Method and apparatus for capturing and carrying away the heat produced by an ultraviolet ray source

A hollow lenticular filter (D, D') of very pure quartz, within which a liquid which carries away the heat irradiated by the lamp, which has the property of high permeability to UV and which maintains this property over time, such as for example distilled or otherwise purified water, is circulated continuously and over the shortest route, is located between the source (L) emitting the UV rays and the substrate (S) being irradiated. A further filter (20) manufactured using an interferometry technique through vacuum plasma deposition of suitable materials in ultrathin layers on the external surface of the quartz filter may be provided on the said surface of the lenticular filter facing the substrate (S) being irradiated, it being provided that this additional filter has transparency characteristics which differ with the frequencies involved so as to be highly permeable to UV radiation and instead reflect towards the cooling liquid a considerable part of the residual infrared radiation which would otherwise escape from the said cooling liquid.
The invention relates to a method and corresponding apparatus for capturing and carrying away the heat produced by a source of ultraviolet rays which would otherwise strike the irradiated surface of the said source, without however reducing the operating temperature of that source and affecting its efficiency. The invention finds industrial application in association with mercury vapour discharge lamps intended for example for the processes of drying and catalysing UV printing pigments on very delicate surfaces such as for example surfaces of paper, wood, plastics materials or others which do not tolerate the high temperatures emitted by the said sources, where approximately 40% of their emitted power is in the infrared band. The known art teaches various solutions which are only partly effective in reducing the temperature irradiated by the said lamps. One solution provides for the use of reflectors with reflecting surfaces and dichroic properties which preferentially reflect the UV radiation and which instead absorb the infrared radiation. This solution substantially reduces the heat towards the printed surface, but makes it necessary to use expensive, bulky and noisy complex means for cooling the said reflectors in order to prevent them from becoming infrared radiation emitters with increasing temperature. Another known solution provides for positioning a strip of high purity quartz, which is therefore permeable to UV rays, between the lamps and the surfaces irradiated in order to form a chamber together with the walls of the lamp-holder and any of the abovementioned dichroic reflectors through which a flow of air is continuously circulated to carry away the excess heat produced by the lamps and prevent this from reaching the irradiated surface. This solution has the disadvantage however that it also cools the lamps and reduces their efficiency.

When UV lamps are of appreciable power, for example around 3-15 KW, the cooling air flows required for the abovementioned two solutions require the use of high-powered fans, which are particularly noisy, and which with their corresponding ducts also give rise to problems of space.

The invention is intended to overcome the limitations of the known art with the following concept for a solution. A hollow lenticular filter of very pure quartz, within which a liquid which carries away the heat irradiated by the lamp, which has the property of high permeability to UV and which does not change in that property over time, is placed between the lamp and the irradiated surface. According to a preferred embodiment the said cooling liquid comprises distilled water, and all the components of the circuit used for circulating and cooling of this liquid are of suitable materials which will not adversely affect the purity characteristics of that liquid.

Further features of the invention and the advantages deriving therefrom will be more apparent from the following description of a number of preferred embodiments illustrated purely by way of non-restrictive example in the figures in the appended plates of drawings, in which:

- Figure 1 illustrates a first embodiment of the filtering apparatus in question mounted on a UV lamp, in transverse cross-section,
- Figure 2 illustrates one side of the apparatus in Figure 1 in magnified form,
- Figure 3 is a plan view of apparatus in Figure 1,
- Figure 4 illustrates the diagram of the circuit for circulating and cooling the liquid which passes through the filter according to the invention,
- Figure 5 shows a perspective view of one extremity of the filter in accordance with one structural variant,
- Figure 6 illustrates other details of the extremity of the filter shown in Figure 5 in cross-section along the line VI-VI.

