SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

NEWSLETTER 2 May-2008

TASK39

Task 39: Polymeric Materials in Solar Thermal Applications

CONTENTS

The contributions of this newsletter were presented at the 4th IEA-SHC Task 39 experts meeting in Oslo, Norway, April 28-30, 2008. 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

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

NEWS

April 28-30, 2008

The **4th IEA-SHC Task 39 Experts Meeting** was arranged at Thon Hotel Opera in Oslo, Norway from April 28-30, 2008. 37 experts participated in the meeting, representing 12 industrial partners and 16 research institutions. For the first time one expert from NREL, USA joint the meeting as an observer and will hopefully become a regular particpant in future. Three new Taskforce groups were initiated at the 3rd experts meeting in Blumau and started the work at the Oslo meeting:

- Standards for polymeric materials in solar thermal applications (lead: Josef Buchinger)
- "Must have": Making solar thermal systems more desirable (lead: Ingvild Skjelland)
- Subtask B / Technical requirements, Visions (lead: Philippe Papillon)

Most of the presentations and work at the Oslo meeting are included in this newsletter.

The ExCo-Vice president of IEA-SHC, Anne G. Lien (Enova SF, Norway), visited the Oslo meeting on Tuesday, April 29 and participated in the Taskforce group-work. Financial support from ENOVA SF, the MATNAT-Faculty at the University of Oslo and Aventa AS for the Task 39 meeting arrangement in Oslo is gratefully acknowledged.

Photos: IEA-SHC Task 39 meeting at Thon Hotel Opera (left), excursion to Oslo Opera (middle) and excursion to a multi-family building in Bjørnveien 119, Oslo (right) with a solar heating system of polymeric collectors. The constructor "Backe Project" has received the Byggherrepris 2007 (building constructor award) for Bjørnveien 119.

FUTURE EVENTS

October 07-08, 2008
EUROSUN 2008 in Lisbon, Portugal. Website: http://www.eurosun2008.org
With 11 contributions from Task 39 experts.

October 13-15, 2008
5th Experts Meeting: hosted by INETI in Lisbon, Portugal (after EUROSUN 2008)

May 4-5, 2009
6th Experts Meeting hosted by Fraunhofer ISE in Staffelstein, Germany (before the 19th Symposium Thermische Solarenergie, Otti-Kolleg)

TASK 39 - PARTICIPANT STATUS by April 2008

The experts in Task 39 are represented by 16 research institutions and 17 industrial companies from 11 European countries. Five industrial companies have signed up as Active Supporters of Task 39: Bosch Thermotechnik (D), EDF - Électricité de France (F), EMS-Chemie (CH), Roth Werke GmbH (D) and Solvay Solexis (B).

BOSCH | EDF | EMS-GRIVORY | Roth | Solvay Solexis | SOLVAY

Operating agent: Michael Köhl, E-mail: michael.koehl@ise.fraunhofer.de, Fraunhofer-Institute Solar Energy Systems, Germany

News on seasonal thermal energy stores with polymer liners

The solar assisted district heating system with seasonal thermal energy storage in Eggenstein-Leopoldshafen (Germany) is the first system realized with existing renovated buildings. The system consists of 1600 m² flat plate collectors and a 4500m³ gravel-water thermal energy store for seasonal thermal storage. Experiences gained within the BMU-project "Further development of the pit heat store technology" contributed to the design of the seasonal thermal energy store. A school, a gym, a public swimming pool and a fire station are connected to the district heating system. The project was initiated by a major refurbishment of school, gym and district heating net. Furthermore, an additional gym with shed roof carrying 600 m² of flat plate collectors (FC) was integrated into the district heating system. Altogether the district heating system consists of buildings with a gross building area of 12 000 m².

