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(19) **United States**(12) **Patent Application Publication****Campbell et al.**(10) **Pub. No.: US 2004/0255805 A1**(43) **Pub. Date: Dec. 23, 2004**(54) **METHOD OF MANUFACTURING A PRINTING SUBSTRATE**

(57)

**ABSTRACT**(76) Inventors: **Jeffrey G. Campbell**, Rutland, VT (US); **Leo Beiser**, Flushing, NY (US)

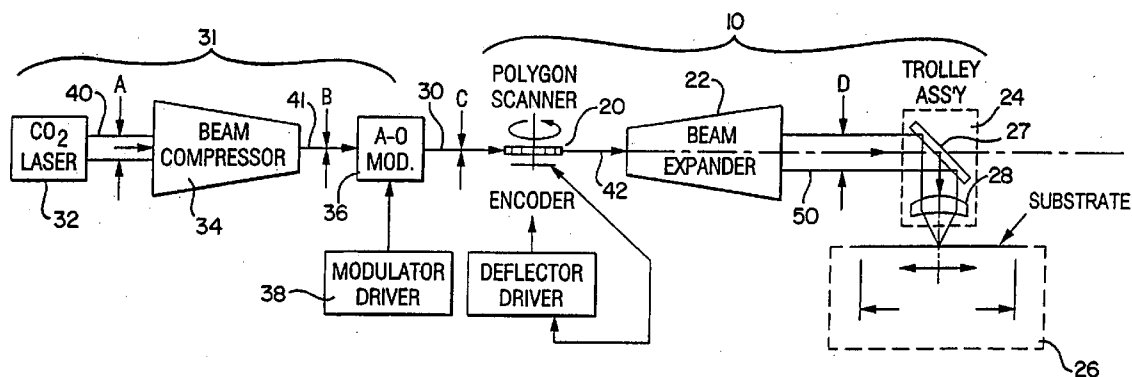
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(60) Division of application No. 10/842,680, filed on May 10, 2004, which is a continuation-in-part of application No. 10/159,492, filed on May 31, 2002.

**Publication Classification**(51) **Int. Cl.<sup>7</sup> ..... B41N 1/00**(52) **U.S. Cl. .... 101/395**

An optical scanning system and method for laser engraving a plurality of data substrasters into a substrate to form a raster of engraved data defining an image on the substrate. Each substraster has a length dimension and a width dimension. The system includes a transport assembly having an objective lens and a mirror, the mirror capable of reflecting a substantially collimated scanning beam incident thereon in a direction transverse to an axis of the incident beam such that it is directed to the objective lens. The objective lens is capable of focusing the scanning beam on the substrate to engrave a set of data in the width dimension of the substraster and the objective lens and mirror combination is capable of moving along the axis of the incident beam to allow subsequent engraving of other sets of data in the width dimension until a complete substraster is formed along its length dimension. The objective lens and mirror combination is also capable of returning to its starting position to begin engraving of a subsequent substraster of the plurality of substrasters forming the raster of engraved data. A thermoset plastic substrate and a substrate having a an inorganic ceramic material are also identified as being suitable for use in a printing process, and particularly suitable for use with the aforementioned system and method.



