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JERMAN, Ivan [SI/SI]; Locica 40, 3305 Vransko (SI).
VODLAN, Marjanca [SI/SI]; Vase 2c, 1215 Medvode
 (SI). **PEROS, Dimitrios** [GR/DE]; Radschläfe 31, 57074
 Siegen (DE).

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(74) **Agent: ZAPF, Christoph**; Patent- und Rechtsanwälte,
 Dr. Solf & Zapf, Schloßbleiche 20, 42103 Wuppertal
 (DE).

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(71) **Applicants** (for all designated States except US): **ALAN-
 OD Aluminium-Veredlung GmbH & Co. KG** [DE/DE];
 Egerstraße 12, 58256 Ennepetal (DE). **KEMIJSKI insti-
 tut - National Institute of Chemistry** [SI/SI]; Hajdrihova
 19, 1000 Ljubljana (SI). **HELIOS, tovarna barv, lakov
 in umetnih smol Kolicovo, d.o.o** [SI/SI]; Kolicovo 65,
 1230 Domzale (SI).

(72) Inventors; and

(75) **Inventors/Applicants** (for US only): **KOZELJ, Matjaz**
 [SI/SI]; Hocevje 7, 1301 Krka (SI). **OREL, Boris** [SI/SI];
 Pod Konstanji 46, 1000 Ljubljana (SI). **STEINBUECH-
 ER, Miha** [SI/SI]; Zupanciceva 5, 1241 Kamnik (SI).

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(54) **Title:** COIL-COATED SPECTRALLY SELECTIVE COATINGS ON COPPER OR ALUMINUM WITH PIGMENTS
 MODIFIED BY AMINOSILANE

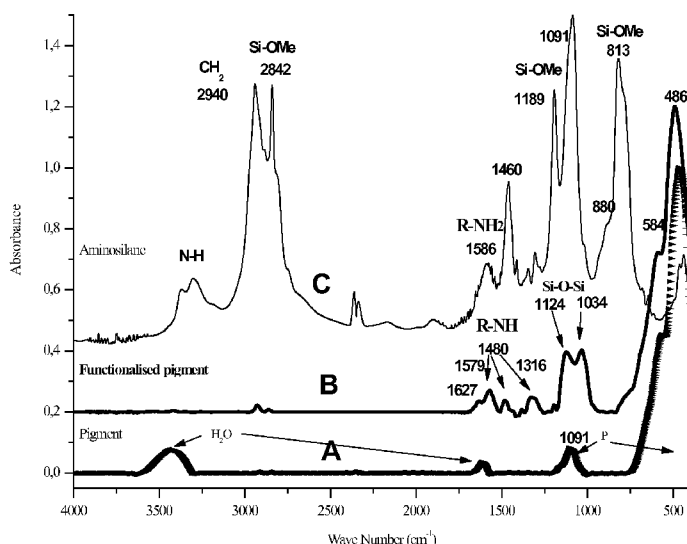


Fig. 1

(57) **Abstract:** The invention relates to TSSS and TISS coatings applied by coil-coating onto substrates of copper or aluminum. Inorganic pigments functionalized by aminosilane are used for making paints, which after the coil-coating onto the substrate form the coatings. For the functionalization the pigment is dispersed in a solution of an aminosilane in a solvent or a mixture of a solvent and a binder without an addition of a non-aminosilane dispersing agent with or without subsequent grinding and use of 0.05-30 % of aminosilane on pigment. An aromatic, aliphatic, cycloaliphatic, ketone, ester, ether or alcohol compound or a mixture thereof can be used as the solvent. A silicone-polyester, polyurethane or fluoropolymer can be used as the binder.



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**ALANOD Aluminium-Veredlung GmbH & Co. KG, Egerstraße 12,
58256 Ennepetal, Germany**

**Kemijski inštitut - National Institute of Chemistry, Hajdrihova 19,
1000 Ljubljana, Slovenia**

**Helios, Tovarna barv, lakov in umetnih smol Količevo, d.o.o, Količevo 65,
1230 Domžale, Slovenia**

**“Coil-coated spectrally selective coatings on copper or aluminum with
pigments modified by aminosilane”**

This invention relates to aminosilane modified pigments, method of their preparation, coatings made with such pigments, their production and application. More specifically, invention relates to a procedure of using aminosilanes for the treatment of various black and coloured pigments with a view to modifying the pigments' surface properties, methods for obtaining the ensuing dispersions and making from them paints and coatings that show enhanced covering efficiency, enabling the preparation of black or coloured Thickness Sensitive Spectrally Selective, TSSS, and Thickness Insensitive Spectrally Selective, TISS, paint coatings, together with the method of their preparation and their use on metal and non-metal substrates.

Pigments treated with various amino functionalized silanes enable the preparation of pigment binder dispersions with essentially improved properties, reflected in smaller particles, their more uniform distribution in organic vehicles, and also providing the compatibility of the pigments' particles with the polymer resin binder matrix, thus enabling the preparation of stable paint systems with enhanced pigment loading and higher hiding properties.

This invention is primarily suitable for obtaining paint coatings for solar absorbers, glazed and unglazed, metallic or non-metallic but it is in no way limited to them.

STATE OF THE ART

The optical properties of any coatings are characterized by their transmittance, T , absorptance, A , and reflectance, R , values, $T + A + R = 1$, which can attain various values in different parts of the electromagnetic spectrum. Typical examples of frequency dependent $T(\lambda)$, $R(\lambda)$ and $A(\lambda)$ in the visible part of the solar spectrum, VIS/ 0.3-0.6 μm , are ordinary paints with various colours, the reflectance of which should only be controlled in this spectral region. Solar cool paints and near infrared camouflage coatings for military applications require careful tuning of the optical properties also in the Near IR, NIR/ 0.6-2.5 μm , spectral region, while for the spectrally selective coatings for solar absorbers and thermovision camouflage coatings for military applications, the corresponding $T(\lambda)$, $R(\lambda)$ and $A(\lambda)$ values must be adjusted over the entire spectral region from 0.3 to at least 50 μm , broad band spectral selectivity. In order to make coatings for the above mentioned applications it is essential to know the optical properties of the pigments and resin binders for each of the spectral regions.

Solar collector paints and corresponding coatings require pigments that exhibit high solar absorptance, $a_s \sim 0.94\text{--}0.95$, values in the VIS and NIR solar regions. This is relatively easy to achieve by using black pigments, carbon soot, etc, since they show inherently high absorption in the entire solar spectrum. However, when such coatings are exposed to solar radiation and their temperature increases above the ambient temperature, up to 200 °C at stagnation conditions and up to 80 °C at operating temperatures for domestic solar heat water systems, the absorber surface starts to emit a large portion of its collected thermal energy in the form of thermal infrared radiation, $\lambda > 2.5 \mu\text{m}$. In order to decrease these thermal radiation losses, the thermal emittance of the solar absorber must be reduced as much as possible, $e_T < 0.10$ or less.

Accordingly, the main characteristic of spectrally selective coatings for solar absorbers is the difference between their solar absorptance, a_s , and thermal emittance, e_T . While high solar absorptance, $a_s \sim 0.94\text{--}0.95$, values are relatively easy to achieve, more effort needs to be devoted to achieve low emittance of coatings.

So far, various strategies exist and have been developed to make black highly solar absorbing coatings that also exhibit low thermal emittance; the chemical vapour deposition technique, CVD, has proved to be the most effective deposition technique on metal, providing solar absorbers with $a_s \sim 0.93\text{--}0.95$ and $e_T < 0.08\text{--}0.05$, depending on the metal used as a substrate. In principle, any black coating showing high a_s values could be low emitting when it is deposited on a metallic substrate with low thermal emittance like copper, stainless steel, aluminum, zincated steel, etc. and its physical thickness is comparable or lower to the wavelength of the thermal radiation. This leads to Thickness Sensitive Spectrally Selective, TSSS, paint coatings.

