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(54) **Method and device for curing a coating**

(57) Method for curing a coating comprising the steps of:
- providing a substrate with an UV-curable coating, the coating being arranged to cure via free radical polymerization;
- irradiating said coating with low energy UV light;
- moving said substrate with respect to the light source, and;
- providing a substantially inert environment at least between the light source and the irradiated coating.

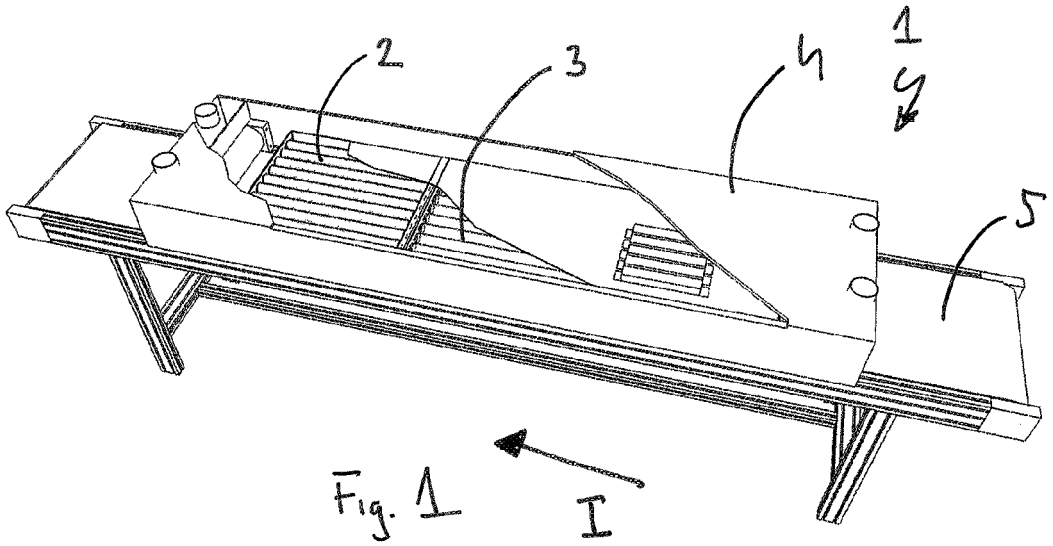

Fig. 1

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Description

[0001] The present invention relates to a method for curing a coating. The invention further relates to a device for curing a coating.

[0002] It is known to cure or harden materials such as coatings provided on a substrate using ultraviolet (UV) light. Such coatings are for instance used to apply coatings to substantially flat surfaces such as vinyl and wood flooring protective and decorative finishes and furniture finishes.

[0003] UV-curable coatings are solvent-free compositions that cure upon exposure to UV or electron beam source. Most available UV curable coatings are based on acrylate chemistry that cures via radical polymerisation. The coatings, before curing in liquid form, contain a mixture of reactive oligomer, one or more reactive monomers, an UV-light absorbing component, i.e. a photo initiator, and some more additives.

[0004] In the known method, a substrate provided with the UV-curable coating is exposed to high energy UV-light, such as a high pressure discharge lamp, with an output of approximately 160 W/cm to induce instant hardening of the coating in a fraction of a second. Since typical a photo initiator tends to react with oxygen in the environment, an overdose of photo initiator is used to ensure in proper polymerization of the coating. Further, the energy of the UV-light source is focused using lenses or mirrors to achieve this high energy exposure.

[0005] It is a drawback of this known method that the curing of the coating costs a lot of energy. Further, due to the fact that a high energy UV-source is used that generates heat, the light source needs to be cooled to ensure proper functioning.

[0006] It is therefore goal of the present invention, amongst other goals, to provide a more energy efficient method for curing a coating.

[0007] The above goal is met by the present invention, amongst other goals, by a method for curing a coating as defined in the appended claim 1.

