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(54) Title: APPARATUS AND METHOD FOR NON-CONTACT SENSING OF TRANSPARENT ARTICLES

(57) Abstract: A laser-based displacement detector 26 is used to detect cosmetic coatings 22 applied to one surface of the transparent article 20 and thereby determine which side is uppermost when loaded into the laser processing system. In particular, articles 20 that are transparent to visible light and are particularly difficult to orient properly in laser processing systems are oriented using a laser-based displacement detector 26 in conjunction with a partial coating 22 on the article 20.

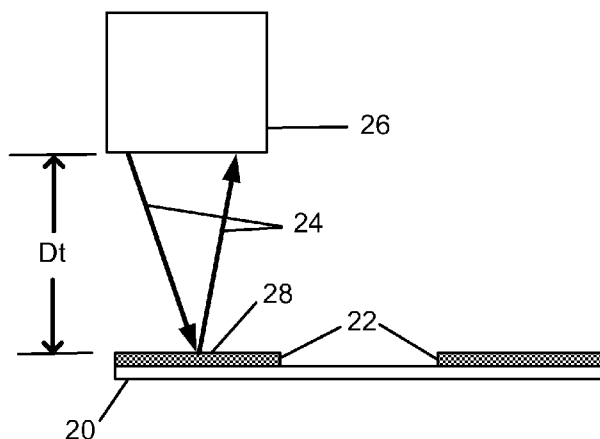


Fig 2a





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APPARATUS AND METHOD FOR NON-CONTACT SENSING OF TRANSPARENT ARTICLES

Technical Field

[0001] The present invention relates to methods and apparatus for non-contact sensing of articles with laser-based displacement sensors, in particular non-contact sensing of articles generally transparent to the laser wavelengths employed by the non-contact laser sensor. In more particular it relates to methods of determining the orientation of articles generally transparent to laser wavelengths by coating one surface of the article with material opaque to the wavelength of laser radiation used.

Background

[0002] As laser processing becomes more capable and economical, more and more parts are being machined using laser processing rather than mechanical, chemical or electrical processing. One particular type of material that is adapting favorably to laser processing is glass and glass-like materials. Processing of glass or glass-like articles using a laser are discussed in two co-pending applications assigned to the assignee of this application, namely US Patent application 12/336,609 METHOD FOR LASER PROCESSING GLASS WITH A CHAMFERED EDGE and 61/164,162 GLASS MACHINING WITH PRECISELY TIMED LASER PULSES, both of which are included by reference.

[0003] During machining of glass articles, it's necessary to make sure that the correct side of the part to be machined is presented to the processing head. This is important since the machining operations are typically not symmetric with respect to the top and bottom of the article, therefore the article must be correctly oriented in order to be properly machined. This may not be trivial if the part in question has two or more sides that look sufficiently similar to make visual identification of the correct processing side difficult. An example is an essentially flat "sheet like" part

that can be placed with either side up into the system. Typically, part manufacturers will try to ensure that there is no ambiguity as to which side of a part is the "processing side" by either marking this side with a unique identifier (such as a label, bar-code, etc.) which can be verified either by an operator or an automated machine vision system, or by drilling into the part fixturing holes that make it impossible to place the part in the processing area in any orientation other than the correct one.

[0004] Some articles, however, do not lend themselves to being oriented in this fashion. Marking or labeling the parts adds time and expense to the manufacturing process. Some articles do not lend themselves to adding part fixturing holes or features since they would detract from the finished product. A method of identifying which side of the part is uppermost is useful to prevent the article from being loaded improperly. In the case where the machine is loaded automatically without human intervention, a method of identifying the orientation of loaded articles can prevent the machine from processing the article on the wrong side.

[0005] There is therefore an ongoing need for a method and apparatus for identifying the orientation of a transparent article loaded into a laser processing machine.

Summary of the Invention

[0006] An aspect of the instant invention relies upon the presence of an opaque coating applied to a portion of the transparent article for cosmetic purposes. This opaque coating one side of the article is detected and used to provide information regarding the orientation of the article. A conventional laser-based displacement detector is used to detect the opaque material on the transparent article to determine which side is uppermost in the machine. If the correct side is uppermost, processing proceeds. If it is determined that the incorrect side is uppermost, the article can be re-oriented automatically if the machine has that capability, or an operator can be alerted to re-orient the part. The applied opaque coating may

remain after the machining operation if it is designed to be a cosmetic addition to the article or it may be removed following machining.

Brief Description of the Drawings

[0007] Fig 1. A sample part.

[0008] Fig 2a. A sample part oriented paint side up.

[0009] Fig 2b. A sample part oriented paint side down.

Detailed Description of Preferred Embodiments

[0010] Embodiments of this invention represent an improved method for processing a transparent article with a laser processing system having a controller. The invention includes applying a coating to one side of the transparent article and providing the laser processing system with a laser range measuring device. The embodiment then measures the location of the transparent article with the laser range measuring device by detecting the coating and communicating the location of the coating to the controller. The controller examines the reported location and decides whether or not to process said transparent article depending upon said location communicated to said controller.