Thin TSSS paint coatings made of black pigment embedded in polymeric resin binder fail in both aspects. The pigment loadings expressed by the pigment to volume ratio – PVC in paints are not as high as in TSSS coatings made by CVD processing, because the absorbing pigment particles do not form a percolated film. Inevitably, as values drop below the values characteristic for the bulk pigment, usually well below 0.90. On the other hand, thermal emittance of even very thin TSSS paint coatings is inherently high, due to the absorption of the polymeric binder stemming from the vibrational modes of the polymer itself. The use of polymeric binder in paint coatings cannot be avoided, because it imparts to the coatings the necessary mechanical strength and other application properties. The problem of how to avoid a reduction of a_s and an increase of e_T values of thin TSSS paint coatings is reduced by making paints that enable the provision of a coating consisting of pigment particles arranged in a single layer, in which the pigment particles are laterally linked one to another with the smallest possible amount of polymer binder,

probably in the form of a monomolecular layer. Such coatings would have the smallest thickness, equal to the diameter of the elementary particle size of pigment, and consist of closely packed pigment particles bonded together by an organic polymer binder. This can only be achieved with paints made of dispersions with uniformly and finely dispersed pigment particles.

The preparation of such pigment dispersions, with non-agglomerated and finely distributed uniform particles, is not easy and requires careful selection of dispersants capable of providing appropriate interactions with the pigment particle surface and, on the other hand, adequate compatibility with the polymer binder systems.

Organic dispersants are normally used for the production of commercial paints. The preparation of the pigment dispersion starts with the addition of the dispersant to the binder solution before the milling process of the pigment is commenced. This procedure is also common to all procedures related to the preparation of TSSS coatings, as described in Z. Crnjak Orel, N. Leskovšek, B. Orel, M. G. Hutchins, Spectrally selective silicon paint coatings: Influence of pigment volume concentration ratio on their optical properties. *Sol. Energy mater. sol. cells*. [Print ed.], **1996**, vol. 40, 197-204. A TSSS paint coating prepared with black spinel type pigment and silicone resin binder is described, demonstrating that the latter pigment provides coatings which have an essentially lower e_T than coatings made with lamp black pigment. In the same patent, it is also shown that it is desirable to prepare paints with the highest possible PVC ratios, thus leading to maximized a_S and minimal e_T values, whereby the limiting factors are the adhesion and temperature stability of the coatings. Optimal PVC ratios are between 16 and 20 %, as stated by the authors, while the thickness of the applied coatings has been expressed with the weight in g of dry coating per unit of area in m^2 , e. g., $2g/m^2$.

The commercial TSSS paint coating, Solarect-Z24®, is manufactured by Color d. d. (SI). The silicone polyester resin binder in a combination of black spinel pigment enables the production of temperature resistant and mechanically durable black

TSSS paint coatings on various metals like copper and aluminum characterized by $a_s = 0.90$ and $e_T = 0.30$, values measured for a copper substrate, which is achieved by a coil-coating or spray application technique.

Production of non-black selective surfaces is highly desirable because of their decorative property. Good examples of their use are façade solar absorbers, passive cooling systems or military applications. Examination of the disclosed properties shows that coloured TSSS paint for solar collectors coatings suffer from either too low a_s but e_T values are adequate or e_T and a_s values are acceptable, i. e. having low e_T and high a_s . In the latter case, the colour strength, C^* of the coatings do not exceed values of about $C^* = 10$, which indicates that the coatings are practically black or gray and thus lack colour. Strong colours, $C^* > 15-20$, are obtained only for thick coatings, i. e. having thickness of at least $2-4 \mu\text{m}$, but such a high thickness inevitably leads to relatively high e_T values, $e_T > 0.5$. Solar absorptance is also low due to the strong reflection of colours in certain parts of the solar spectrum. The main reason that a high a_s and low e_T cannot be achieved in combination with high C^* values is hiding efficiency of the pigments used is too small, stemming from the imperfect dispersal of the pigments in the organic polymer binder [Z. Crnjak Orel, M. Klanjšek Gunde, B. Orel, M. Köhl, Optical properties of black and green selective paints: stability studies of black painted spectrally selective coatings. In: EuroSun'96 proceedings, A. Goetzberger, J. Luther (Eds.), DGS-Sonnenenergie, Freiburg, Germany, 1996, p. 500–504; Z. Crnjak Orel, B. Orel, A. Lenček, M. Hutchins, Optical properties of black and mixed paint coating in different colour shade on Alsubstrate. In: Eurosun 98, Book of Abstracts, (A. Kreiner, R. Perdan, Ž. Kristl (Eds.), International Solar Energy Society – Slovenian Section, Ljubljana, 1998, p. III.1.3.; Z. Crnjak Orel, M. Klanjšek Gunde, Solar Energy Mater. Solar Cells, 61 (2000) 445–450.; Z. Crnjak Orel, M. Klanjšek Gunde, M. G. Hutchins, Solar Energy Mater. Solar Cells, 85 (2005) 41–50.]. Moreover, red TSSS paint coatings have not yet been reported.

TISS coatings which can be applied onto metal and non-metal surfaces have been developed over last two decades. Their spectral selectivity has been achieved by adding aluminum pigments and/or other metal and alloy pigments to the coating formulation. Notable publications on the matter have been published by Hoeflaak [M. Hoeflaak: Optimization of spectrally selective coatings for flat plate solar collectors, 8th International conference »Optimising paint formulation: preservation, stabilisation and care«, Amsterdam, November, 1988]. The lowest e_T values achieved in the case of black coatings have been $e_T = 0.41$, together with the highest solar absorptance of $a_S = 0.90$.

The addition of non-black pigments or coloured metallic flake pigments to TISS coatings has yielded a series of non-black coatings with either low selectivity or low colour strength due to the less than satisfactorily hiding power of the pigments dispersions used B. Orel, H. Spreizer, L. Slemenik Perše, M. Fir, A. Šurca Vuka, D. Merlini, M. Vodlan, M. Köhl, Silicone-based thickness insensitive spectrally selective (TISS) paints as selective paint coatings for coloured solar absorbers (Part I), *Solar Energy Materials & Solar Cells* 91, 2007, 93–107 and B. Orel, H. Spreizer, A. Šurca Vuka, D. Merlini, M. Vodlan, M. Köhl, Selective paint coatings for coloured solar absorbers: Polyurethane thickness insensitive spectrally selective (TISS) paints (Part II), *Solar Energy Materials & Solar Cells* 91, 2007, 108–119]. The described coatings are the most suitable for thermal masking of objects and vehicles as camouflage coatings. However, due to the modest spectral selectivity, they are not the best choice TISS coatings for solar absorbers.

The object of the invention is to avoid the deficiencies of the known solutions and to provide production of paints and coatings that show enhanced covering efficiency, enabling the preparation of black or coloured Thickness Sensitive Spectrally Selective and Thickness Insensitive Spectrally Selective paint coatings.

DESCRIPTION OF THE INVENTION AND REALISED EXAMPLES

Fig. 1: IR spectra of the bare untreated spinel black pigment (A), coated pigment functionalized with aminosilane (B) and amino silane used as dispersant (C).

Fig 2: SEM image of TSSS paint coating prepared with silane functionalized black spinel pigment, scale 10 μm .

Fig. 3: SEM image of TSSS paint coating prepared with black spinel pigment dispersed with Disperbyk 163® (BYK Chemie GmbH), scale 10 μm .

Fig. 4: Solar absorptance a_s as a function of the weight of the paint layer in g/m^2 for TSSS paint coatings described in Example 2. For comparison, the same data are given for the commercially available coating Solarect-Z24®, manufactured by Color d. d..

Fig. 5: Thermal emittance e_T as a function of the weight of the paint layer in g/m^2 for the TSSS paint coatings described in Example 2. For comparison, the same data are given for the commercially available coating Solarect-Z24®, manufactured by Color d. d..