[0008] Specifically, the above goal, amongst other goals, is met by the present invention by a method for curing a coating comprising the steps of:

- providing a substrate with an UV-curable coating, the coating being arranged to cure via free radical polymerization;
- irradiating said coating with low energy UV light;
- moving said substrate with respect to the light source, and;
- providing a substantially inert environment at least between the light source and the irradiated coating.

[0009] The method according to the invention allows the use of low energy UV light to cure a coating. Due to the fact that the irradiating takes place in a substantially inert environment, the problem of the photo initiator reacting with oxygen is reduced such that a low energy UV light can be used. The method thus allows curing coatings with less energy compared to traditional curing methods using for instance high discharge lamps for irradiating a material, for instance a coating.

[0010] Preferably the substrate provided with a coating facing towards the light source for irradiating the UV-light is moved through the inert environment. The light source can hereby remain stationary, while the substrate is moved, for instance using an endless belt.

[0011] According to a preferred embodiment, the step of irradiating comprises irradiating the coating with a power of between approximately 0,01 to 0,04 W/cm^2, preferably between approximately 0,02 to 0,03 W/cm^2 and more preferably with a power of approximately 0,025 W/cm^2. Preferably, the total dosage of UV-light is between 0,15 and 0,60 J/cm^2, more preferably between approximately 0,30 and 0,45 J/cm^2 and even more preferably the total dosage is approximately 0,375 J/cm^2. Preferably, the coating is irradiated during approximately 15 seconds.

[0012] According to a further preferred embodiment, the step of irradiating comprises irradiating the coating with at least one low pressure discharge lamp, preferably a low pressure mercury vapour lamp. Such lamps have a high efficiency and long life time. Further, such lamps do not require cooling as with the lamps used in conventional methods.

[0013] According to a further preferred embodiment, the step of irradiating comprises irradiating the coating with a plurality of UV-wavelengths, preferably UV-A and UV-C, more preferably with a wavelength of approximately 254 nm, respectively approximately 365 nm. Preferably, the coating is first irradiated with UV-C light and subsequently with UV-A light. This allows curing of the coating throughout the whole height of the coating.

[0014] According to a further preferred embodiment, the step of irradiating comprises irradiating the coating with UV-A with a power of between approximately 0,0067 and 0,0267 W/cm^2, preferably between approximately 0,013 and 0,020 W/cm^2 and more preferably with a power of approximately 0,0167 W/cm^2. The total dosage of the UV-A is preferably approximately between 0,075 and 0,3 J/cm^2, more preferably between approximately 0,15 and 0,225 J/cm^2 and more preferably approximately 0,1875 J/cm^2. This ensures proper curing of the parts of the coating extending towards the light source, i.e. the top layer of the coating.

[0015] According to a further preferred embodiment the step of irradiating comprises irradiating the coating with UV-

C with a power of between approximately 0,0033 and 0,0133 W/cm^2, preferably between approximately 0,067 and 0,01 W/cm^2 and more preferably with a power of approximately 0,083 W/cm^2. The total dosage of the UV-C is preferably approximately between 0,075 and 0,3 J/cm^2, more preferably between approximately 0,15 and 0,225 J/cm^2 and more preferably approximately 0,1875 J/cm^2. This ensures proper curing of the parts of the coating extending away the light source, i.e. the deeper parts of the coating.

[0016] According to a further preferred embodiment, the coating is irradiated along a length of said substrate, the length being between 0,5 and 4 meters, preferably between 1 and 2 meters and more preferably the length is approximately 1,5 meters, and wherein the step of moving the substrate comprises moving the substrate with a speed of 5 to 40 meter per minute, preferably between 10 to 20 meter per minute and more preferably with a speed of approximately 15 meter per minute. The processing speed is thus lower compared to conventional curing methods. However, due to the low power UV-light, the problem of heating associated with the high power UV-light sources is reduced.