Fig. 1: Solar assisted district heating system with 1600 m² flat plate collectors and seasonal storage in Eggenstein-Leopoldshafen (Germany)

For seasonal storage a gravel-water thermal energy store is used. The liner is made of a HDPE membrane with vapor barrier. The aluminium layer prevents water vapor diffusion and thus protects the thermal insulation from getting wet during the entire period of operation of more than 30 years. The external liner for ground water protection and the internal barrier liner are welded together such that they form chambers, which are filled with expanded glass granules. The 30 chambers are evacuated after filling. This procedure enables leakage detection during construction and if desired also during operation.

A complete presentation of the project will be given at the Eurosun 2008 Conference in Lisbon

Fabian Ochs ITW, University of Stuttgart, Germany, ochs@itw.uni-stuttgart.de

New Taskforce: Standards regarding polymeric materials in solar thermal applications

A task force on standards was initiated to develop recommendations for future revisions of relevant standards for solar thermal applications to take full account of the state of the art and provide a framework for future technological development. Wherever possible, it is the aim of this taskforce to define requirements that express rather the performance of solar thermal products than design or descriptive characteristics. This approach is according to ISO/IEC Directives and leaves maximum freedom to technical development. Primarily those characteristics shall be included that are suitable for worldwide acceptance. Around this core standard – the definition of performance requirements – the specification of test methods to approve if the product fulfils these performance requirements are designed.

Here references to already existing standards of the polymeric industry are sought. Of special interest are test methods on accelerated aging and degradation due to water, heat and irradiation. A further approach is to take care of limitations by the manufacturer as there is currently not and never will be the typical solar thermal product and its application.

Taskforce "Standards" participants:
Josef Buchinger, lead (arsenal research); Harald Drück and Fabian Ochs (both ITW Stuttgart), Barry Johnston (Solar Twin), Markus Heck (Fraunhofer ISE), Kenneth Moller (SP), Katharina Resch (PCCL), Florian Ruesch (SPF), Maik Saphörster (Bosch Thermotechnik), Franz Ruemer (Borealis Poleolefins), Gernot Wallner (University of Leoben).

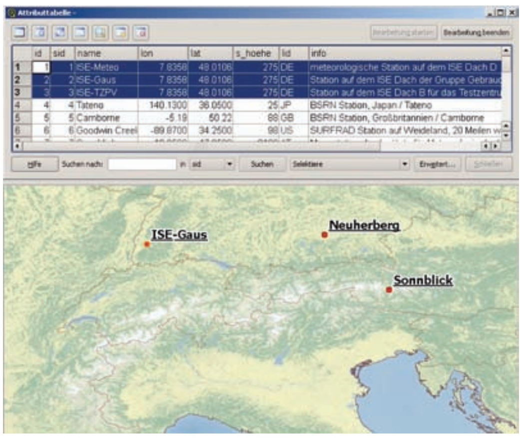
Josef Buchinger, arsenal research, Austria; josef.buchinger@arsenal.ac.at

Climate database with geographic information system (GIS)

For numerical simulations of degradation processes on polymers considering different climatic conditions, high-density and continuous measured climate data is needed. The data is stored in a high-performance and reliable database and can be linked to a geographic information system with the support of a database extension for spatial storage.

A geographic information system (GIS) is a system for capturing, storing, analyzing and managing data. With the combination of the measured climate data and additional (meta) data, such as vector files, raster files (for example satellite images) or digital terrain models, a GIS can be used for spatial and numerical analysis and presentation within diagrams or maps.

The climate database at the Fraunhofer ISE contains data from own measurements, data from project partners and is supplemented with free available data from national and international organizations. To simplify the access to the data sets for simulation applications, a browser based web-GIS and data export application can be set up at the intranet.