In Figure 1 L indicates the lamp emitting UV radiation and S indicates the substrate being irradiated by that lamp, which for example operates continuously in the direction of arrow F. In the example in Figure 1 support S is placed beneath lamp L but the relative positions of the two parts may be altered without thereby going beyond the scope of the invention (see below). R1 and R2 indicate reflectors which may have dichroic properties and P diagrammatically indicates the lamp-holder structure. According to the invention a filter D of small thickness formed of two parallel and preferably curved sheets 1 and 101 of very pure quartz, which in the example in question are located with the convex part in the direction of support S, which are of small thickness and are spaced a small distance apart, for example by means of spaces 2 which are also of quartz and are for example placed at intervals along the perimeter of the two sheets, is placed between lamp L and support S in such a way as to cover lamp L over its entire length. The straight and parallel sides of the filter formed by the said sheets 1-101 are placed within corresponding recesses 3,103 made with sufficient accuracy longitudinally in metal tubes 4,104 of appropriate diameter (see below) and which are only provided on those tubes over a distance equal to their length, as shown by the detail in Figure 3. Tubes 4, 104 have an internal diameter which is very much greater than the distance between sheets 1,101, in such a way as to act as conduits. If the distance between sheets 1,101 is between 2 and 8 mm, for example approximately 5 mm, the internal diameter of tubes 4, 104 will for example be approximately 20-22 mm. After the sides of filter 1-101 have been inserted in slots 3, 103 in tubes 4, 104, the ends of the said tubes which are not affected by the slots are inserted through corresponding holes 5,105 made in metal plates 6, 106 of suitable thickness, which abut against the said filter frontally in such a way as to close off its extremities, and these are attached to the said tubes by dowels 7, 107. The seal between sheets 1, 101 and tubes 4, 104 and between the sheets and front plates 6, 106 is provided by the external application.
of a suitable material, for example beads of any suitable sealing material, as indicated by 8, 108 and 9, 109. Plates 6, 106 and tubes 4, 104 provide an effective rigid frame to support filtering screen 1, 101 which is for example attached to lamp-holder structure P or any other suitable support by means of appropriate connectors 10 (Figure 1).

[0006] As illustrated in Figure 3, one extremity of one of the two tubes, for example 4, is attached through a connection 11, preferably of the universal type, with the delivery of a pump 12 (Figure 4) circulating a cooling liquid, while the other extremity of the tube is sealed with a cap 13. One extremity of the other tube, for example 104, is connected by means of a connection 111 which is also preferably of the universal type so as not to give rise to any mechanical stresses on the quartz screen to a discharge conduit 14, while the other extremity of the tube is sealed with a cap 113. The liquid which is caused to circulate within filter screen 1, 101 in order to remove the heat produced by lamp L preferably comprises distilled or condensed water, that is water free from impurities which might become coloured by the radiation emitted by lamp L and which would reduce the UV transparency of the cooling liquid. In order to avoid reactions between the distilled water and the surfaces of the circuit through which it passes, because this liquid is relatively acid, the circuit will be manufactured from suitable materials which will not create impurities. For this purpose tubes 4, 104, plates 6, 106 and all metal components in the circuit will for example be manufactured from stainless steel or other suitable material. Where possible suitable plastics material may be used instead.

[0007] Figure 4 shows that conduit 14 forms part of an annular conduit which ends at the inlet to pump 12 and on which are located in series cooling unit 15, for example of the radiator type with an electrically-powered fan and corresponding thermostat sensor, and provided with a tank 16 which may have a corresponding level sensor 116. Thermometric sensors 17, 117 which determine the temperature of the liquid before and after cooling by unit 15 are provided on the annular conduit and a pressure switch 18 which detects whether or not liquid is circulated through conduit 14 and through the filter is located immediately downstream from the filter in question. All the components of the circuit in Figure 4 are controlled by a processing unit 19 which provides the power supply to lamp L only if pressure switch 18 indicates that there is sufficient circulation of liquid in conduit 14. If this is not the case lamp L is kept off during the start-up stage, or is switched off during the operating stage, in order to avoid dangerous overheating.

