PA-pipes with thermotropic coating as overheating protection, a collaborative work between SPF and EMS-Chemie (Fig, right bottom).

*T. Doll, SÖHNER Kunststofftechnik GmbH, Germany;* *t.doll@soehner-worldwide.com*
*J. Rekstad, AVENTA AS, Norway;* *jr@aventa.no*
*S. Brunold, SPF, Switzerland;* *stefan.brunold@solarenergy.ch*

## ■ TASK 39: System simulations for the determination of thermal loads

Thermal loads are a major aspect concerning the durability of polymeric parts. The optimum choice of polymeric materials requires information on the expected temperatures the material will have to sustain. Since the system concept has main influence not only on the performance but also on the temperature distributions in different parts of thermal solar systems, a simulation study will be performed that provides for different system concepts temperature profiles and histograms for specific system components.

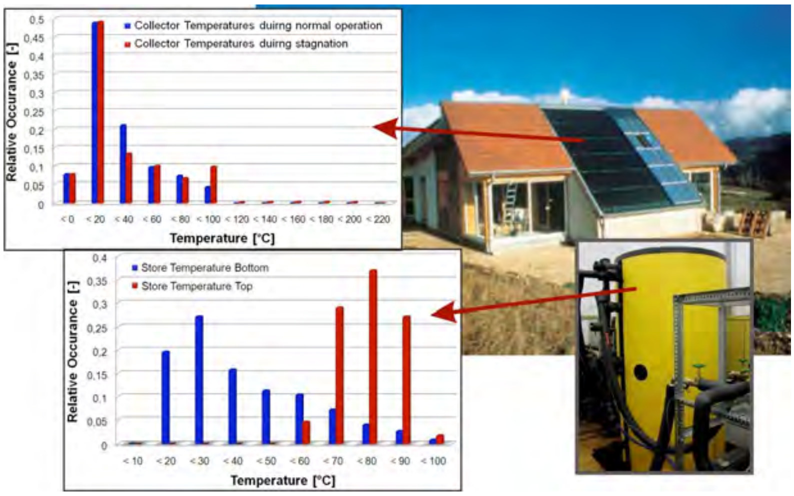



*Fig. 8. Temperature histograms of collector and store*

Seven different system concepts and three different locations (Stockholm, Würzburg and Athens) have been chosen for simulation. The system concepts are split up into two categories, systems for domestic hot water preparation and combisystems (systems for combined domestic hot water preparation and space heating). Simulation results will be thermal loads of specific system components in terms of temperature profiles and histograms throughout the year dependant on the system concept, dimensioning and control strategy. An approach will be proposed for the simulation of the collector surface temperature.

*Jens Ullmann, Stephan Fischer, Harald Drück, ITW, Germany; ullmann@itw.uni-stuttgart.de, fischer@itw.uni-stuttgart.de*

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*The contributions of this newsletter were presented at the 6th IEA-SHC Task 39 experts meeting in Rapperswil, Switzerland, April 27-29, 2009. The authors are responsible for the content of their contributions. The newsletter is available as PDF-file at: http://www.iea-shc.org/task39/newsletters/. For more information on Task 39 visit the official website http://www.iea-shc.org/task39.*