[0017] According to a further preferred embodiment providing a substantially inert environment comprises providing a volume of an inert gas at least between the light source and the coating, the gas comprising at least one gas chosen from the group of nitrogen, carbon dioxide and helium. The space surrounding the substrate may be filled with an inert gas, most preferably nitrogen, using means known in the art. For instance, the method may be performed in an enclosed space, wherein a pump is arranged to supply the gas to the enclosed space. In case multiple light sources are used, each of the light sources and the coating to be irradiated extends in the volume of gas. It is however possible to use multiple volumes, each extending at least between the light sources and the coating.

[0018] According to a further preferred embodiment, the coating comprises a radical-type photo initiator of the hydrogen abstraction type, preferably at least one chosen from the group of benzophenon, αHydroxyketone, Phenylglyoxylate, Benzyldimethyl-ketal, α -Aminoketone, Mono-AcylPhosphine,Bi-Acyl-Phosphine.

[0019] According to a further preferred embodiment, the coating comprises at least one coating chosen from the group of Epoxy Acrylate, Urethane Acrylate,, Polyester Acrylate, Polyether Acrylate.

[0020] The invention further relates to a device for curing a coating comprising:

- moving means arranged for moving a substrate provided with a UV-curable coating;
- irradiating means arranged for irradiating the coating provided on the substrate with low energy UV light, and;
- environment control means arranged for providing an inert environment at least between the irradiating means and the moving means.

[0021] The moving means are arranged to hold and move the substrate with a coating with respect to the irradiating means. The irradiating means can thus remain stationary. According to a preferred embodiment, the irradiating means comprise at least one low pressure discharge lamp, preferably a low pressure mercury vapour lamp. The irradiating means irradiate the coating on the substrate while the substrate is moved. The environment means create a substantially inert environment at least in the space between the irradiating means and the moving means in the region where the coating is irradiated.

[0022] Preferably the lamp extends in the direction of movement of the moving means. A low pressure discharge lamp is normally tube shaped. By placing such a lamp with the longitudinal axis parallel to the direction of movement of the moving means, a larger area in the direction of movement is irradiated by the lamp.

[0023] A further preferred embodiment of the device comprises a plurality of lamps for irradiating the coating along a length on the moving means. This ensures that a proper dosage as described above is applied to the coating to allow proper curing.

[0024] Preferably at least one the lamps is arranged to irradiate UV-A and at least one of the lamps is arranged to irradiate UV-C, more preferably at least one lamps is arranged to irradiate light with a wavelength of approximately 254 nm and at least one lamp is arranged to irradiate light with a wavelength of approximately 365 nm. It may be possible to use a single lamp principally irradiating both wave lengths.

[0025] According to a further preferred embodiment, the moving means are arranged to move the substrate with a speed of 5 to 40 meter per minute, preferably between 10 to 20 meter per minute and more preferably with a speed of approximately 15 meter per minute with respect to the irradiating means.

[0026] The present invention is further illustrated by the following example and figures of a preferred embodiment of the method according to the invention, and is not intended to limit the scope of the invention in any way, wherein figures 1 and 2 show a preferred embodiment of the device according to the invention in perspective and cross sectional view, respectively.

[0027] Referring to figures 1 and 2, 10 UVA lamps 2 and 10 UVC lamps 3 are placed within a gas tight housing 4, longitudinal to the transportation direction of the coating indicated with I. The device 1 is provided with an endless belt 5 to move a substrate provided with a coating through the housing 4 in the moving direction I. The UVC lamps 3 have a length of 120 cm and a power of 55 Watt. The lamps are placed adjacent to each other to cover a width of 50 cm. The UVA lamps 2 have a length of 60 cm and a power of 60 Watt the lamps are also placed adjacent to each other to cover

a width of 50 cm.

[0028] The coating comprising of water based PUD dispersion, a Benzophenone based photo initiator and several additives for levelling, wetting and matting, is transported along the length of the lamps in a time frame of 15 seconds. Within housing 4, an inert environment is created using nitrogen gas coming from pressurized cylinders at a flow of 7 1/ min resulting in an oxygen concentration of <0,1%. To seal of the environment between the lamps 2 and 3 and the substrate, rollers 6 are provided.