[0011] This invention refers to establishing the correct processing side of a transparent article for machining purposes. Transparency in this case is defined principally as visual transparency to a human observer, however transparency with respect to the laser processing or measuring beam is also possible. An exemplary laser processing system for processing articles as described herein is the ESI Model

MM5900 micro-machining system, manufactured by Electro Scientific Industries, Inc, Portland, OR. In a particular case, the material is clear glass, and the article is an essentially flat sheet with a band of black paint at the perimeter as shown in Fig 1. Fig 1 shows an article 10 with a coating 12 applied to the top surface of the article. Also in this case, it is important that the orientation is known since the machining operation is not symmetric with respect to the top and bottom surfaces of the article. In this embodiment a laser displacement sensor is used to detect the location of the article. An exemplary laser displacement sensor is the Acuity AR200 series sensor from Schmitt Industries, Portland, Oregon 97210. Principles of operation of laser displacement sensors are well known and will not be discussed herein.

[0012] This sensor is selected so that the material to be located is transparent to the laser wavelength used. The coating applied to the article is selected to be opaque or at least partially reflective to the laser wavelength used. The laser sensor is directed to the article from a position above the article and perpendicular to the surface to be measured. The distance from the sensor to the article is measured and compared to predetermined distances stored in the controller of the laser processing system. By comparing the measured location of the reflective surface of the article, it can be determined whether the part has been inserted into the laser processing system right side up or upside down.

[0013] Fig 2a shows an article 20, loaded into a laser processing system (not shown) right side up with a coating 22 which is at least partially reflective to the laser radiation 24 emitted by the sensor 26, reflected off the top surface of the coating 28 and received by the sensor 26. This yields a value of D_t for the displacement of the article 20 from the sensor 26. Fig 2b shows an article 30 loaded into a laser processing system (not shown) upside down with a coating 32 at least partially reflective to laser radiation 34 emitted by sensor 36, reflected off the bottom surface of the coating 38 and received by the sensor 36. This yields a measured displacement value of D_b . Since D_b is not approximately equal to the nominal value of D_t , the right side up measurement, the system concludes that the

article has been inserted improperly. At this point the system can direct material handling elements of the system to turn the article over, if the embodiment of the invention is so equipped, or alert the operator that a part has been improperly inserted or simply stop.

[0014] In order to accomplish this, the laser sensor should be mounted in a position where it can report valid and repeatable locations for the measured part. This requires that the sensor be mounted in a known location so that the location can be reliably measured and communicated to the laser processing system controller. The sensor should be mounted so that the laser beam intersects the article as close to perpendicular as possible. The sensor should be mounted so that the laser beam will reflect off the coated portions of the article. In embodiments which have material handling elements, the article can be positioned by the material handling elements under the direction of the controller to direct the laser beam emitted by the laser sensor to impinge upon the coated portions of the article.

Coatings used by embodiments of this invention include paints, epoxies or powders that can be made to adhere to the glass or glass-like materials which comprise the articles to be laser machined. This adherence can be temporary, where the coating will be removed following machining, or permanent, where the coating forms a part of the cosmetic finish of the article. The coating can also be in the form of a film to be adhered to the article for the purpose of machining and removed following. This film could be made of plastic or paper for example. All of these embodiments are capable of adhering to an article made of glass or glass-like material and can reflect or partially reflect laser light at a wavelength to which the material is transparent or semi-transparent.

[0015] Determination of the orientation of the article depends upon a priori information programmed into the controller of the laser processing system. One manner of determining this is to insert an article correctly into the laser processing system and instruct the system to measure the article and store the results in the controller. An article which is subsequently incorrectly inserted into the system and measured will yield a measurement which differs from the stored value by the

thickness of the transparent article. Once this data is acquired, the part orientation may be identified by comparing the acquired data with stored data with appropriate tolerances due to measurement error. For example, if the measured distance to the part inserted topside up is D_t and the measured distance to the part inserted bottom side up is D_b , then a dual measurement threshold T_d may be set

$$T_d = (D_t + D_b)/2$$

Measurement less than or equal to T_d indicate the part is correctly inserted. If, on the other hand, the perceived thickness, which is equal to t/n , where t is the thickness of the part and n the index or refraction of the material with respect to the laser wavelength is known, a single measurement threshold T_s may be calculated

$$T_s = D_t + t/2n$$

Where a measurement less than T_s indicates the article is correctly inserted.