Karl-Anders Weiß, Fraunhofer ISE, Germany, karl-anders.weiss@ise.fraunhofer.de

New Taskforce: "Must have": Making solar thermal systems more desirable

Photo: Nils Peter Dale

The today's impression of solar thermal systems is that they are suffering a bit from low-tech/low status image – technically complicated but low-tech. It is important to correct this impression in order to get more attention. The use of polymer materials can make a big difference by "moving" the idea of solar thermal from something mature/old to something new and hi-tech;

- New materials – hi-tech
- More flexible module design and dimensions – better aesthetics and easier to integrate
- Low weight – easier to install
- Recyclable – better climate protection
- Reduced cost – better economy

Good communication, words and illustrations, is a strong tool for establishing wanted opinion and action. Effort should be put into finding the right arguments for the relevant target groups and presentation of products, systems and projects should be done in an appealing way – show something that architects want to use.

Taskforce "Must have" participants:
Ingvild Skjelland, lead (Aventa); Michael Köhl (Fraunhofer ISE), Axel Müller (HTCO), Christian Roecker (EPFL ENAC), Brigitte Neubauer (Solvay Solexis), Luis Godinho (Prirev), Vania Dobreva (Chevron Phillips), Michaela Meir (University of Oslo)

Ingvild Skjelland, Aventa AS, Norway, is@aventa.no

Solar Polymer Collector Projects in the U.S.

A number of solar polymer collector projects have been active in the U.S. NREL has been testing the optical and mechanical durability of polymeric glazing, absorber, and connecting materials.
Solar-weighted transmittance as a function of UV dose for glazing samples of interest to industry teams are shown in Fig. 2. Optical performance does not degrade after a cumulative UV dose equivalent greater than 6 years outdoor exposure in Miami, FL. Sandia has investigated thermochromic polymer gel for overheat protection. Roughly a 50% reduction in transmittance was demonstrated at a transition temperature of ~80°C. The University of Minnesota (UM) provides support to the industry teams in the areas of storage, heat exchangers, polymer tubing durability, and scaling. The UM team has explored ways to improve the thermal performance of storage tanks with immersed heat exchangers. Davis Energy Group / SunEarth has developed a polymer SWH system that uses a rotomolded PE tank with a single, thermoformed PC "cap" glazing and a dual-serpentine copper heat exchanger. FAFCO has commercialized an unglazed "Do It Yourself Hot2o" solar hot water system. Both of these systems are low cost and easy to install.

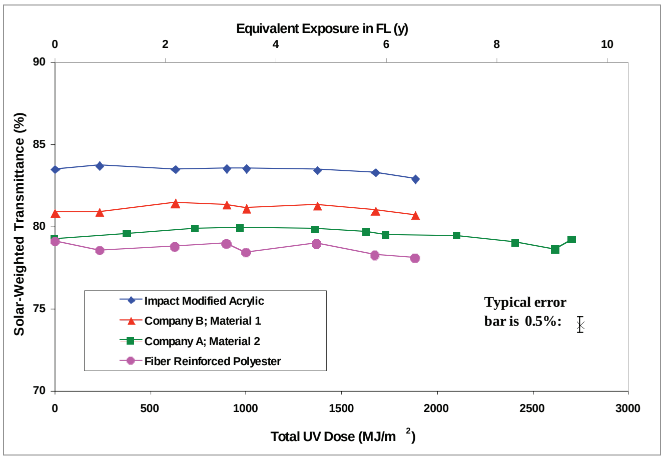


Fig. 2. Optical durability of polymer sheet glazing samples in NREL's UV Concentrator.

Gary Jorgensen, National Renewable Energy Laboratory, USA, gary_jorgensen@nrel.gov

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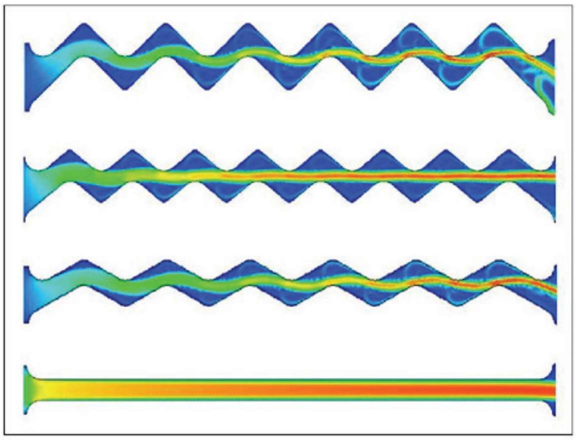
Simulation Tools

Simulation tools will play an important role in the design process of technical products in the near future. The key advantage of simulation tools is the possibility to examine a product's functionality before any real manifestation has to be carried out. Thus possible faults can be seen and eliminated beforehand and possible design improvements can be done before realizing the first prototype.