[0029] With this method it is proven that the resulting coating can be cured to a high cross linking density.

[0030] Table 1 shows the energy density and energy dose of the low power UV source in comparison to 3 commercial available high intensity light sources. The values are measured using an EIT UV power puck, This device is measuring four wavelengths. UVA (320-390nm), UVB (280-320nm), UVC (250-260nm) and UVV (395-445nm). The unit measures intensity in W/cm^2 and total dose in J/cm^2.

Table 1

	UV A		**UV B**		**UV C**		**UV V**	
UV source	*W/cm²*	*J/cm²*	*W/cm²*	*J/cm²*	*W/cm²*	*J/cm²*	*(W/cm²)*	*(J/cm²)*
Low power UV	0,01	0,06	--	--	0,00 3	0,03	--	--
Metal halide arc lamp	1,16	0, 67	0,86	0,50	0,30	0,17	0,77	0,46
Mercury arc lamp	0,79	0,56	0, 61	0,41	0,18	0,12	0,31	0,25
Microwave powered	2, 64	1,78	0, 69	0,76	0,15	0,13	1, 17	1,33

[0031] The invention uses a large uniform source compared to the focussed light found in common exposure units. This is resulting in longer exposure times. Common units have a small light footprint resulting in radiation times of +/- 0,5 seconds. The invention uses long lamps with a large footprint, resulting in an exposure time of +/- 15 seconds.

Coating tests

[0032] Due to the high levels of IR radiation found in medium pressure arc lamps the substrate is heated during exposure. Due to the higher mobility at elevated temperatures the cross linking density of these systems is very much depending on line speed and pre heating times. The low power and large area of the invention results in little heating and a more constant level of cross linking. To compensate for the lower cross linking density one can heat the substrate or change the coating recipe by adding higher functional oligomers.

[0033] Table 2 shows the resistance of the coating against rubbing with a cloth drained with Methyl Ethyl Ketone. The lower cross linking values result in poorer rub resistance.

Table 2

MEK rub test		
Light source	UV dose	# of rubs
None	0	1
Low power UV	0,06	5
Low power UV	0,09	5
Low power UV	0,09	5
Low power UV	0,15	10
Low power UV	0,22	10
Low power UV	0,45	10
Microwave powered	1,24	10
Low power UV	0,30	20
Microwave powered	2,49	30
Microwave powered	3,73	30

(continued)

MEK rub test		
Light source	UV dose	# of rubs
Low power UV	0,30	40
Metal halide arc lamp	0,45	40
Low power UV	0,45	40
Mercury arc lamp	0,73	40
Metal halide arc lamp	0,89	40
Mercury arc lamp	1,09	50
Microwave powered	3,74	70
Microwave powered	0,75	100
Mercury arc lamp	1,09	100
Metal halide arc lamp	1,34	100
Mercury arc lamp	2,18	100

[0034] Table 3 shows the results of the pen test. The coating is marked with a permanent marker and after 5 minutes the mark is removed with MEK. This also confirms that the low density exposure results in a less densely cross linked but more flexible coating.

Table 3

Pen resistance test		
UV Source	UV dose	value
None	0	1
Low power UV	0,06	1
Low power UV	0,09	1
Low power UV	0,09	1
Low power UV	0,15	1
Low power UV	0,30	1
Low power UV	0,45	1
Microwave powered	1,24	1
Low power UV	0,03	2
Low power UV	0,45	2
Low power UV	0,22	3
Microwave powered	3,74	3
Metal halide arc lamp	0,45	4
Mercury arc lamp	0,73	5
Metal halide arc lamp	0,89	5
Mercury arc lamp	1,09	5
Mercury arc lamp	1,09	5
Metal halide arc lamp	1,34	5
Mercury arc lamp	2,18	5

[0035] The present invention is not limited to the embodiment shown, but extends also to other embodiments falling within the scope of the appended claims. It may for instance be possible to use different lengths for the low power lamps, provided that the dosage of the UV-light is suitable for curing the coating.