The optical properties of the samples were determined from the measured IR absorption and reflectance spectra of at least $5 \times 5 \text{ cm}^2$ sized samples. Reflectance spectra in the visible (VIS) and near-infrared (NIR) range were measured on a Perkin Elmer Lambda 950 UV/Vis/NIR with integration sphere (module 150 mm), while spectra in the middle IR spectral range were obtained on a Bruker IFS 66/S spectrometer equipped with an integrating sphere (OPTOSOL), using a gold plate as a standard for diffuse reflectance. The solar absorptance (a_s) and thermal emittance (e_T) values for bare Sunselect MTMS-protected Sunselect were calculated according to a standard procedure: M. Kohl, G. Jorgensen, A.W. Czanderna, Performance and Durability Assessment: Optical Materials for Solar Thermal Systems, Elsevier, The

Netherlands, 2004 and M.G. Hutchins, Spectrally selective materials for efficient visible, solar and thermal radiation control, in: M. Santamouris (Ed.), Solar Thermal Technologies for Buildings, James & James, London, 2003. C* values were determined from reflectance spectra (recorded on previous mentioned machines) according to CIE Technical report: Colorimetry 3rd ed. 2004, The International Commission on Illumination, Wien, p. 17 (ISBN 3 901 906 33 9).

The core of this invention is the functionalization of the inorganic pigment with aminosilane, performed by dispersing the pigment in a solution of aminosilane in solvent or various solvent mixtures together with the organic polymer binder, followed by the milling of pigment/aminosilane/solvent/binder dispersion. This process leads to firm and irreversible bonding of the silanes onto the pigment surface. Dispersions/pigment pastes made of functionalized pigments enable the preparation of various paints appropriate for various applications, as described in the examples below and the patent claims.

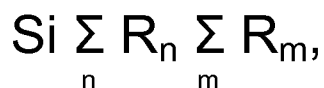
Functionalization of pigment particles with aminosilanes and evidence for the applied procedure

The pigments intended to be functionalized are of, but are not limited to, spinel and oxides of titanium, chromium, iron, zinc and the corresponding mixed oxides and oxyhydroxydes.

Solvents are preferably, but not limited to, aliphatic, cycloaliphatic, aromatic and heteroaromatic compounds, alcohol, ester, ether type or mixtures thereof.

The binders are preferably, but not limited to, silicone or substituted silicones, polyurethanes and fluoro co-polymers or a mixture of corresponding binders.

The key compounds of this invention are various aminosilanes described by the formula



where $n + m = 4$ and R_n represents an un-substituted or substituted alkyloxy or cycloalkyloxy group of C_1 to C_7 or an un-substituted or substituted aryloxy or heteroaryloxy 5–7 member ring group or chloro substituent, R_m represents an amino or polyamino substituted alkyl or cycloalkyl group of C_1 to C_{18} or aminosubstituted aryl or heteroaryl 5–7 member ring. In addition, the aminosilane could be an oligomere of such a compound.

Additives are compounds or mixtures of them added to paint formulations in an amount of 10 % or less of the total formulation, which serve to improve the dispersion process, the application of the dispersed pigments and the adjustment of specific properties of the paints and the ensuing coatings such as, but not limited to, their rheological, surface and adhesion properties. The term additive does not comprise dispersal agents.

The procedure for inorganic pigment functionalization with aminosilanes consists of dispersing the pigment in a solution of 0.05–30 % of the aminosilane by weight of the pigment, in a solvent or solvent binder mixture for 5 minutes to 6 hours. Dispersal may be followed by grinding of the said dispersion to the desired fineness. In order to improve the efficiency of dispersal and or milling the pigments, a suitable amount of binder and/or standard additives may be included in the formulations.

The functionalization of an inorganic pigment by aminosilanes is demonstrated by three interrelated but independent sets of results: (i) infrared spectra of functionalized pigments (Fig. 1), (ii) the state of dispersions obtained after the application of aminosilane dispersants (Fig. 2 and 3) and (iii) the optical properties of the paint coatings (Fig. 4 and 5) prepared from the corresponding pigment dispersions.

(i) The first experiment undoubtedly proves that the aminosilanes bond onto the surface of the pigment particle during the dispersal and subsequent milling of the pigment in the aminosilane-solvent-resin binder solution.

Fig. 1 shows the IR spectra of the bare 24-3060 PK pigment (Ferro GmbH) (A), pigment functionalized with aminosilane (B) and aminosilane (C). For example, in the spectrum of the bare pigment, in addition to the bands attributed to the pigment indicated by P weak bands of the water were seen due to the moisture present in untreated commercial pigment. The presence of moisture is important, since it triggers hydrolysis of the aminosilane which leads to the formation of the silanol groups required for achieving condensation of the aminosilane directly onto the surface of the pigment.

The functionalized pigment was taken out of the reaction mixture and immediately thoroughly rinsed with solvent in order to remove all the non-bonded species from its surface, then the IR spectra (Fig. 1B) was recorded. In the IR spectra, the characteristic absorption bands of the amino groups, marked R-NH, were recognized, together with bands attributed to the siloxane groups, marked Si-O-Si. The frequencies of the R-NH and the Si-O-Si bands shifted and changed their intensities, clearly demonstrating the condensation of the hydrolyzed aminosilane and its bonding to the pigment surface. Because the IR spectra of the surface functionalized pigment (Fig. 1B) showed bands of the condensation products of the hydrolysis-condensation reactions of the aminosilane (Fig. 1C), it was impossible to rule out the possibility of self-condensation of aminosilane molecules. However, self-condensed aminosilane species did not detrimentally impact on the effectiveness of the pigment particles' functionalization, but merely indicated that a thicker thicker aminosilane layer formed during the bonding and dispersal process. Accordingly, the IR spectra proved the formation of a pigment wrapped by variously interlinked aminosilane moieties via the Si-O-Si bonds, thus excluding the existence of two separated and non-interacting pigment and aminosilane phases.

(ii) The second experiment shows the difference in morphology of dispersions of aminosilane functionalized and non-functionalized pigments.

Two pigment dispersions with the same PVC ratios were made by dispersion, and subsequently ground to the same fineness $< 1 \mu\text{m}$, measured according to ISO 1524. Both dispersions were applied in the form of thin layer onto the metal substrate and allowed to dry and cure to harden. Comparison of the corresponding SEM micrographs (Fig. 2 and 3) shows that the pigment particles are more evenly distributed in the dispersion prepared with the aminosilane-functionalized pigment, which can be inferred from the even distribution and smaller size of the pigment particles, while the SEM micrographs of the paint dispersions made of non-functionalized pigment showed lumps and regions in which the pigment particles were agglomerated and their distribution was not uniform.

(iii) This experiment provided the final and the most convincing proof of the effective modification of the pigments' surface by aminosilane dispersants. Two different TSSS paint coatings were applied onto a copper substrate by spraying in order to make TSSS coatings with various thicknesses. The first, called Example 2, was based on the aminosilane functionalized pigment corresponding to the paint described in Example 2, while the second one, called Solarect Z-24®, corresponded to commercial Solarect Z-24® TSSS paint coatings manufactured by Color d. d. (SI). The thickness of the deposited TSSS paint coatings was controlled by altering the amount of solvent added to the prepared paints and was expressed by the weight of dry paint per m^2 . The paints were first dried and then temperature cured and their a_s and e_T values were then determined from the measured hemispherical IR reflection spectra. The results shown in Fig. 4 and 5 reveal that the coatings made of the paint (Example 2) with the functionalized pigments exhibited higher solar absorptance and lower thermal emittance values than the Solarect Z-24® paint coatings with the same physical thickness. Higher solar absorptance values indirectly proved that the covering efficiency of the paints made from the aminosilane treated pigment

dispersions was higher than those made of the commercial Solarect Z-24® coatings (Fig. 5). The beneficial effect of functionalized pigment can also be understood from Fig. 4, which shows the variation of thermal emittance values of the commercial Solarect Z-24® and Example 2 coatings as a function of the coating thickness expressed in grams of dry paint film per m². The thermal emittance of the coatings made of functionalized pigment dispersion clearly exhibited lower e_T values than the thermal emittance of the commercial Solarect Z-24® paint coatings. The beneficial effect of the aminosilane treatment on thermal emittance values was more pronounced, up to 10 %, than on solar absorptance values, 1-3 %, when the same coating thicknesses were considered. To conclude, the results showed that the use of aminosilane for the paint preparation resulted in increased solar absorptance and simultaneous reduction of the thermal emittance of the coatings. In other words, the former TSSS coatings exhibited higher spectral selectivity.