Potential Shapes of Heat Exchanger Tubes.

In the solar heating environment, where the heat exchange from solar energy into the absorber and from the absorber into the storage device is essential, simulation technology can take over a major role in the future, especially when new materials such as polymers are concerned.

For polymeric heat exchangers it is crucial – due to the lack of thermal conductivity – to improve the convective heat transfer at the surfaces, which means to optimize the flow conditions at the surface and the shape of the surface itself. The latter is an essential advantage of polymeric materials. The design and development of polymeric heat exchangers has been for Dr. Axel Müller – HTCO, a company specialized in computer simulations in the field of fluid dynamics and heat transfer since more than 20 years, a main focus during the recent years. With the help of CFD it has been possible to design a polymeric heat exchanger, which has the same efficiency as an aluminium exchanger, but with less weight, less pressure drop and less costs.

Since the shape of the exchanger dominates the fluid flow (see examples below), which itself has a considerable impact on the heat transfer, heat exchangers made of polymeric materials can be perfectly tailored according to their geometrical and technical requirements. New materials and new tools - like the simulation - can open up a new age in the world of solar heat transfer.

Dr. Axel Müller, HTCO, Germany, info@cfd-fem.com

Subtask B : Collectors / New Taskforce: Technical requirements, Visions

As the full potential of polymeric materials can only be used when several product functions are integrated into a single component in a fundamentally new design (in contrary to the simple substitution of materials), the work in this subtask is based on a review and detailed definition of technical and economic parameters for collectors and the development of novel designs of collectors.

The concept development and the following verification phase with the demonstration of examples should therewith lead to different, polymeric material oriented, collector designs. The benefits could be the replacement of expensive materials (e.g. copper), enhanced freedom of design, realization of cost potentials or the integration of several functions into the collector structure.

The figures below illustrate some of the examples which were presented during the Oslo meeting: The Bubble-collector concept, a new all-polymeric collector development and a patented, low-cost, self-limited temperature control system suitable for polymeric collectors.

A fruitful brainstorming session held during the 3rd meeting in Blumau (October 2007) provides valuable information with regard to solar thermal applications, building integration, design of thermal system, collectors in a "polymeric" way of thinking. Additionally, some ideas for really innovative concepts have been issued. For the 4th meeting in Oslo (April 2008), additional technical requirements, in order to help the material selection, have been expressed. This work is continued in the Taskforce "Technical requirements, Visions".

Thanks to this raw material, we can expect that innovative concepts for polymeric solar collectors will result from this Task.

Participants, Taskforce: Philippe Papillon, lead (CEA-INES); Christian Rytka (EMS-Chemie), John Rekstad (University of Oslo, Aventa), Markus Peter (ITW), Stefan Brunold (SPF), Karl-Anders Weiss (Fraunhofer ISE), Robert Hausner (AEE-INTEC), Mihai Radulescu (EDF), Helmut Vogel (FH Osnabrück), Stefan Kuethe (Kassel University), Karl Schnetzinger (APC);

Philippe Papillon, CEA-INES, France, philippe.papillon@cea.fr

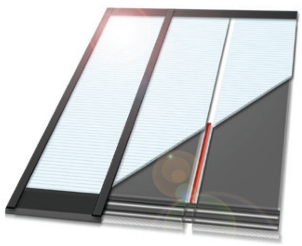
The bubble-collector

A concept based on foam properties

sub micron cells at top -> transparent
open cells for water channels
large closed cells at bottom -> insulation