Claims

1. Method for curing a coating comprising the steps of:

   - providing a substrate with an UV-curable coating, the coating being arranged to cure via free radical polymerization;
   - irradiating said coating with low energy UV light;
   - moving said substrate with respect to the light source, and;
   - providing a substantially inert environment at least between the light source and the irradiated coating.

2. Method according to claim 1, wherein the step of irradiating comprises irradiating the coating with a power of between approximately 0,01 to 0,04 W/cm^2, preferably between approximately 0,02 to 0,03 W/cm^2 and more preferably with a power of approximately 0,025 W/cm^2.

3. Method according to claim 1 or 2, wherein the step of irradiating comprises irradiating the coating with at least one low pressure discharge lamp, preferably a low pressure mercury vapour lamp.

4. Method according to claim 1, 2 or 3, wherein the step of irradiating comprises irradiating the coating with a plurality of UV-wavelengths, preferably UV-A and UV-C, more preferably with a wavelength of approximately 254 nm, respectively approximately 365 nm.

5. Method according to any of the preceding claims 1 to 4, wherein the step of irradiating comprises irradiating the coating with UV-A with a power between approximately 0,0067 and 0,0267 W/cm^2, preferably between approximately 0,013 and 0,020 W/cm^2 and more preferably with a power of approximately 0,0167 W/cm^2, and/or irradiating the coating with UV-C with a power of between approximately 0,0033 and 0,0133 W/cm^2, preferably between approximately 0,067 and 0,01 W/cm^2 and more preferably with a power of approximately 0,083 W/cm^2.

6. Method according to any of the preceding claim 1 to 5, wherein the coating is irradiated along a length of said substrate, the length being between 0,5 and 4 meters, preferably between 1 and 2 meters and more preferably the length is approximately 1,5 meters, and wherein the step of moving the substrate comprises moving the substrate with a speed of 5 to 40 meter per minute, preferably between 10 to 20 meter per minute and more preferably with a speed of approximately 15 meter per minute.

7. Method according to any of the preceding claim 1 to 5, wherein providing a substantially inert environment comprises providing a volume of an inert gas at least between the light source and the coating, the gas comprising at least one gas chosen from the group of nitrogen, carbon dioxide and helium.

8. Method according to any of the preceding claim 1 to 6, wherein the coating comprises a radical-type photo initiator of the hydrogen abstraction type, preferably at least one chosen from the group of benzophenon, αHydroxyketone, Phenylglyoxylate, Benzyldimethyl-ketal, α -Aminoketone, Mono-Acyl-Phosphine,Bi-Acyl-Phosphine.

9. Method according to any of the preceding claim 1 to 7, wherein the coating comprises at least one coating chosen from the group of Epoxy Acrylate, Urethane Acrylate,, Polyester Acrylate, Polyether Acrylate.

10. Device for curing a coating comprising:

    - moving means arranged for moving a substrate provided with a UV-curable coating;
    - irradiating means arranged for irradiating the coating provided on the substrate with low energy UV light, and;
    - environment control means arranged for providing an inert environment at least between the irradiating means and the moving means.

11. Device according to claim 10, wherein the irradiating means comprise at least one low pressure discharge lamp, preferably a low pressure mercury vapour lamp.

12. Device according to claim 11, wherein the lamp extends in the direction of movement of the moving means.

13. Device according to claim 11 or 12, comprising a plurality of lamps for irradiating the coating along a length on the moving means.

14. Device according to claim 13, wherein at least one the lamps is arranged to irradiate UV-A and at least one of the lamps is arranged to irradiate UV-C, more preferably at least one lamps is arranged to irradiate light with a wavelength of approximately 254 nm and at least one lamp is arranged to irradiate light with a wavelength of approximately 365 nm.