[0016] More elaborate algorithms can use the part distance measurements utilizing a sensor of the type described in this disclosure while still remaining within the scope of the approach outlined here. For this reason we request that the scope of this invention be determined solely by the following claims:

We claim:

1. An improved method for processing a visually transparent article with a laser processing system having a controller comprising:
 - applying a coating to one side of said transparent article;
 - providing said laser processing system with a laser range measuring device;
 - measuring the location of said transparent article with said laser range measuring device by detecting said coating and communicating said location to said controller; and
 - deciding whether or not to process said transparent article depending upon said location communicated to said controller.
2. The method of claim 1 wherein said laser range measuring device operates at a wavelength in the visible range.
3. The method of claim 1 wherein said laser processing system is a laser machining system.
4. The method of claim 1 wherein said transparent article is glass.

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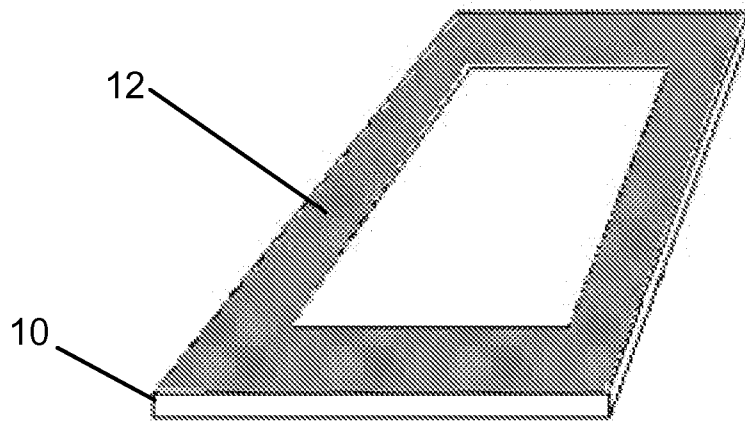


Fig 1

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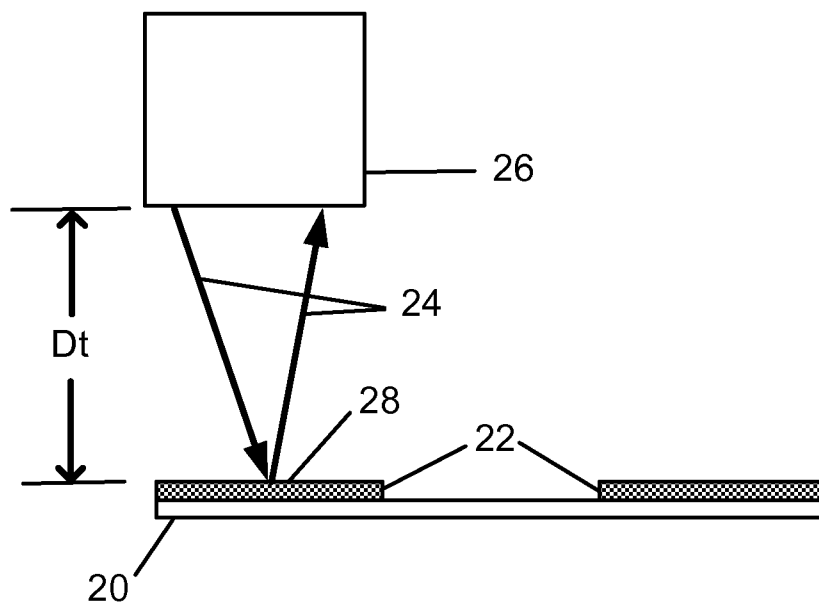


Fig 2a

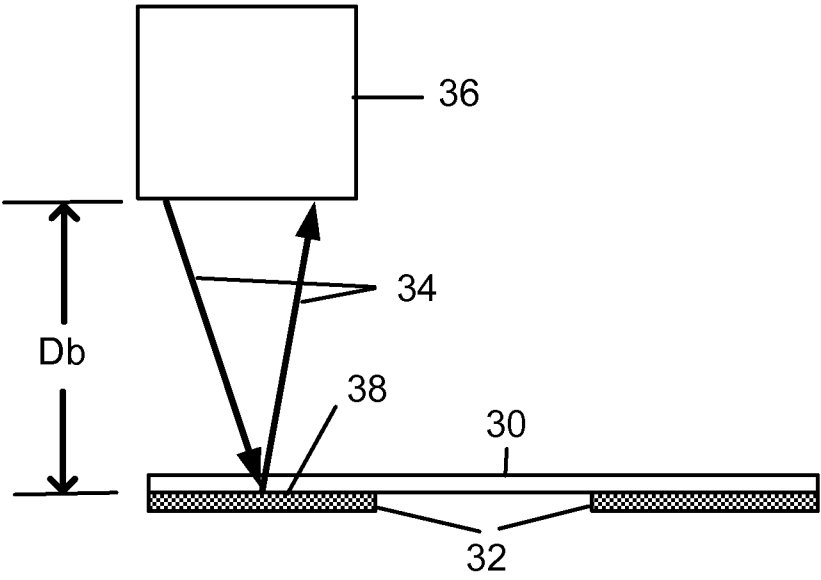


Fig 2b