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(54) HIGH RESOLUTION LASER PATTERN DEFINING APPARATUS

(71) We, R C A CORPORATION, (formerly RADIO CORPORATION OF AMERICA), a corporation organised under the laws of the State of Delaware, United States of America, of 30 Rockefeller Plaza, City and State of New York, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to high resolution laser pattern defining apparatus and, more particularly, to such apparatus for defining very fine patterns on a member by means of a laser beam.

The use of focused coherent light from a laser for "drilling" small holes in a solid material member is known in the art. In this process a pulse of coherent light from a high power Q-switched laser is focused by a lens system on a point of the member. Depending upon the intensity and time duration of the pulse produced by the laser, the diameter of a hole "drilled" by this process is ten microns or more. Further, the depth of the hole produced by this process is quite deep. Microscopic examination of a hole "drilled" by this process shows that the evaporation of the material to form the hole occurs in cataclysmic fashion, the inside surface of the hole being composed of re-solidified molten material. This causes the hole to have a crater-like appearance. From the foregoing, it is clear that the process of "drilling" a hole with focused coherent light from a laser is an essentially disorderly process.

Since "drilling" the hole by means of a laser is an essentially disorderly process, it was assumed in the prior art that it was not possible to produce high resolution engravings of very fine patterns on a normally solid member by evaporating material from

the member in an orderly fashion by means of coherent light from a laser.

An object of the present invention is to provide a high resolution pattern defining apparatus utilizing coherent light from a laser.

According to one aspect of the present invention there is provided a process for producing a high resolution pattern on a member having a surface area on which a predetermined pattern is to be defined, which member has a property which is alterable in accordance with the amount of heat which it absorbs, the process including momentarily illuminating said area with a pulse of coherent laser light having a cross-section equal to said area, the relative intensity of the light varying from point to point over its cross-section in accordance with the predetermined pattern, so that the light pulse differentially heats said area in accordance with the relative intensity of the light impinging on each respective point of said area, the intensity and time duration of the light being sufficient to alter selectively the surface to thereby define the pattern on the member, the intensity and time duration of the light being insufficient to permit significant heat transfer between adjacent points of the pattern.

According to another aspect of the present invention there is provided a high resolution pattern defining apparatus for performing the above process, including a laser and lens means through which a pulse of coherent light emitted by the laser is passed in combination with a member having a property which is alterable in accordance with the amount of heat which it absorbs, a surface of the member being arranged to be illuminated by the coherent light, intensity varying means in the path of said light for projection of a predetermined pattern onto said surface and means for adjusting the time duration and intensity of the laser pulse

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to alter selectively the surface of the member, the intensity and time duration being insufficient to permit heat transfer between adjacent points of the pattern and the pulse of coherent light having a cross-section equal to the area, which light varies in relative intensity from point to point over its cross-section in accordance with the predetermined pattern to define the pattern on the surface.

The present invention will now be described by way of examples with reference to the accompanying drawing in which:

FIGURE 1 is a block diagram of a first embodiment of the present invention; and

FIGURE 2 is a block diagram of a second embodiment of the present invention.

Referring now to FIGURE 1, there is shown a pulsed laser 100 which during each pulse thereof produces beam 102 of coherent light. Beam 102 is widened into beam 104 by means of lenses 106 and 108. Beam 104 is shone through a transparency 110 which incorporates the predetermined pattern to be engraved. Transparency 110, by differential absorption of the light from point to point in accordance with the predetermined pattern thereon, causes the relative intensity of the coherent light in beam 112 emerging from the transparency 110 to vary from point to point in accordance with the predetermined pattern. Thus, the intensity of beam 112 over its cross-section is effectively spatially modulated in accordance with the information in the predetermined pattern.

Beam 112 is narrowed by means of lenses 114 and 116 into a beam 118. Beam 118 is then projected on a given surface area of member 120 which is to be engraved.

It has been found that if the duration of the coherent light pulse from pulsed laser 100 has a sufficiently short time duration (which depends upon the particular material of which member 120 is composed, but which preferably does not exceed 100 nanoseconds) and the intensity of the coherent light produced by pulsed laser 100 is properly selected, it is possible to obtain an engraving on member 120 having an area of several square millimeters while details of the order of two microns in the engraved pattern can be resolved. Further, the maximum depth of evaporation is also of the order of two microns.

Member 120 may be composed of a metal, such as copper, for instance, or a semiconductor, such as silicon, for instance.

In one case an engraving of a pattern having dimensions 2.4×0.8 mm., and having a resolution of the order of two microns was produced on a copper member utilizing a laser pulse having two joules of energy in its duration of 30 nanoseconds. In general, the impinging flux can be between 10^9

and 10^{10} watts per square cm. to produce good results.