The preparation of the aminosilane-functionalized pigments and dispersions

Aminosilane functionalized pigments can be isolated after functionalization by filtering the dispersion, washing it with solvents and then drying the washed pigment. Other separation methods, subject to practicability or their availability, can also be used.

Pigment pastes could be prepared from aminosilane functionalized pigments in much the same way as pastes made of other non-functionalized pigments: functionalization can be preformed, preferably at the earliest possible stage, in the production of the pastes or an isolated functionalized pigment can be used.

For functionalized pigment paints, pigments can be functionalized *in-situ* during preparation of the paint. It is recommended that pigment functionalization be performed at the earliest possible stage in the production process. Alternatively, functionalized pigment paste or an isolated functionalized pigment can be used.

In general, the preparation procedure for functionalized pigment dispersions followed common procedures used in the paint industry.

The application and usage of aminosilane functionalized pigments for making paints:
TSSS and TISS spectrally selective coatings

Due to their enhanced covering efficiency and the ability to form stable pigment dispersions with much higher pigment loadings than ordinary paints, aminosilane-functionalized pigments are suitable for the manufacture of any paint coatings in which high pigment loadings combined with excellent mechanical stability and specific optical effects, such as high solar absorptance and low thermal emittance are desired. TSSS and TISS paint coatings for solar absorbers are typical examples of their application.

- Black TSSS paint coatings for solar absorbers with spectral selectivity as high as $a_S = 0.91$, $e_T = 0.06$ and good adhesion and thermal stability can be made by using aminosilane functionalized pigments. Coloured, i. e., non-black or gray, TSSS coatings for solar absorbers, where their aesthetic appearance is important, with spectral selectivity as high as $a_S = 0.85$, $e_T = 0.18$ and colour strength of $C^* = 18$, retaining good adhesion and thermal stability, can be made by using aminosilane functionalized pigments. All the aforementioned TSSS paint coatings should have a solid matter content, i. e., aminosilane functionalized pigment, of 30–75 %, 25–70 % of binder, 0–40 % of other pigments, 0–30 % fillers and 0–10 % additives.

- TSSS paints can be applied to a metal or a metalized surface by spraying, coil-coating or dipcoating.

- Black and gray TISS coatings for solar absorbers suitable for solar collector systems with spectral selectivity as high as $a_S = 0.91$ and $e_T = 0.35$, and coloured, i. e., non-black or gray, TISS paint coatings for solar absorbers with spectral

selectivity as high as $a_S = 0.84$, $e_T = 0.40$ and colour strength ranging from $C^* = 10$ up to $C^* = 20$, can be made by using aminosilane modified pigment dispersions. Regardless their colour, TSSS and TISS paint coatings offer excellent coatings, showing good adhesion, thermal and UV stability and excellent corrosion resistance and moderate abrasion resistance. TISS coatings should have a solid matter content of 5–70 % aminosilane functionalized pigment, 10–50 % metal flakes of either natural look or coloured, 0–40 % other pigments, 0–30 % fillers, 25–70 % binder and 0–10 % additives.

- Aminosilane functionalized pigments offer an excellent choice for thermovision camouflage paints for military applications for moving or stationary objects and are characterized by a broad frequency response from 0.3 up to 50 μm and the ability to provide camouflage in the form of a single coat of the paint. Their shade can be adjusted in terms of the need to make an object with low observance in various environments like marine, earth, snow, deserts, forests, with the ability to reduce the radiative temperature by at least 50 %. They offer good adhesion, thermal and UV stability and excellent corrosion resistance, and adequate abrasion resistance for this application. Their optical properties in the VIS, NIR and thermal IR parts of the electromagnetic spectrum ensure good blending with the surroundings. Their typical composition is similar to those used for coloured TISS paint coatings: 5–70 % aminosilane functionalized pigment, 10–50 % metal flakes of either natural look or coloured, 0–40 % other pigments, 0–30 % fillers, 25–70 % binder and 0–10 % additives.

- TISS paints can be applied to a metal or a non-metal surface by spraying, coil-coating or dipcoating.

- Aminosilane functionalized pigments, such as titanium dioxide or zinc oxide, are suitable for making solar cool paints and as micro-fillers for transparent lacquers and bulk commodity plastics. The invention is additionally explained by the following examples, which are in no way limiting.

Example 1

General procedure for a 45 % pigment paste made of aminosilane functionalized pigment and silicone-polyester binder

Silikoftal® Non-stick 60 (Evonik Tego Chemie GmbH)	170 g
An inorganic pigment	450 g
Bentone® SD-2 (Elementis Specialties, Inc.)	10 g
[3-(2-aminoethyl)aminopropyl]trimethoxysilane	25 g
Xylene	230 g
n-butylacetate	115 g

An inorganic pigment is gradually added to a solution of [3-(2-aminoethyl)aminopropyl]trimethoxysilane in xylene under continuous dispersion. When the addition has been completed, dispersion is continued for a further 15 minutes, then 150 g Silikoftal® Non-stick 60 is added under constant dispersion, followed by Bentone® SD-2 and dispersion continued for a further 15 minutes. The obtained dispersion is milled in a sand mill at approximately ~ 3000 RPM to a particle size < 1 µm (ISO 1524). N-butylacetate is added under constant dispersion.

Example 2

Black silicone-polyester TSSS coating prepared from an aminosilane functionalized pigment paste

45 % black aminosilane functionalized pigment paste made according

to Example 1 with 24-3060 PK pigment (Ferro GmbH)	890 g
Silikoftal® Non-stick 60 (Evonik Tego Chemie GmbH)	110 g

Silikofтал® Non-stick 60 is added under constant dispersion to a 45 % black aminosilane functionalized pigment paste made according to Example 1 with 24-3060 PK pigment (Ferro GmbH).

A coating prepared in such a way, suitably diluted, can be applied by coil-coating or spray coating methods. The deposited coating is hardened by heating at 200–250 °C for 10-20 min, or for a longer time at lower temperatures, if the substrate requires such a reduction of the curing temperature.

By spraying the paint onto a copper substrate, the prepared coating with an equivalent thickness of 1 g/m² has adhesion of Gt0 (ISO 2409), and its spectral selectivity is denoted by $a_s = 0.91$ and $e_T = 0.06$.

Example 3

Black 2-component polyurethane TSSS coating

Desmophen® A 365 (Bayer MaterialScience AG)	240 g
24-3060 PK (Ferro GmbH)	381 g
Bentone® SD-2 (Elementis Specialties, Inc.)	13 g
3-aminopropyltrimethoxysilane	13 g
Xylene	168 g
<i>n</i> -butylacetate	..91 g
BYK® 410 (BYK-Chemie GmbH)	3 g
Desmodur® N 75 (Bayer MaterialScience AG)	91 g

Component A is prepared by gradually adding black pigment 24-3060 PK to a solution of 3-aminopropyltrimethoxysilane in xylene under continuous dispersion. After adding has been completed, mixing continues for a further 15 minutes, then 150 g Desmophen® A 365 is also added under constant dispersion, followed by Bentone® SD-2 and dispersion continued for a further 15 minutes. The obtained

dispersion is milled in a sand mill at approximately 3000 RPM to a particle size $< 1 \mu\text{m}$ (ISO 1524). While continuously dispersing, a further 90 g Desmophen® A 365, butylacetate and BYK® 410 are added to the paste.

Prior to use, component A of the coating prepared in such a way is mixed with component B, Desmodur® N 75.

A coating prepared in such a way, suitably diluted, can be applied by coil-coating or spray coating methods.

By spraying the paint onto a copper substrate, the prepared coating with an equivalent thickness of 1 g/m^2 has adhesion of Gt0 (ISO 2409), and its spectral selectivity is denoted by $a_S = 0.92$ in $e_T = 0.18$.