15. Device according to any of the preceding claims 10 to 14, wherein the moving means are arranged to move the substrate with a speed of 5 to 40 meter per minute, preferably between 10 to 20 meter per minute and more preferably with a speed of approximately 15 meter per minute with respect to the irradiating means.

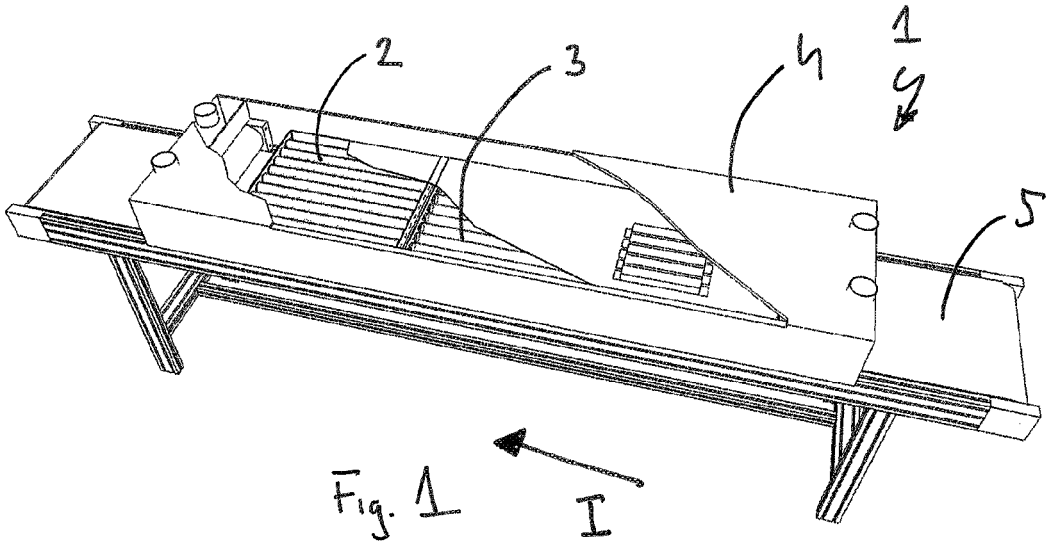

Fig. 1

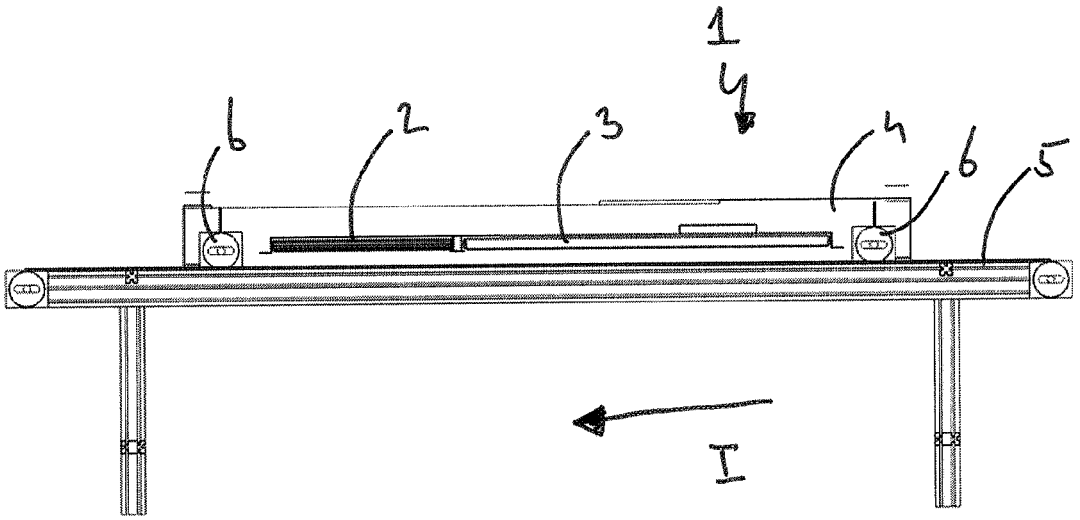

Fig. 2

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EUROPEAN SEARCH REPORT

Application Number
EP 10 15 9399

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	DE 10 2004 030674 A1 (BASF AG [DE]) 19 January 2006 (2006-01-19) * paragraphs [0065], [0068], [0071], [0083] - [0085], [0111], [0119], [0126], [0127]; claims 1,10 *	1,3, 6-13,15	INV. B05D3/04 B05D3/06
A	DE 10 2005 024362 A1 (BASF COATINGS AG [DE]) 30 November 2006 (2006-11-30) * paragraphs [0031], [0035], [0104], [0105]; claims 1-4; tables *	1,2,5,10	
X	US 3 918 393 A (HAHN ERNEST A) 11 November 1975 (1975-11-11) * example 3 *	1,10	
A	DE 23 55 657 A1 (MITSUBISHI RAYON CO) 16 May 1974 (1974-05-16) * example 3 *	1,10	

TECHNICAL FIELDS SEARCHED (IPC)

B05D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	18 August 2010	Slembrouck, Igor

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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EPO FORM 1503 03.82 (P04C01)

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Application Number
EP 10 15 9399

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☒ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☐ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

☐ The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).

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LACK OF UNITY OF INVENTION
SHEET B

Application Number
EP 10 15 9399

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 2, 5(completely); 1, 10(partially)

method and apparatus for curing a coating comprising the steps of:
-providing a substrate with a UV-curable coating;
-irradiating said coating with UV light;
-moving said substrate with respect to the light source, and;
-providing a substantially inert environment at least between the light source and the irradiated coating,
wherein in the step of irradiating the coating the power is specified

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2. claims: 3, 11-13(completely); 1, 10(partially)

method and apparatus for curing a coating comprising the steps of:
-providing a substrate with a UV-curable coating;
-irradiating said coating with UV light;
-moving said substrate with respect to the light source, and;
-providing a substantially inert environment at least between the light source and the irradiated coating,
wherein irradiating is made with a low pressure discharge lamp.