[0008] In special cases, for example when lamp L operates at high power, a further filter indicated by 20 and shown by dashed lines in Figure 1, constructed using an interferometry technique through the plasma vacuum deposition of suitable materials onto the said sheet in ultrathin layers may be applied to the outer face of lower sheet 1, that facing printed substrate S. Filter 20 may have transparency properties which differ with the frequencies involved so that it is highly permeable to UV radiation and instead reflects towards the cooling liquid an appreciable part of the residual infrared radiation which would otherwise escape from the cooling liquid. The reduction in the intensity of UV emission due to the presence of interference filter 20 will be substantially similar to that resulting from an increase in the thickness of the intermediate cooling layer in filter D which would otherwise be necessary in order to achieve equivalent aims.

[0009] According to another structural variant of the apparatus illustrated in Figures 5 and 6, conduits 4, 104 may be made of one piece with sheets 1, 101, this assembly D' being produced by extrusion and hot forming as a single piece of very pure quartz having a cross-section substantially in the form of a figure of eight, with an elongated curved central part 1, 101 formed by parallel layers joined in a single piece to longitudinal conduits 201, 301. In this case closure of the extremity of filter D' may be effected through metal plates 6' joined together by means of tie rods 21 provided on the inside of recesses 22 in which the extremities of the quartz moulding D' are housed with intermediate seals 23 having a grooved profile which close upon themselves to form a ring. On the portions of at least one of plates 6' corresponding to conduits 201, 301 holes 24 are provided in which the fixed components of universal attachments 11, 111 connecting to the means circulating the cooling liquid are loosely screwed. Both in this arrangement and the previous one the quartz filter can always be replaced if damaged.

[0010] The filter according to the invention must also be understood to be protected if it is used in ways other than those illustrated in the drawings. If substrate S is mounted vertically the lamp with the filter may be placed on one side of the said substrate with the advantage that it will not damage it if there are any slight leaks or drips of cooling liquid. This advantage may also be achieved when the substrate is in a horizontal plane, by placing the lamp with the filter beneath the substrate. In this case the quartz filter D will have its concave curve orientated towards the substrate to prevent any small bubbles of gas accumulating in the intermediate part or, again for the same purpose, the filter may still have its convex surface directed towards the support but with an appropriate transverse inclination so that one of conduits 4, 104 or 201, 301 is at a higher level.

[0011] The advantages deriving from use of the filter as described can be summarised as follows: heat removal is effected within filter D or D', as a result of which the temperature in the area where lamp L is located is not affected by the cooling and can therefore be adjusted in such a way that the lamp operates under optimum conditions,

- the thermal absorption capacity of water is appreciably greater than that of air, as a result of which the throughput and power of the cooling liquid circulation system is appreciably less than that of existing air-
cooled systems,
- the use of very thin quartz sheets 1, 101 and the minimum space between these sheets makes it possible to form a diaphragm which is almost wholly permeable to ultraviolet radiation and which does not affect its physical properties,
- the movement of the cooling liquid is continuous, there are no preferential routes and it does not give rise to the formation or trapping of air bubbles in the quartz filter, in that the curved shape of sheets 1, 101 and the raised position of lateral conduits 4, 104 or 201, 301 with respect to these has the result that any bubbles of air delivered from a conduit flow to the upper conduit through buoyancy without remaining between the parallel sheets,
- by varying the curvature of sheets 1, 101 the filter can be used as a lens, optimising the transmission optics and focusing the UV radiation on substrate S,
- the cooling liquid circulates through the filter in a transverse direction and therefore via the shortest route. This condition means that there is less overheating of the cooling liquid, avoiding boiling phenomena and the formation of bubbles of vapour, even in a circuit which is not pressurised. The mechanical strength of the thin quartz filter will not be subjected to dangerous stresses, as all the cooling liquid circulating system is at low pressure. Phenomena of the explosive type will thus be avoided and if any cracking occurs only drips will be produced which can be controlled as mentioned previously and/or by providing means for collecting and removing any losses of liquid at the extremities of the filter, which are the most critical areas,
- by varying the flow of cooling liquid it is possible to control the temperature of the filter and the rate of transfer to the printed substrate in order to obtain the required level of UV radiation on that substrate,
- the use of distilled water in a closed circuit manufactured of materials compatible with that type of liquid avoids the formation of photosynthesis products in that liquid whose presence would reduce the transparency of the filter to UV radiation,
- the presence of calibrated pressure switch 18 in the return circuit to radiator 15 will only allow the UV lamp to be lit when cooling liquid is circulating and will act as an alarm if there is a pressure drop due to the loss of water from the filter and/or other parts of the circuit.