Source: EMS-Chemie

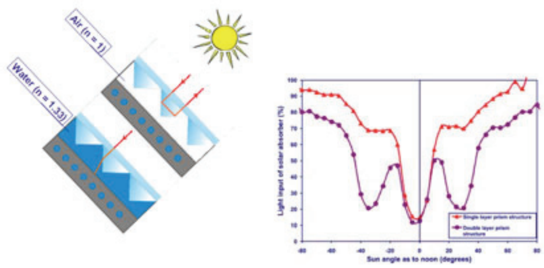
Design of a new polymeric collector



Source: Aventa

Solar collector overheat protection

- A cheap but efficient self limited temperature control system suitable for polymeric collectors



Source: R. Griessen, M. Slaman, Vrjie Universiteit Amsterdam

The Sunny World of Fluoropolymers

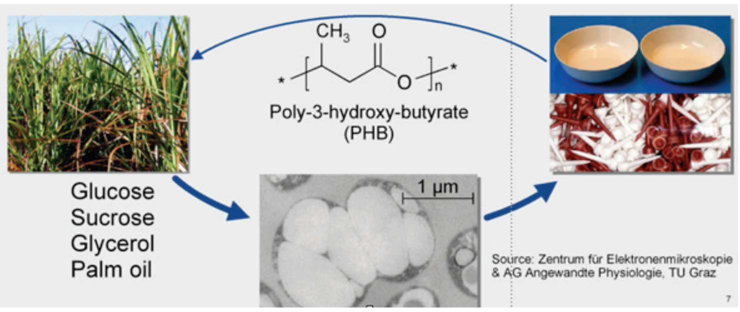
Fluoropolymers have been used for decades in out door applications requiring resistance to sunlight, in particular UV-A and UV-B. The commercial applications cover sun-resistant paints for metallic surfaces as well as protection sheet to more sensitive polymers such as PMMA, PVC, PET, and others. Fluoropolymers are also used for green houses exploiting the fact that they are mainly transparent in the range of UV and visible while infrared radiation is partly absorbed. Fluoropolymers have good mechanical properties so that they can even be used for pressure piping systems, with maximum usage temperatures from 120°C to more than 200°C, depending on the material. As a matter of fact, some fluoropolymers have already found access to our domestic drinking water and floor heating piping systems.
Solvay is - though its subsidiary Solvay Solexis - amongst the leading companies in the field of fluorinated materials and strongly committed to sustainable growth. In this spirit, Solvay is main sponsor for the technically challenging Solar Impulse Project - around the world in a solar driven airplane - which will be a showcase for the performance of its high performance products.

Brigitte Neubauer, Solvay Solexis, Belgium, Brigitte.Neubauer@solvay.com

Biomass-based polymers

The interest for biomass based polymer production has increased recently since the need to diversify the feedstocks and reducing emissions from industry is getting stronger. Polymers may be produced from biomass in many different ways. One potential production path is to first convert biomass to clean syngas, then to methanol or dimethyl ether, which may be further converted to ethylene and propylene, finally to be polymerized to PE and PP.

Figure below: Synthesis by fermentation: Poly-Hydroxy-Butyrate (PHB)



Another method of manufacturing plastics from renewable resources utilizes the ability of some bacteria to accumulate polymers as an energy reserve in the cell. The technical production process consists of a fermentation phase during which the polymer is formed as micrometer sized particles.
BASF is currently concentrating on developing methods of manufacturing polyhydroxy fatty acids, especially poly-3-hydroxyburyrate (PHB). PHB can be synthesized in high yields by many types of bacteria. For this purpose, the bacteria can be fed with different nutrients such as glucose, sucrose or palm oil. The resulting polymer structure and thus also the profile of properties is always the same, whatever the nutrient. This high tolerance of the bacteria towards their nutrient source is a major difference compared to crude oil based polymer synthesis: the producer can use the renewable raw material which happens to be cheap and available in large amounts at the time.