Although in FIGURE 1 a transparency 110 is utilized to modulate the cross-section of the coherent light with information of the pattern to be engraved, it is clear that spatial modulation of the relative intensity of the beam from point to point may be obtained by variable reflection or scattering of light, rather than by variable absorption from point to point, as is the case with transparency 110.

Referring now to FIGURE 2, there is shown an apparatus for engraving a hologram of a scene shown in a transparency. The hologram and the method of forming the hologram pattern are both described and claimed in our co-pending patent appl. No. 49218/70 Serial No. 1,236,225.

More particularly, as shown in FIGURE 2, pulsed laser 200 produces beam 202 of coherent light, which is split into first component beam 204 and second component beam 206 by quartz wedge beam splitter 208. Beam 204 is reflected from mirror 210 to form reference beam 212 which is directed to a given area of member 214 to be engraved. Beam 206 is reflected from mirror 216 and after being widened by diverging lens 218 is spatially modulated by the pattern incorporated in transparency 220. After being spatially modulated, the beam of light emerging from transparency 220 is narrowed by convex lens 222 and projected as information beam 224 on the same given area of member 214 on which reference beam 212 is projected.

Information beam 224 and reference beam 212 will produce an interference pattern on the given area of member 214. This interference pattern forms a hologram made up of light and dark fringe lines spaced from each other by an amount of the order of two microns. It will be seen that this interference pattern will be engraved on member 214 in the same manner as the pattern projected on member 120, as described above. Thus, the present invention may be utilized to engrave hologram patterns, as well as pictorial patterns. The hologram also may be of a three dimensional object rather than a transparency, as is known in the hologram art.

By making member 214 out of a magnetic material, the pattern may be "defined" in magnetic form. For instance, if the member in either FIGURE 1 or FIGURE 2 is a thin film of already magnetized magnetic material, either in pure form or suspended in a binder, and the intensity of the pulsed laser is insufficient to cause evaporation of the material, but sufficient to cause relative loss of magnetization of the material from point to point by heating in accordance with the relative intensity of the light reaching

that point, a nondestructive magnetic pattern may be obtained.

If the intensity of the laser is sufficient to cause a partial loss of material according to the relative intensity of the coherent light reaching the thin film of magnetic material, it will result in the predetermined pattern not only being visibly engraved in the material, but, by magnetizing the material either before or after the application of the pulse of coherent light, will result in a magnetic field which is altered in accordance with the thickness of the thin film and, therefore, manifests in magnetic form the engraved pattern.

WHAT WE CLAIM IS:—

1. A process for producing a high resolution pattern on a member having a surface area on which a predetermined pattern is to be defined, which member has a property which is alterable in accordance with the amount of heat which it absorbs, the process including momentarily illuminating said area with a pulse of coherent laser light having a cross-section equal to said area, the relative intensity of the light varying from point to point over its cross-section in accordance with the predetermined pattern, so that the light pulse differentially heats said area in accordance with the relative intensity of the light impinging on each respective point of said area, the intensity and time duration of the light being sufficient to alter selectively the surface to thereby define the pattern on the member, the intensity and time duration of the light being insufficient to permit significant heat transfer between adjacent points of the pattern.

2. A process as claimed in claim 1, wherein the duration of illumination does not exceed one hundred nano-seconds.

3. A process as claimed in claim 1 or 2 for producing a high resolution pattern on a vaporizable solid material wherein the intensity of light is preset to vaporize selected portions of said solid material within said time duration, to form a relief pattern on said area.

4. A process as claimed in claim 3, wherein the relative intensity of light is preset to control the amount of solid material vaporized and therefore the depth of pattern.

5. A process as claimed in any one of claims 1 to 4 wherein said pattern includes details spaced from each other by no more than two microns.

6. A process for producing a high resolution pattern on a normally solid member substantially as herein described with reference to Figure 1 of the accompanying drawing.

7. A high resolution pattern defining apparatus for performing the process as claimed in any one of claims 1 to 6, including a laser and lens means through which a pulse of coherent light emitted by the laser is passed in combination with a member having a property which is alterable in accordance with the amount of heat which it absorbs, a surface of the member being arranged to be illuminated by the coherent light, intensity varying means in the path of said light for projection of a predetermined pattern onto said surface and means for adjusting the time duration and intensity of the laser pulse to alter selectively the surface of the member, the intensity and time duration being insufficient to permit heat transfer between adjacent points of the pattern and the pulse of coherent light having a cross-section equal to the area, which light varies in relative intensity from point to point over its cross-section in accordance with the predetermined pattern to define the pattern on the surface.

8. An apparatus as claimed in claim 7, wherein the laser produces a beam of coherent light having a duration not exceeding one hundred nanoseconds.

9. An apparatus as claimed in claim 7 or 8, wherein the intensity-varying means comprises a transparency containing the pattern through which the beam is shone.

10. A high resolution pattern defining apparatus substantially as herein described with reference to, and as illustrated in Figure 1 of the accompanying drawing.

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