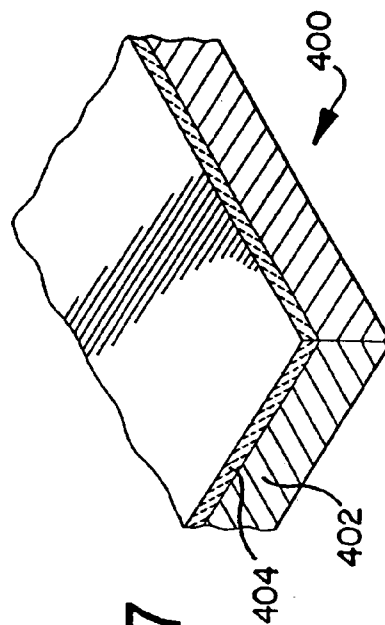
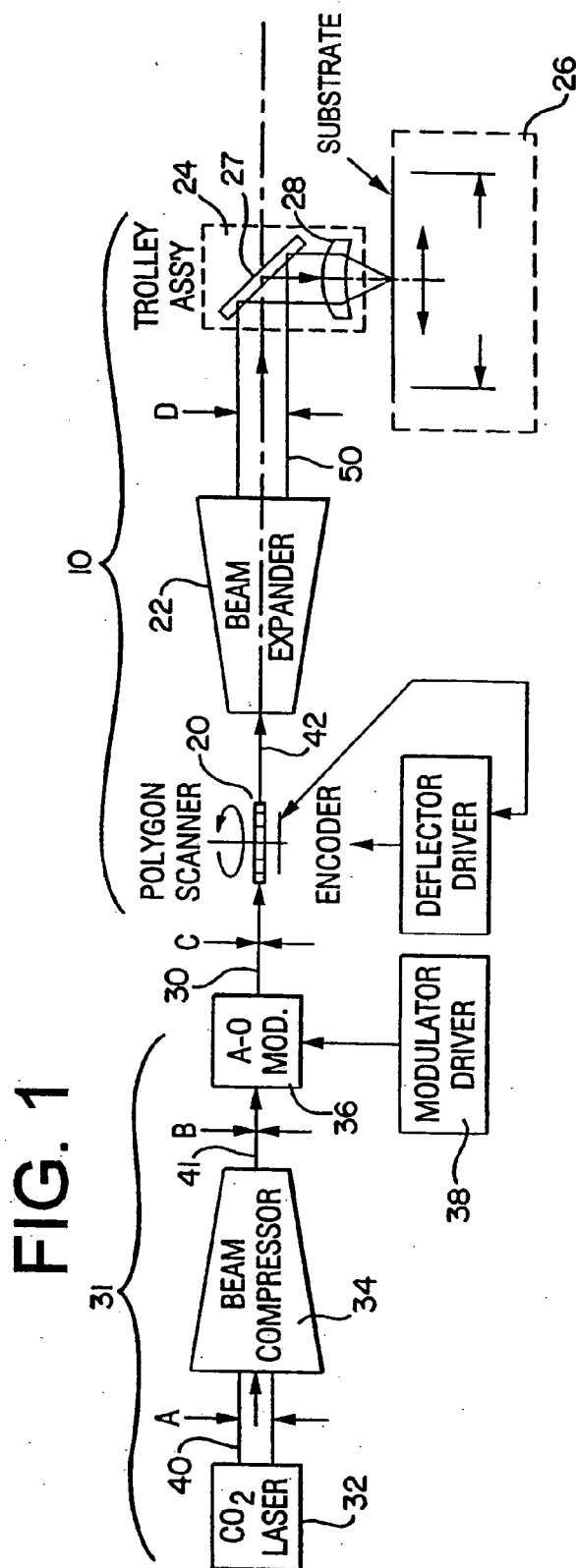