Example 4

Black silicone-polyester TISS coating prepared from an aminosilane functionalized pigment paste

45 % black aminosilane functionalized pigment paste made

according to Example 1 with 24-3060 PK pigment (Ferro GmbH)	327 g
Alubright 3100 (Schlenk Metallic Pigments GmbH)	274 g
BYK® 410 (BYK-Chemie GmbH)	10 g
4-hydroxy-4-methylpentan-2-one	12 g
Silikoftal® Non-stick 60 (Evonik Tego Chemie GmbH)	245 g
<i>n</i> -butylacetate	50 g
Solvesso® 100 (Exxon Mobil Corporation)	50 g
Additol® XL 186 (Cytec Industries inc.)	32 g

The 45 % black aminosilane functionalized pigment paste made according to Example 1 with 24-3060 PK pigment (Ferro GmbH) is slowly worked into Alubright

3100 and Silikoftal® Non-stick 60, 4-hydroxy-4-methylpentan-2-one, n-butylacetate, Solvesso® 100, Additol® XL 186 and BYK® 410 are added under constant dispersion.

A coating prepared in such a way, suitably diluted, can be applied by the coil-coating or spray coating methods.

When properly applied by the spray coating method, a coating prepared in such a way with a thickness of 30 to 100, mm has adhesion of Gt0 (ISO 2409) and its spectral selectivity is denoted by $a_s = 0.90$ in $e_T = 0.35$.

Example 5

Brick red silicone-polyester TSSS coating prepared from aminosilane functionalized pigment pastes

45 % red aminosilane functionalized pigment paste

made according to Example 1

with Bayferrox 130M pigment (LANXESS Deutschland GmbH)	855 g
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45 % black aminosilane functionalized pigment paste made

according to Example 1 with 24-3060 PK pigment (Ferro GmbH)	95 g
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Silikoftal® Non-stick 60 (Evonik Tego Chemie GmbH)	50 g
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The 45 % black aminosilane functionalized pigment paste made according to Example 1 with 24-3060 PK pigment (Ferro GmbH) and Silikoftal® Non-stick 60 is added under constant dispersion to 45 % red aminosilane functionalized pigment paste made according to Example 1 with Bayferrox 130M pigment (LANXESS Deutschland GmbH).

A coating prepared in such a way, suitably diluted, can be applied by the coil-coating or spray coating methods. The deposit is hardened by heating at 200–250 °C for 10–20 min, or longer at lower temperatures if the substrate requires such a reduction.

A coating prepared in such a way, properly sprayed onto a copper substrate with a gramature (thickness) of 2 g/m², has adhesion of Gt0 (ISO 2409), its spectral selectivity is denoted by $a_s = 0.85$ and $e_T = 0.18$ and its color strength is denoted by $C^* = 18$.

Example 6

Blue silicone-polyester TISS coating prepared from an aminosilane functionalized pigment paste and colored metal pigment

45 % black aminosilane functionalized pigment paste made

according to Example 1 with 24-3060 PK pigment (Ferro GmbH)	58 g
Standart® Alucolor Blau 1504 (Eckart GmbH & Co. KG)	232 g
BYK® 410 (BYK-Chemie GmbH)	4 g
4-hydroxy-4-methylpentan-2-one	8 g
Silikoftal® Non-stick 60 (Evonik Tego Chemie GmbH)	234 g
Methoxypropylacetate	174 g
Solvesso® 100 (Exxon Mobil Corporation)	174 g
Color Uni pasta Violet RL (Color d.d.)	116 g

The 45 % black aminosilane functionalized pigment paste made according to Example 1 with 24-3060 PK pigment (Ferro GmbH) is slowly worked into Standart® Alucolor Blau 1504 (Eckart GmbH & Co. KG) and, under constant dispersion, Silikoftal® Non-stick 60, 4-hydroxy-4-methylpentan-2-one, n-butylacetate, Solvesso® 100, Additol® XL 186 and BYK® 410 are added.

A coating prepared in such a way, suitably diluted, can be applied by coil-coating or spray coating methods.

When properly applied by the spray coating method, a coating prepared in such a way with a thickness of 30 to 100 μm has adhesion of Gt0 (ISO 2409), its spectral selectivity is denoted by $a_s = 0.87$ in $e_T = 0.43$ and its color strength is denoted by $C^* = 17$.

Example 7

Olive green silicone-polyester TISS coating prepared from an aminosilane functionalized pigment pastes

45 % green aminosilane functionalized pigment paste made according to Example 1 with GN-M pigment (LANXESS Deutschland GmbH)	216 g
45 % yellow aminosilane functionalized pigment paste Made according to Example 1 with Bayferrox 3920 pigment (LANXESS Deutschland GmbH)	110 g
45 % black aminosilane functionalized pigment paste made according to Example 1 with 24-3060 PK pigment (Ferro GmbH)	80 g
Alubright 3100 (Schlenk Metallic Pigments GmbH)	310 g
BYK® 410 (BYK-Chemie GmbH)	10 g
4-hydroxy-4-methylpentan-2-one	12 g
Silikoftal® Non-stick 60 (Evonik Tego Chemie GmbH)	150 g
<i>n</i> -butylacetate	40 g
Solvesso® 100 (Exxon Mobil Corporation)	40 g
Additol® XL 186 (Cytec Industries inc.)	328 g

All three 45 % aminosilane functionalized pigment pastes made according to Example 1 are slowly worked into Alubright 3100 and, under constant dispersion, Silikoftal® Non-stick 60, 4-hydroxy-4-methylpentan-2-one, *n*-butylacetate, Solvesso® 100, Additol® XL 186 and BYK® 410 are added.

A coating prepared in such a way, suitably diluted, can be applied by coil-coating or spray coating methods.

When properly applied by the spray coating method, a coating prepared in such a way with a thickness of 30 to 100 mm has adhesion of Gt0 (ISO 2409), its spectral selectivity is denoted by $a_S = 0.83$ in $e_T = 0.42$ and its color strength is denoted by $C^* = 13$.

PATENT CLAIMS

1. A TSSS coating on copper or aluminum applied by coil-coating and having a solid matter content of:
 - an inorganic pigment functionalized by aminosilane 30–75 %,
 - a binder 25–70 %,
 - other pigments 0–40 %,
 - fillers 0–30 %,
 - additives such as but limited to rheological additives 0–10 %,wherein for the functionalization of the pigment by aminosilane the pigment is dispersed in a solution of an aminosilane in a solvent or a mixture of a solvent and a binder without an addition of a non-aminosilane dispersing agent with or without subsequent grinding and use of 0.05–30 % of aminosilane on pigment and/or use of an aromatic, aliphatic, cycloaliphatic, ketone, ester, ether or alcohol compound or a mixture thereof as the solvent and/or use of a silicone-polyester, polyurethane or fluoropolymer binder, whereas said procedure is performed either *in-situ* during coating or pigment paste production or followed by an isolation of the aminosilane functionalized pigment.
2. The coating on copper or aluminum according to Claim 1, prepared by use of the pigment paste, the pigment paste having a solid matter content of:
 - the pigment functionalized by aminosilane 30–90 %,
 - a binder 7–70 %,
 - additives such as but not limited to rheological additives 0–10 %.

3. The coating on copper or aluminum according to Claim 1 or 2, characterized by the use of a silicon-polyester polymer or a polyurethane or a fluoropolymer or a mixture thereof as the binder.

4. A TISS coating on copper or aluminum applied by coil-coating and having a solid matter content of:

- an inorganic pigment functionalized by aminosilane	5–70 %
- metal flakes	10–50 %,
- other pigments	0–40 %,
- binder	25–70 %,
- fillers	..0–30 %
- additives such as but not limited to rheological additives	0–10 %,

wherein for the functionalization of the pigment by aminosilane the pigment is dispersed in a solution of an aminosilane in a solvent or a mixture of a solvent and a binder without an addition of a non-aminosilane dispersing agent with or without subsequent grinding and use of 0.05–30 % of aminosilane on pigment and/or use of an aromatic, aliphatic, cycloaliphatic, ketone, ester, ether or alcohol compound or a mixture thereof as the solvent and/or use of a silicone-polyester, polyurethane or fluoropolymer binder, whereas said procedure is performed either *in-situ* during coating or pigment paste production or followed by an isolation of the aminosilane functionalized pigment.