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Review on structural polymers - Polymer structure and thermal transitions

Polymers are classified into commodity, engineering and high performance plastics as shown in Fig. 3. Commodity plastics such as polyethylene or polypropylene can resist temperatures up to about 80 °C. The costs per kilogram are in the range between 1 and 2 €. Engineering plastics such as polycarbonate or polyamide can withstand temperatures up to about 140 °C. 1 kilogram costs up to 15 €. High performance plastics such as polyehteretherketone allow for service temperatures above 140 °C. However, costs are ranging from 15 to 100 € per kilogram. The properties of the polymers are strongly influenced by the material structure such as the morphology and the chemical composition. By varying the polymer structure and the additives used, plastics can be tailored for a specific application. For a proper design of polymeric components for solar thermal systems the appropriate material selection is of prime importance.

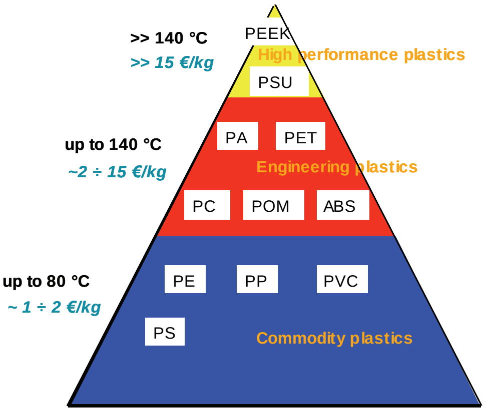
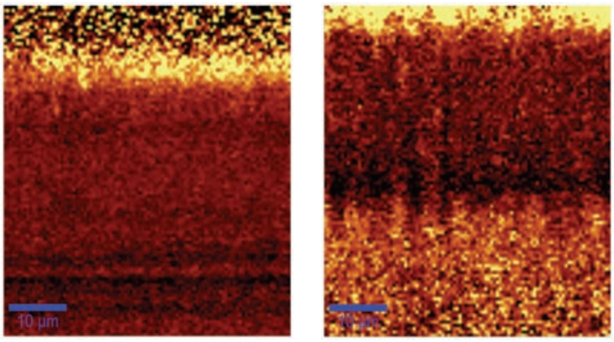


Fig. 3. Materials/costs/performance-pyramid

Susanne Kahlen, PCCL/Polymer Competence Center Leoben GmbH, Austria, kahlen@pccl.at

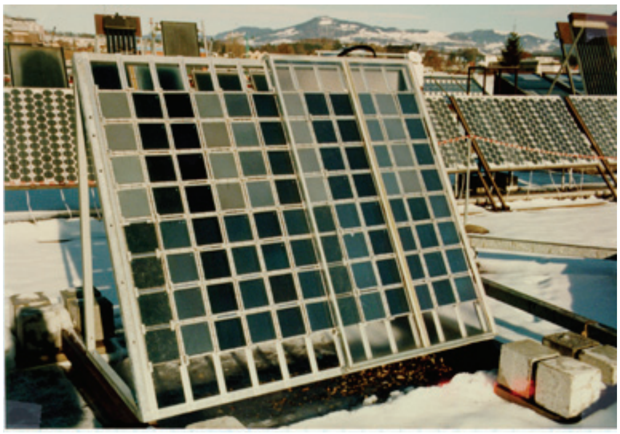
Micro-Raman analysis of polymers and compounds



The usability of polymeric materials for solar thermal applications depends strongly on their degradation behaviour. Analytical methods are required which identify material changes of promising materials during accelerated aging tests like high-UV treatment or exposition at high humidity and high temperatures. Scanning Raman microscopy offers the possibility to analyze the materials chemistry with high lateral resolution. Transparent materials allow depth scans, too. These non-destructive measurements are of particular importance for tracking the progress of degradation.
The example in the Figures to the right shows the distribution of a poly-propylene degradation product (1163 1/cm) near the surface (50µm depth scan of 50 µm line) of an unaged sample (left image) and after 800h UV irradiation (right image).
The same technology is also helpful to identify inhomogenities in compounds, for example different additives or fillers.