FIG.2

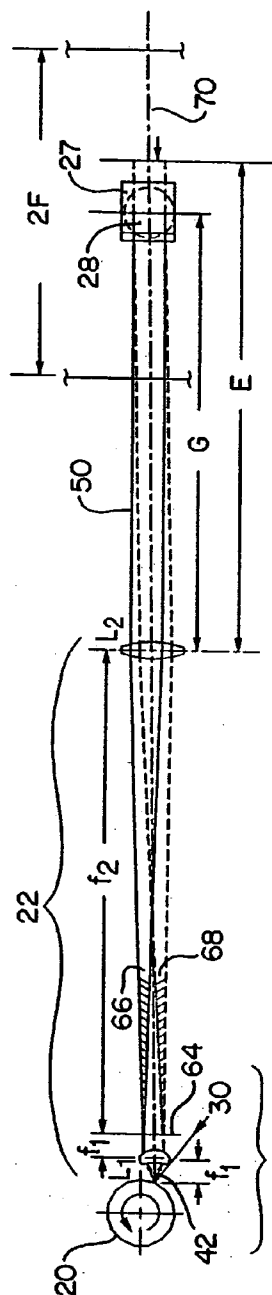


FIG.3

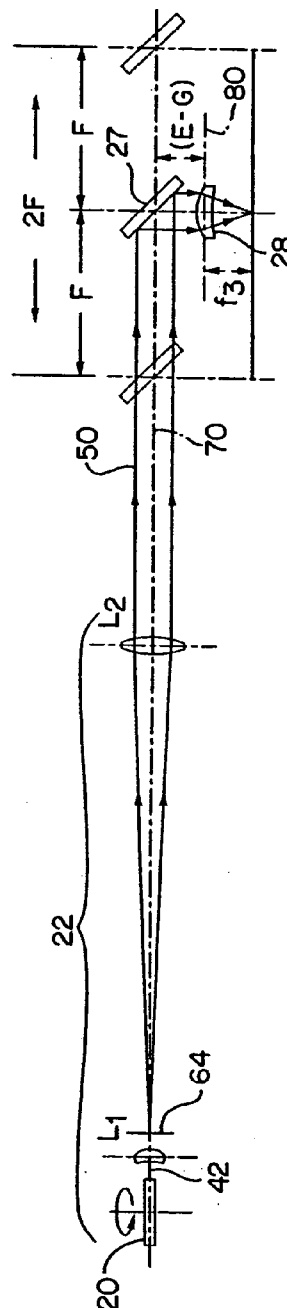
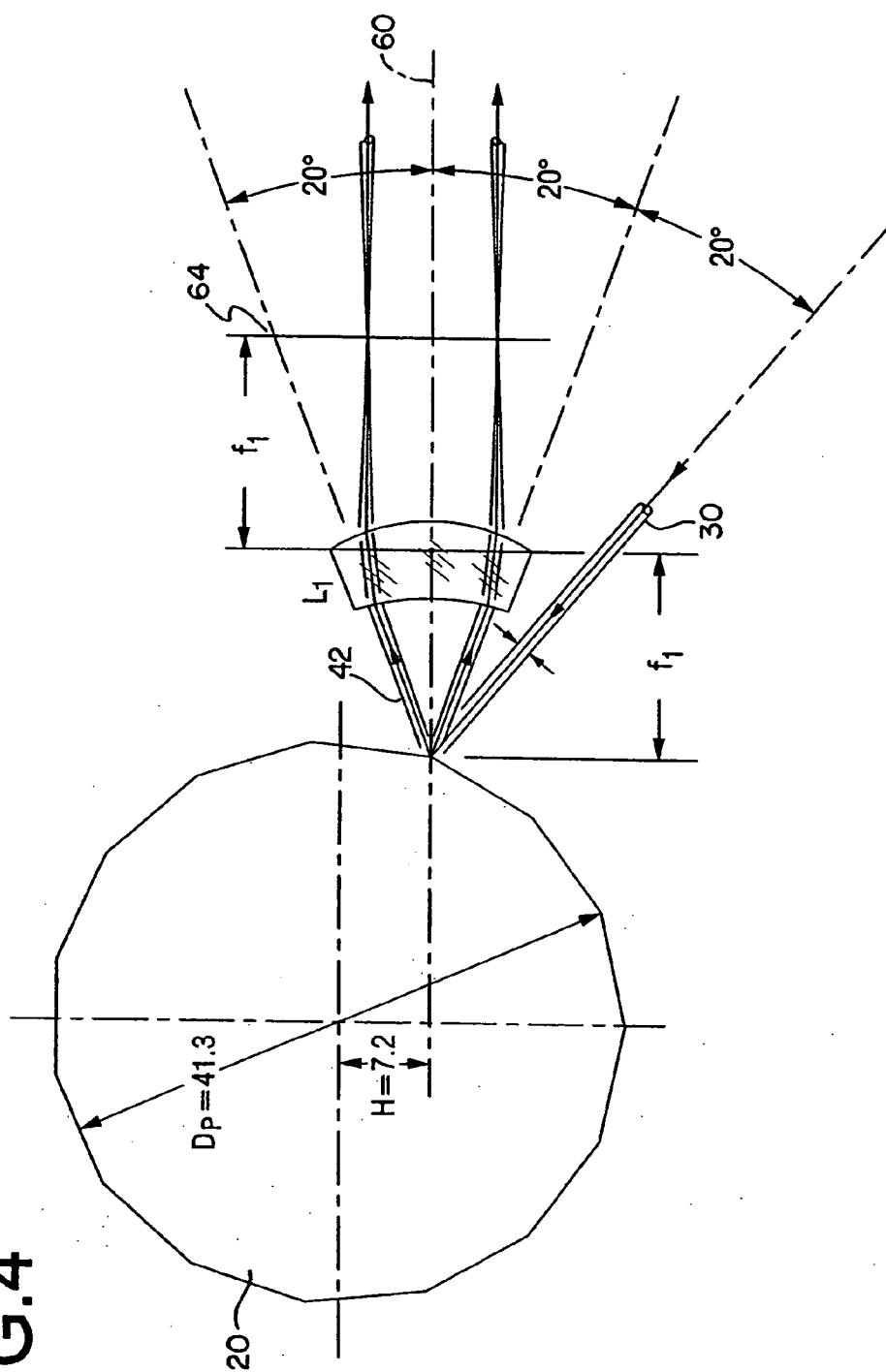