5. The coating on copper or aluminum according to Claim 4, prepared by use of the pigment paste, the pigment paste having a solid matter content of:

- the pigment functionalized by aminosilane	30–90 %,
- a binder	7–70 %,
- additives such as but not limited to rheological	0–10 %.

6. The coating on copper or aluminum according to Claim 4 or 5, characterized by the use of coated metal flakes
and/or by the use of a silicon-polyester polymer
and/or polyurethane and/or fluoropolymer as the binder.
7. The coating on copper or aluminum according to one of Claims 1 to 6, characterized by its use for solar energy exploitation.
8. The coating on copper or aluminum according to one of Claims 1 to 7, characterized by a spectral selectivity of $a_s \geq 0.90$ solar absorptance and by a thermal emittance of $e_T \leq 0.20$, preferably $e_T \leq 0.40$.
9. The coating on copper or aluminum according to one of Claims 1 to 8, wherein the coil-coating is performed as an application of a paint or a lacquer by rollers.
10. The coating on copper or aluminum according to one of Claims 1 to 9, wherein the coil-coating is performed as an application of a paint or a lacquer by one or more slot dies.
11. A coil of copper or aluminum with a coating according to one of Claims 1 to 10.

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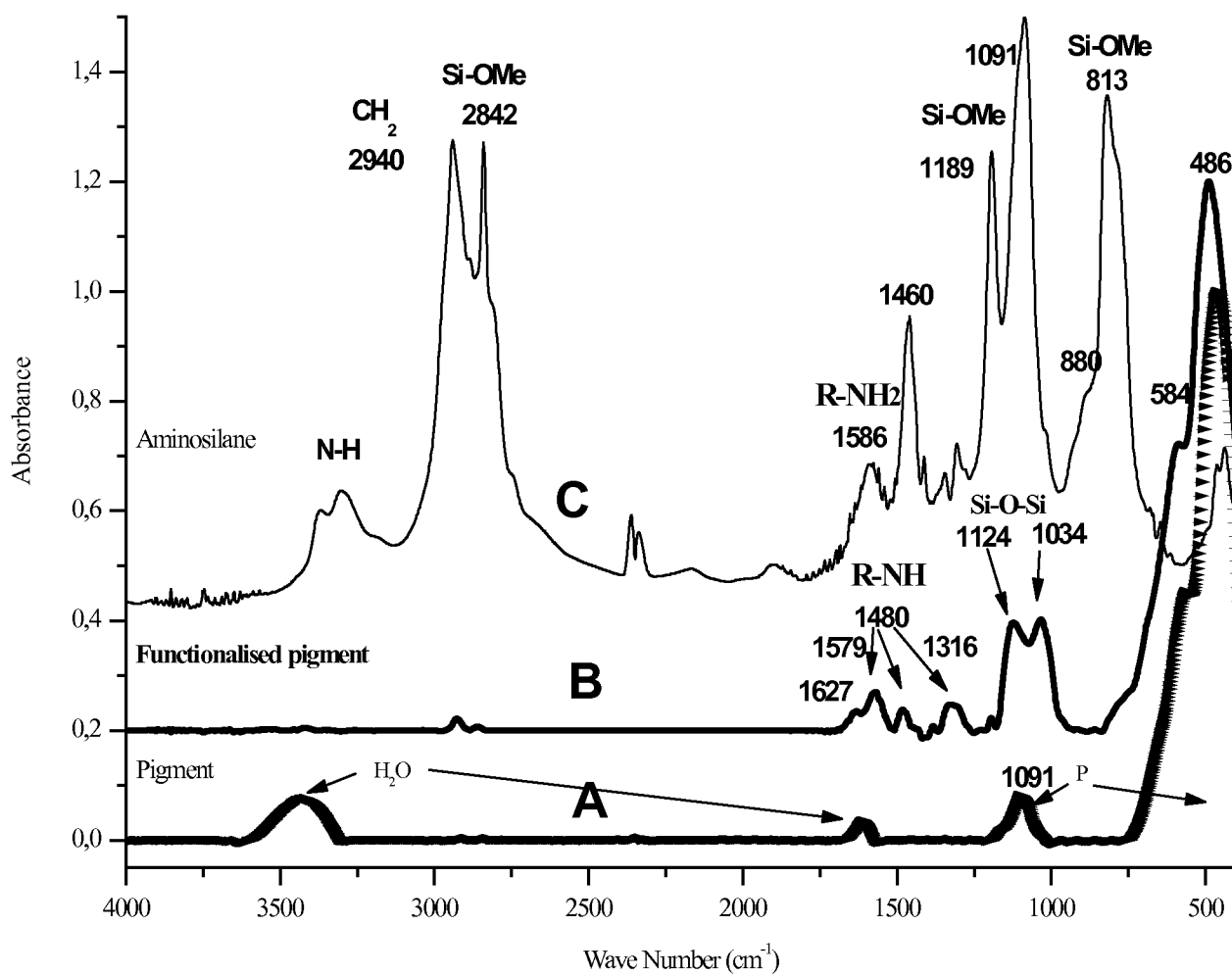


Fig. 1

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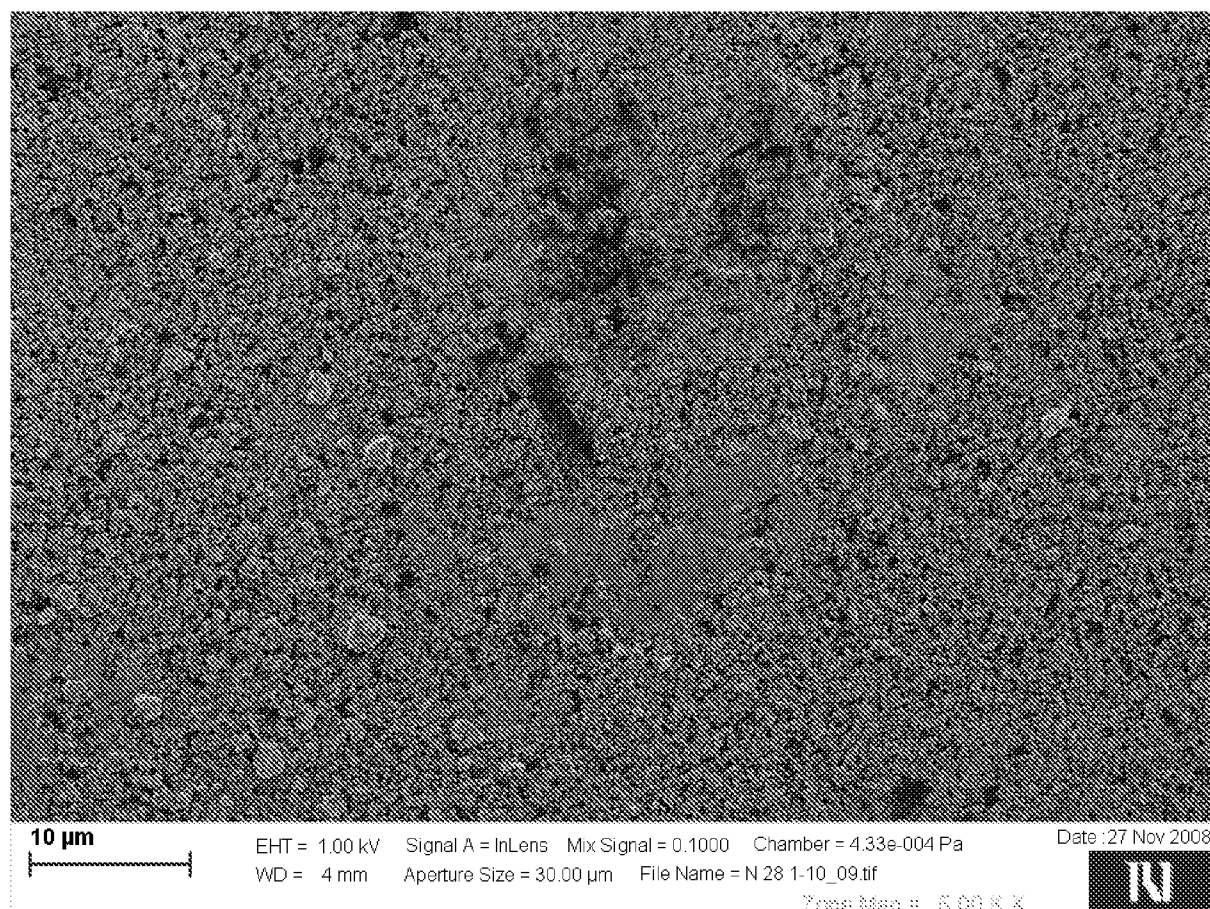