Karl-Anders Weiss, Fraunhofer ISE, Germany; Karl-Anders.Weiss@ise.fraunhofer.de

Ageing of Polymeric Glazing Materials - Results from 20 Years of Outdoor Weathering



The outdoor weathering performance of collector glazings was investigated by SPF in Switzerland over a time range of 20 years. A variety of 58 glazing types composed of glass and different polymeric materials were exposed on 'mini-collectors' to simulate the application as flat plate collector glazing. Fife samples of each glazing type were exposed to different climatic conditions at two Swiss sites (Rapperswil and Davos). One sample from each type was collected, analyzed and placed in storage following 40 days, 1, 3, 10 and 20 years of exposure.
No significant material degradation was detected after 20 years of exposure for PMMA, FEP and PVF, but a surprisingly high fouling was observed on some fluoropolymers. On the other hand PMMA showed even a slightly lower tendency for soil accumulation than glass.
Degradation occurred at the surfaces of the tested PC samples in the form of yellowing and material removal. The PET-, PVC-, UP and fibre reinforced PMMA-samples proved to be unsuitable for use in collector glazing. They suffered from elevated losses in transmittance or were destroyed after 20 years of exposure.
The results will be presented in more detail at EUROSUN 2008 in Lisbon.

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State-of-the-art absorber designs - Evaluation from a polymer engineering point of view

Depending on the absorber and the manifold, five different concepts are used for the design of commercial polymeric solar absorbers: (1) pipe+pipe (see figure), (2) panel+pipe, (3) panel+ endcap, (4) film+pipe, (5) panel.
These absorber concepts were evaluated from a polymer engineering point of view. While the concepts (1) to (4) are based on extruded absorbers and injection moulded manifolds, which are connected by mechanical fixing, gluing or welding, the panel concept is based on blow- or roto-moulded components with integrated semi-finished fittings. Advantages of the panel concept are a reduced number of processing steps, the use of semi-finished components (fittings) and the possible realization of more complex absorber designs. However, panel concepts are limited in the length of the absorber. An important prerequisite for concepts (1) to (4) is the use of similar materials, especially thermoplastics, for the absorber and the manifold. Compared to absorbers with pipe geometry, absorbers with flat surfaces exhibit a better functionality/material-ratio (less material is required) and a better applicability of functional layers.

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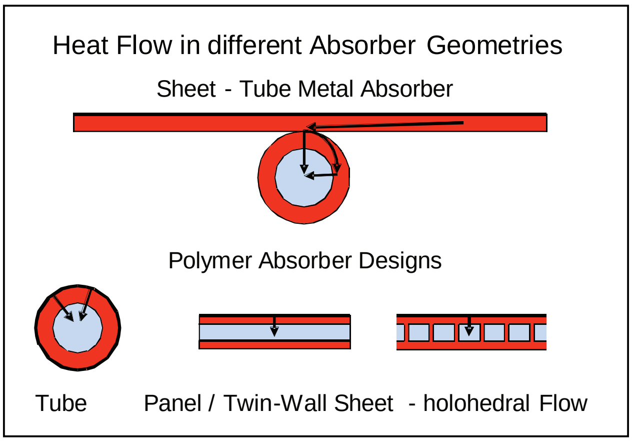
Polymeric Absorbers and Thermal Conductivity of Polymers