FIG. 4



# FIG.5

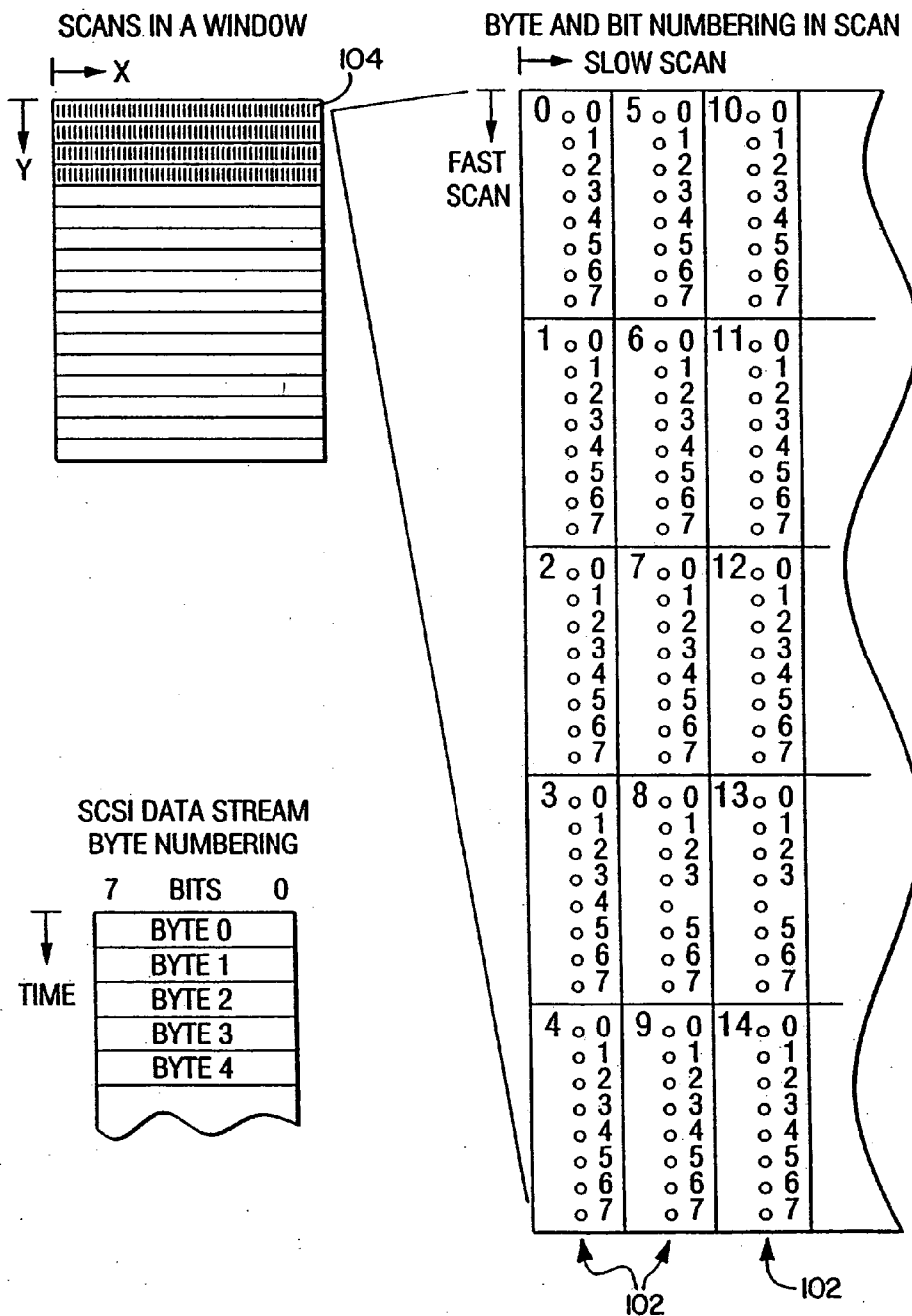
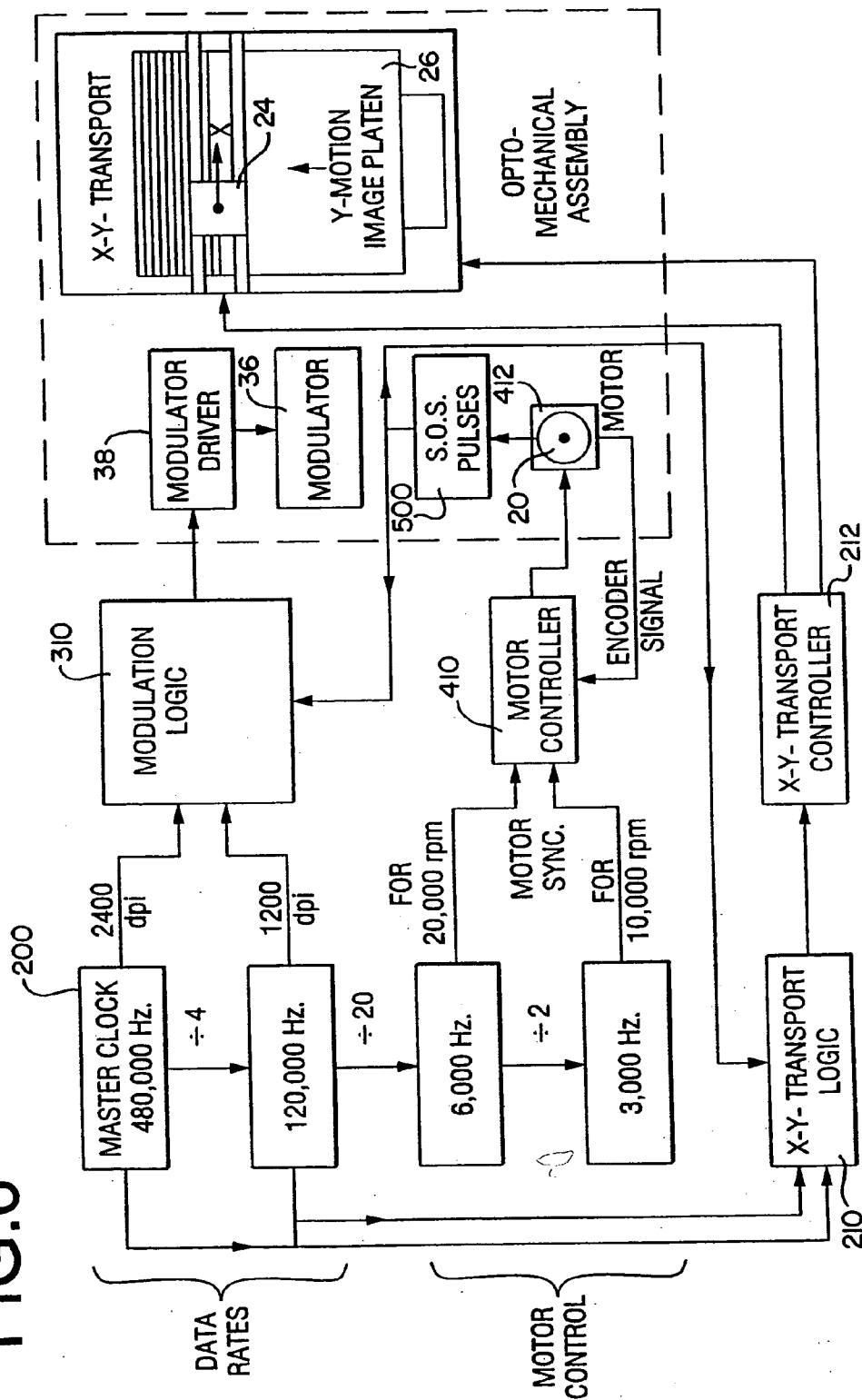


FIG. 6



## METHOD OF MANUFACTURING A PRINTING SUBSTRATE

### RELATED APPLICATIONS

[0001] This application is a continuation-in-part of U.S. patent application Ser. No. 10/159,492, filed May 31, 2002, upon which a claim of priority is based.