Fig. 2

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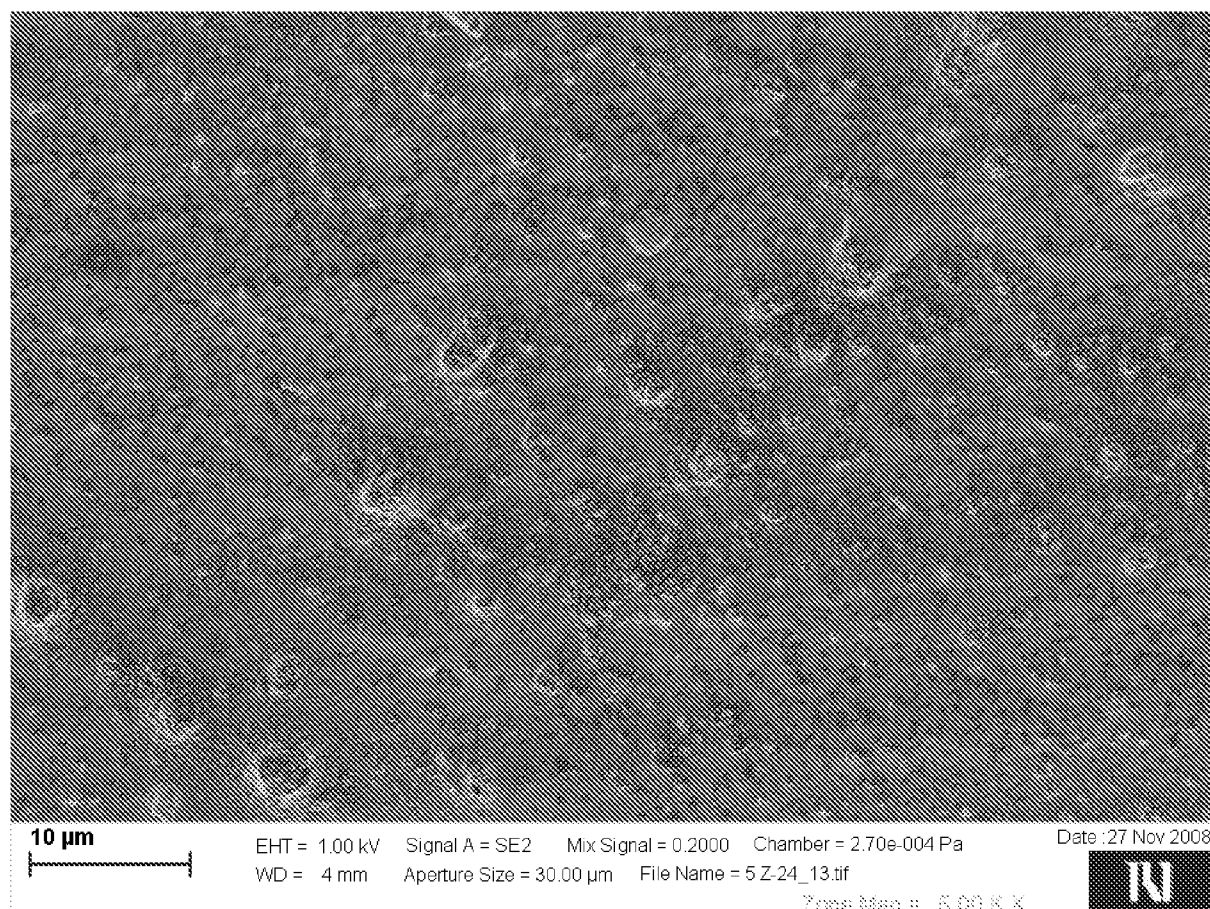


Fig. 3

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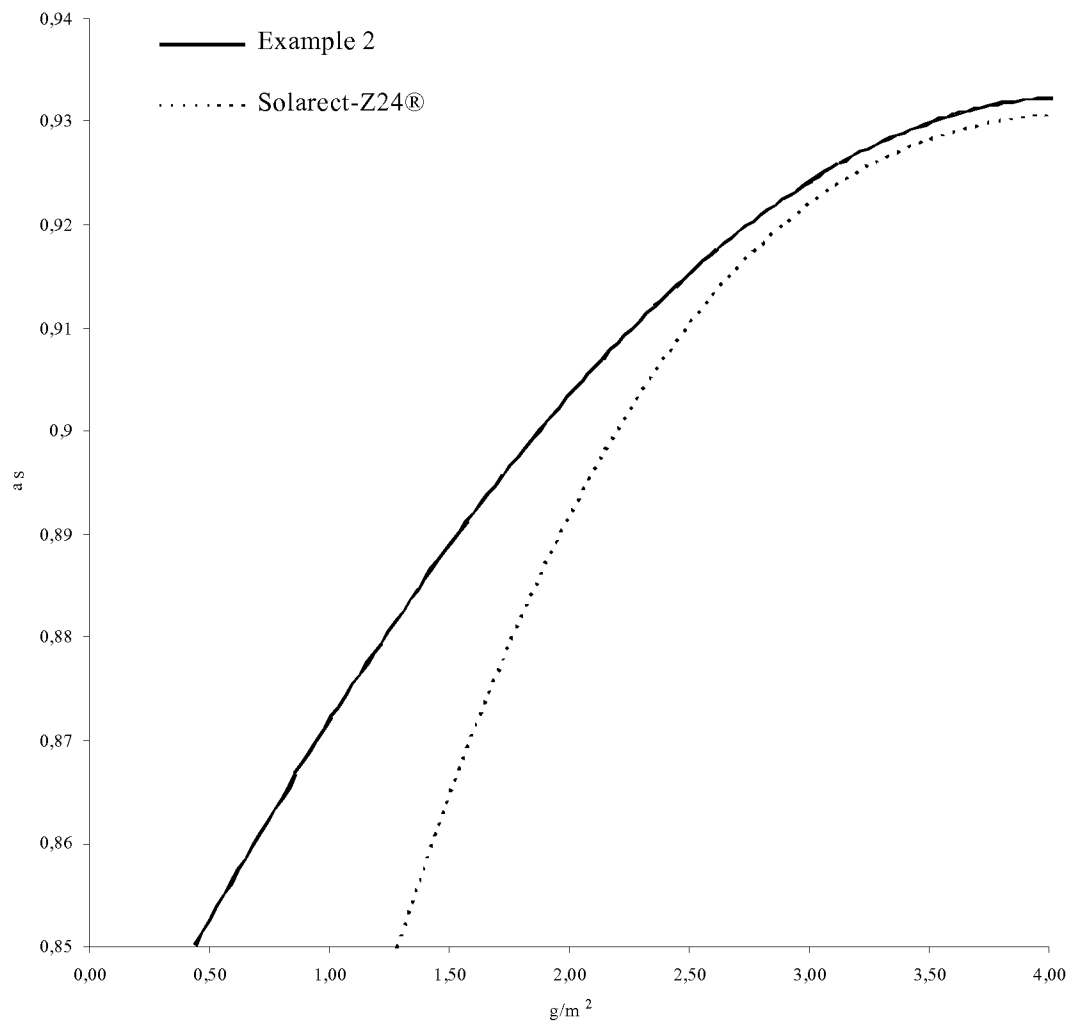