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3. claims: 4, 14(completely); 1, 10(partially)

method and apparatus for curing a coating comprising the steps of:
-providing a substrate with a UV-curable coating;
-irradiating said coating with UV light;
-moving said substrate with respect to the light source, and;
-providing a substantially inert environment at least between the light source and the irradiated coating,
wherein in the step of irradiating, wavelength domains are specified

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4. claims: 6, 15(completely); 1, 10(partially)

method and apparatus for curing a coating comprising the steps of:
-providing a substrate with a UV-curable coating;
-irradiating said coating with UV light;
-moving said substrate with respect to the light source, and;
-providing a substantially inert environment at least

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LACK OF UNITY OF INVENTION
SHEET B

Application Number
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The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

between the light source and the irradiated coating, wherein irradiating path length and line speed are specified.

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5. claims: 7(completely); 1, 10(partially)

method and apparatus for curing a coating comprising the steps of:
-providing a substrate with a UV-curable coating;
-irradiating said coating with lUV light;
-moving said substrate with respect to the light source, and;
-providing a substantially inert environment at least between the light source and the irradiated coating, wherein inert environement is provided by an inert gas

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6. claims: 8(completely); 1, 10(partially)

method and apparatus for curing a coating comprising the steps of:
-providing a substrate with a UV-curable coating;
-irradiating said coating with UV light;
-moving said substrate with respect to the light source, and;
-providing a substantially inert environment at least between the light source and the irradiated coating, wherein the coating comprises a specific photo-initiator.

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7. claims: 9(completely); 1, 10(partially)

method and apparatus for curing a coating comprising the steps of:
-providing a substrate with a UV-curable coating;
-irradiating said coating with UV light;
-moving said substrate with respect to the light source, and;
-providing a substantially inert environment at least between the light source and the irradiated coating, wherein the coating comprises a specific polymer.

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 10 15 9399

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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18-08-2010

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