### TECHNICAL FIELD

[0002] This invention relates to direct laser engraving of a flat substrate for use in a printing process, such as intaglio printing. More particularly, the invention relates to an optical scanning system and substrate material particularly suitable for high-speed and high-resolution engraving.

### BACKGROUND OF THE INVENTION

[0003] Many printing processes utilize substrates, platens or forms as printing surfaces to transfer an image to a printable medium. One such process is called intaglio printing. Intaglio printing involves application of printed indicia or images below the surface of a platen or substrate that is utilized as a printing surface. Traditionally, intaglio substrates have been prepared by mechanically engraving or chemically etching a recessed pattern into the printing surface of the substrate, which defines an image. The pattern may comprise an array of dots in the printing surface of the substrate. The recessed pattern, such as the array of dots, define tiny recesses within which ink is held and transferred to the printable medium, such as a sheet or surface. This intaglio process is typically used in die stamping or in engraved processes, sometimes referred to as copper plate printing. It is also used in connection with pad printing, which is typically used to decorate plastic surfaces, as well as in the gravure printing process.

[0004] Mechanical engraving and chemical etching techniques are time-consuming processes. Mechanical techniques are typically slow due to limitations of engraving equipment. A mechanical stylus must be used to engrave the image into the substrate, which requires a certain amount of time to penetrate and cut the substrate material. Furthermore, accuracy of the engraving becomes an issue when the stylus becomes worn and dull. On the other hand, chemical etching is time consuming due to the many steps involved. Chemical etching is a multi-step process that first involves producing the image onto a film negative, such as with an imagesetter. Once the film is produced, it becomes a mask that can be laid on top of a copper or steel substrate having a thin film coating of sensitizing material. The substrate and mask combination is exposed to light for subsequent chemical development, which transfers the mask to the copper plate. After development, the substrate is ready for acid etching to complete the process. Accuracy is also an issue with chemical etching, due to the limited controllability of the chemical-etching process.

[0005] Another technique involves direct laser etching, which is a single-step process that requires much less time than mechanical engraving and chemical etching techniques. In this technique, a laser is used to directly engrave the substrate material. However, because metals have a high reflectance, the laser/metal interaction is not conducive to producing plates having sharp engravings. With metals and a majority of plastics, direct laser engraving causes the

material to melt, which creates the recessed areas, but also creates pooling of melted material around these recessed areas. This pooling of material acts as a ridge surrounding the recessed areas, which adversely affects the accuracy and usefulness of the printing surface of the substrate. Thus, accuracy remains an issue. Furthermore, although the direct laser technique is only a single-step process, the speed of the engraving process still remains an issue at higher resolution levels, which require the laser to engrave a higher number of tightly focused dots to achieve such resolutions. With presently known systems, the engraving process time is increased when the resolution level is increased.

[0006] The system and method of the present invention addresses these and other problems associated with direct laser engraving of substrates.

### SUMMARY OF THE INVENTION

[0007] An optical scanning system for laser engraving a plurality of data substrasters into a substrate to form a raster of engraved data defining an image on the substrate. Each substraster has a length dimension and a width dimension. The system includes a transport assembly having an objective lens and a mirror, the mirror capable of reflecting a substantially collimated scanning beam incident thereon in a direction transverse to an axis of the incident beam such that it is directed to the objective lens. The objective lens is capable of focusing the scanning beam on the substrate to engrave a set of data in the width dimension of the substraster and the objective lens and mirror combination is capable of moving along the axis of the incident beam to allow subsequent engraving of other sets of data in the width dimension until a complete substraster is formed along its length dimension. The objective lens and mirror combination is also capable of returning to its starting position to begin engraving of a subsequent substraster of the plurality of substrasters forming the raster of engraved data.