Fig. 4

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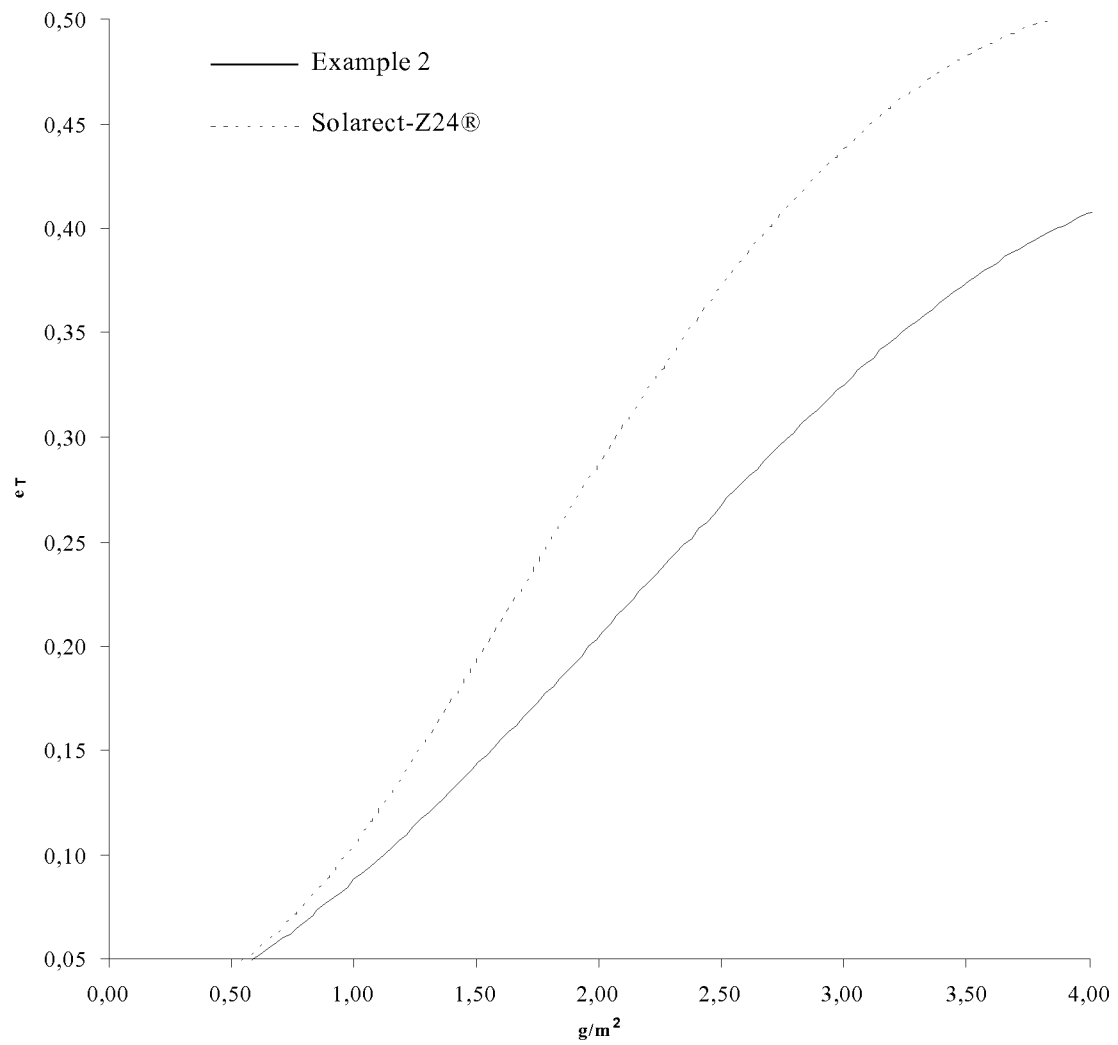


Fig. 5

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2010/057032

A. CLASSIFICATION OF SUBJECT MATTER

INV. C09C1/24 C09C1/34 C09C3/08 F24J2/48 H01L31/0216
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C09C F24J H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, BIOSIS, CHEM ABS Data, COMPENDEX, EMBASE, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	B. OREL, Z. C. OREL, A. KRAINER, M.G. HUTCHINS: "FTIR spectroscopic investigations and the thermal stability of thickness sensitive spectrally selective (TSSS) paint coatings" SOLAR ENERGY MATERIALS, vol. 22, 1991, pages 259-279, XP002581949	1-3,7-11
Y	the whole document ----- -/--	4-6



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

A document defining the general state of the art which is not considered to be of particular relevance

E earlier document but published on or after the international filing date

L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

O document referring to an oral disclosure, use, exhibition or other means

P document published prior to the international filing date but later than the priority date claimed

T later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

X document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

Y document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

Z document member of the same patent family

Date of the actual completion of the international search

14 July 2010

Date of mailing of the international search report

22/07/2010

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

King, Ruth

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2010/057032

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	OREL ET AL: "Silicone-based thickness insensitive spectrally selective (TISS) paints as selective paint coatings for coloured solar absorbers (Part I)" SOLAR ENERGY MATERIALS AND SOLAR CELLS, ELSEVIER SCIENCE PUBLISHERS, AMSTERDAM, NL LNKD- DOI:10.1016/J.SOLMAT.2006.07.013, vol. 91, no. 2-3, 11 November 2006 (2006-11-11), pages 93-107, XP005760334 ISSN: 0927-0248 the whole document -----	4-6
Y	OREL ET AL: "Selective paint coatings for coloured solar absorbers: Polyurethane thickness insensitive spectrally selective (TISS) paints (Part II)" SOLAR ENERGY MATERIALS AND SOLAR CELLS, ELSEVIER SCIENCE PUBLISHERS, AMSTERDAM, NL LNKD- DOI:10.1016/J.SOLMAT.2006.07.012, vol. 91, no. 2-3, 11 November 2006 (2006-11-11), pages 108-119, XP005760335 ISSN: 0927-0248 the whole document -----	4-6
A	CRNJAK OREL Z: "Characterisation of high-temperature-resistant spectrally selective paints for solar absorbers" SOLAR ENERGY MATERIALS AND SOLAR CELLS, ELSEVIER SCIENCE PUBLISHERS, AMSTERDAM, NL LNKD- DOI:10.1016/S0927-0248(98)00181-0, vol. 57, no. 3, 1 March 1999 (1999-03-01), pages 291-301, XP004363841 ISSN: 0927-0248 the whole document -----	1-11
A	CRNJAK OREL Z C ET AL: "Spectrally selective paint coatings: Preparation and characterization" SOLAR ENERGY MATERIALS AND SOLAR CELLS, ELSEVIER SCIENCE PUBLISHERS, AMSTERDAM, NL LNKD- DOI:10.1016/S0927-0248(00)00367-6, vol. 68, no. 3-4, 1 June 2001 (2001-06-01) , pages 337-353, XP004230574 ISSN: 0927-0248 the whole document ----- -/--	1-11

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2010/057032

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CRNJAK OREL Z ET AL: "Spectrally selective solar absorbers in different non-black colours" SOLAR ENERGY MATERIALS AND SOLAR CELLS, ELSEVIER SCIENCE PUBLISHERS, AMSTERDAM, NL, vol. 85, no. 1, 1 January 2005 (2005-01-01), pages 41-50, XP025333174 ISSN: 0927-0248 [retrieved on 2005-01-01] the whole document -----	1-11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2010/057032

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-3(completely); 7-11(partially)

TSSS (thickness sensitive spectrally selective) coating on copper or aluminum having a composition as defined in claim 1 and a foil of copper or aluminum with said coating.

2. claims: 4-6(completely); 7-11(partially)

TISS (thickness insensitive spectrally selective) coating on copper or aluminum having a composition as defined in claim 4 and a foil of copper or aluminum with said coating.