The thermal conductivity λ of polymers (~0,2 W/mK) is three orders of magnitude lower compared to metals, which are widely in use for common absorbers (Copper: 385 W/mK, Aluminium: 210 W/mK). Nevertheless with an appropriate design of the absorber this disadvantage can be compensated. An assessment criterion for the effectiveness of the heat transfer from the absorbing surface to the fluid is the collector efficiency factor F'. This value is a function of the geometry of the absorber (collector), the physical properties of the materials, the heat losses to the surrounding and the effectiveness of the heat transfer from the inner surface of the fluid cannel to the fluid. The thermal collector efficiency is direct proportional to F' and his maximum possible value is 1. F' can be measured or easily calculated for the most common geometries.
To point out mainly the influence of the thermal conductivity l of the absorber material, the value F' was calculated for some geometries with a good heat transfer to the fluid (turbulent flow). Usual metal absorber designs (sheet – tube) are optimised with respect to technical and economical efforts, so F' values in the range of about 0.93 to 0.97 (for turbulent flow) are common.

Covered polymer collectors (with twin-wall sheet or panel absorbers) with a thickness of the duct wall of about 1 mm are reaching excellent F' values of about 0,97 to 0,98 even with a l value of 0.2 W/mK. F' drops down to about 0.92 – 0.95 if the wall thickness is 3 mm.



For uncovered polymer collectors (mainly absorbers for swimming pools) with a wall thickness of 1 mm and λ = 0.2 W/mK F' is in the range of 0.92 to 0.94. With a wall thickness of 3 mm F' drops down to disadvantageous values of 0.82 to 0.85. With enhanced λ values (e.g. 0.4 W/mK) F' is rising up clearly to 0,95 to 0,97 for 1 mm and 0.89 to 0.92 for 3 mm respectively. Thus it would be advantageous to enhance the thermal conductivity for covered collectors only for thicker duct walls, whereas it is necessary to enhance this value considerably for uncovered collectors especially for thicker walls.

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Some results about the Project
"Novel nanocomposite coating with nanoparticles for solar absorbers"

Paints with epoxy-silicone binder and organic pigments (C_{60}/C70 and also black carbon) working as absorber pigments were prepared and applied with a coil on copper substrate, resulting in high solar absorption values (96%), but emissivity values between 80 and 84%, depending on paint thickness. Decreasing the thickness, spray technique was also used and for the minimum thickness of 4 μm it was obtained, the final solar absorption of 96% and 74% thermal emissivity. The impossibility to reduce thickness to values less then 4 μm and the need to decrease emissivity implied the addition of metallic particles to paint formulation, as a way to confer emissivity insensibility to thickness. Metallic pigments: stainless steel particles of 3 μm and also copper particles of 60 to 90 μm were added to paint formulation, with 20% in weight. However, for such metallic pigment proportion, solar absorption had 1% reduction and no decrease on emissivity. Ongoing work has the objective to enhance the contact between metallic particles, between particles and the substrate, and to reduce the percentage of binder in the paint.

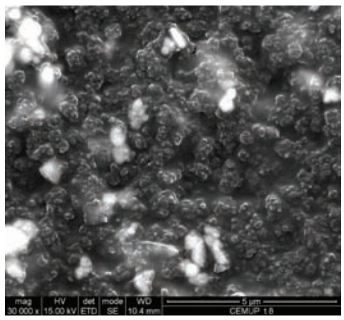

Fig. 1- SEM (30000x) micrograph of paint. Agglomerate grains in resin

Coatings of titanium oxide layer on copper substrate were produced by magnetron sputtering, followed by immersion in saturated solution of organic pigments; these ones were a mix of anthocyanin extracted from sambucus nigra fruit, with absorption peak around 530 nm. Optimized layer of titanium oxide is a graded layer with thickness of 100 to 300 nm, decreasing de titanium concentration from the substrate to the surface, with amorphous microstructure and columnar morphology, with columns perpendicular to the substrate and with the best optical properties of 87% for solar absorption and corresponding emissivity of 7%. Others organic pigments, with absorption peak located at different wavelength are being prepared to increase solar absorption, without increase on thermal emissivity.

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