Claims

1. Method for capturing and carrying away the heat produced by a source of ultraviolet rays, characterised in that the hollow lenticular filter (D, D') of very pure quartz, within which a liquid which carries away the heat radiated by the lamp, which has the property of permeability to UV and which maintains these properties over time, is caused to circulate continuously, is located in relation to that source (L) between it and the surface (S) being irradiated.

2. Method according to Claim 1), in which the cooling liquid comprises distilled or otherwise purified water.

3. Method according to Claim 1) in which, particularly when the UV source (L) is working at high power, a further filter (20) manufactured using an interferometry technique through plasma vacuum deposition of appropriate materials onto the said face of the quartz filter in ultrathin layers is provided on the outer surface of the lenticular filter facing the surface (S) being irradiated, it being provided that this additional filter (20) has transparency properties which differ with the frequencies involved so that it is highly permeable to UV radiation and instead reflects the cooling liquid an appreciable part of the residual infrared radiation which would otherwise escape from the cooling liquid.

4. Apparatus for capturing and carrying away the heat produced by a source (L) of ultraviolet rays, especially by implementing the method in one or more of the preceding claims, characterised in that it comprises in association with the said source (L), between it and the surface (S) being irradiated, a hollow lenticular filter (D, D') of very pure quartz within which a liquid which carries away the heat radiated by the lamp, which has the property of being highly permeable to UV and which maintains this property over time, such as for example distilled or otherwise purified water, is caused to circulate within it continuously and over the shortest route.

5. Apparatus according to Claim 4), in which the said lenticular filter (D) is formed from two parallel sheets (1, 101) of very pure quartz, of small thickness and held a short distance apart, for example by means of spacers (2) which are also of quartz and which are placed at intervals for example on the perimeter of the said sheets, the longer straight and parallel sides of the said pair of sheets (1, 101) abutting corresponding recesses (3, 103) provided longitudinally in metal tubes (4, 104) of suitable diameter provided in the tubes only over a distance equal to their own length, the extremities of the said tubes which are not affected by the said slots being inserted into corresponding holes (5, 105) made in metal plates (6, 106) of suitable thickness, which are abutted frontally against the sheets of the filter in such a way as to close off the latter at the extremities and which are secured to the said tubes by means of dowels (7, 107), the seal between the said sheets (1, 101) of the filter and the said tubes (4, 104) and between the sheets and the said frontal plates (6, 106) being provided through the preferably external application
of a suitable material, for example beads of any suitable sealing material (8, 108, 9, 109).

6. Apparatus according to Claim 5), in which the said end plates (6, 106) with the tubes (4, 104) form an effective rigid frame supporting the quartz filter screen (1, 101), which are for example secured to a supporting structure by means of suitable connectors (10).

7. Apparatus according to Claim 5), in which the said tubes (4, 104) have an internal diameter which is very much greater than the distance between the sheets (1, 101) of the quartz filter (D), in order to act as conduits.

8. Apparatus according to Claim 7), in which if the distance between the sheets (1, 101) of the quartz filter (D) is between 2 and 8 mm and is for example approximately 5 mm the internal diameter of the said tubes (4, 104) will be for example approximately 20-22 mm.

9. Apparatus according to Claim 5), in which one extremity of one (4) of the said tubes will be connected through a connection (11) preferably of the universal type with the outlet of the pump (12) continuously circulating the cooling liquid, while the other extremity of the said tube will be sealed with a cap (13), one extremity of the other tube (104) being connected by means of a connection (111), which is also preferably of the universal type so as not to induce any mechanical stresses on the quartz screen, to a discharge conduit (14), while the other extremity of the said tube is closed off by a cap (113), it being provided that the said conduit (14) forms part of an annular conduit which ends at the intake of the said pump (12) and that a cooling unit (15) for example of the radiator type with an electric fan and a corresponding thermostat sensor is located on the annular conduit downstream of the filter, and that downstream of this unit there is a tank (16) with cooling liquid which may have a corresponding level sensor (116), thermometric sensors (17, 117) being provided on the said annular conduit to detect the temperature of the liquid before and after cooling by that unit (15) and with for example a pressure switch (18) which detects whether or not liquid is circulating in the annular conduit (14) and through the said filter is provided for example immediately downstream of the filter in question, all the components of the circuit being controlled by a processing unit (19) which provides the power supply to the pump (L) only and if the said pressure switch (18) indicates that liquid is circulating in the conduit (14).

10. Apparatus according to Claim 9), in which circulation of cooling liquid through the quartz filter (D) is effected at low pressure so as not to prejudice the integrity of that filter.

11. Apparatus according to Claim 9), characterised in that in order to avoid reactions between the distilled water cooling the filter (D) and the surfaces of the circuit through which it passes the circuit is constructed of suitable materials which will not create photosensitive impurities, the said tubes (4, 104) and the said head plates (6, 106) and all the metal components of the circuit being for this purpose constructed of for example stainless steel or another suitable material.

12. Apparatus according to Claim 4) and according to one or more of the preceding claims, characterised in that the said lenticular filter (D') is obtained by extrusion and hot forming in such a way as to form a single piece of very pure quartz having a cross-section substantially in the shape of a figure of eight with the elongated curved central part (1, 101) formed of parallel layers joined together in a single piece with the longitudinal and lateral conduits (201, 301) in this case also of quartz, the closure at the extremities of such a filter (D') being provided by plates (6') of for example stainless steel joined together by means of tie rods (21) and provided on their inner faces with recessed seats (22) in which the extremities of the said quartz moulding (D') are housed with intermediate seals (23) having an appropriate profile which are closed upon themselves forming a ring, holes (24) being provided on the portions of at least one of the said plates (6') corresponding to the conduits (201, 301) in which the fixed components of the attachments preferably of the universal type (11, 111) providing connection to the means for circulation of the cooling liquid are screwed with a lateral seal.

13. Apparatus according to any one or more of the preceding claims characterised in that the parallel sheets (1, 101) of the quartz filter (D, D') are curved and have their convex face towards the underlying substrate (S) being irradiated, so that any air bubbles delivered by a conduit (4, 104 or 201, 301) flow to the other collector through buoyancy without accumulating in the intermediate part of the filter between the said parallel sheets (1, 101).

14. Apparatus according to Claim 13), in which the curvature of the sheets (1, 101) forming the quartz filter (D, D') can be selected in such a way as to optimise the transmission optics and focussing of the UV radiation on the substrate (S) being irradiated.

15. Apparatus according to any one or more of the preceding claims, characterised in that it may be used in any arrangement with respect to the substrate (S)
being irradiated, for example including alongside that substrate if this is mounted vertically or substantially so, or beneath the said substrate (S), in which case the quartz filter (D, D’) will have its concave surface facing the said support, or if still the convex surface then in that case with appropriate transverse inclination so that one of the lateral conduits (4, 104, 201, 301) is at a higher level, this again with the object of preventing bubbles of air or other gas remaining in the filter.

16. Apparatus according to any one or more of the preceeding claims, characterised in that it comprises possible means for varying the throughput of cooling liquid through the quartz filter (D, D’) to regulate the operating temperature of that filter and comprising possible means for regulating the rate of transit of the printed substrate (S) in order to obtain the required level of UV radiation on that substrate.
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The present search report has been drawn up for all claims.

Place of search: Munich
Date of completion of the search: 1 August 2006
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