[0008] In a particular embodiment, an optical scanning system for laser engraving of a plurality of substrasters of data into a substrate to form a raster of engraved data is provided and includes a scanner capable of deflecting an input laser beam incident thereon from a first beam direction to create a scanning beam. The system also includes a beam expander capable of receiving the scanning beam and expanding it to create an expanded scanning beam. A transport assembly of the system has an objective lens and a mirror, wherein the mirror is capable of reflecting the expanded scanning beam in a second beam direction transverse to the first beam direction such that it is incident on the objective lens. The objective lens and mirror is capable of moving along an axis defined by the first beam direction. The objective lens is capable of focusing the expanded scanning beam on the substrate to engrave a set of data oriented in a width dimension of the substraster and is also capable of moving along the first beam axis to allow subsequent engraving of other sets of data oriented in the width dimension until a complete substraster is formed to define a length dimension of the substraster. The objective lens and mirror combination is further capable of returning to its starting position to initiate engraving of a subsequent substraster.

[0009] According to another aspect of the invention, an optical scanning system is provided that is capable of engraving at two different resolutions.

[0010] According to another aspect of the invention, a substrate is provided for use with a direct laser engraving process to create an intaglio printing substrate. The substrate consists essentially of a thermoset plastic which substantially vaporizes in response to an impinging laser beam that engraves portions of the substrate, thereby substantially eliminating the formation of slag material adjacent to engraved portions of the substrate.

[0011] According to another aspect of the invention, a substrate is provided for use with a direct laser engraving process to create a printing substrate, wherein the substrate comprises a base material and an inorganic ceramic material disposed on the base material.

[0012] According to yet another aspect of the invention, methods of manufacturing such a substrate and methods for making such a substrate into a printing substrate in accordance with the principles of the present invention are provided.

[0013] According to yet another aspect of the invention, a method of laser engraving a substrate for use in a printing process is provided. The method comprises the steps of: (a) directing a substantially collimated scanning beam having a beam axis to an objective lens that is movable along the beam axis, wherein the scanning beam defines a scan width; (b) focusing the scanning beam through the objective lens and onto the substrate; (c) engraving onto the substrate a set of subraster width data having a width equal to the scan width of the beam; (d) continuously moving the objective lens along the beam axis to subsequent positions relative to the substrate and engraving subsequent sets of subraster width data to form a complete subraster; (e) incrementing the substrate and engraving an additional subraster adjacent to the previously completed subraster; and (f) repeating the steps of incrementing the substrate and engraving an additional subraster until a complete raster made up of a plurality of subrasters is created that defines an engraved image on the substrate.

[0014] These and other aspects of the invention will become apparent from the specification, drawings and claims.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0015] FIG. 1 is a schematic diagram of an embodiment of a direct laser engraving system in accordance with the present invention.

[0016] FIG. 2 is a top plan view of a portion of the system of FIG. 1.

[0017] FIG. 3 is a side elevational view of the portion of the system shown in FIG. 2.

[0018] FIG. 4 is a detailed top plan view of the scanner and first lens of the beam expander shown in FIG. 2.

[0019] FIG. 5 is a schematic diagram of a byte and bit layout of a sampling of data sets of a subraster in a sample 1200 dpi scan in accordance with the principles of the present invention.

[0020] FIG. 6 is a functional block diagram of data handling of the system of FIG. 1.

[0021] FIG. 7 is a schematic diagram of an embodiment of a substrate in accordance with a particular aspect of the present invention.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0022] While this invention is susceptible of embodiments in many different forms, there is shown in the drawings and will herein be described in detail one or more preferred embodiments of the invention with the understanding that the present disclosure is to be considered as an exemplification of the principles of the invention and is not intended to limit the broad aspect of the invention to the embodiments illustrated.

[0023] FIG. 1 depicts a schematic diagram of an embodiment of an optical scanning system 10 in accordance with the principles of the present invention. The system 10 can be utilized for laser engraving a substrate for use in a printing process. A particular feature of the system 10 is the ability to engrave at two different resolutions with the same optical system. In a preferred embodiment, the system 10 is capable of engraving at 1200 dpi and 2400 dpi. Referring to FIG. 1, the system 10 includes a polygon scanner 20, a beam expander 22 and a transport (or trolley) assembly 24. A receptor assembly 26 is disposed adjacent to the transport assembly 24 and supports the substrate to be engraved. The receptor assembly 26 is capable of incrementally translating the substrate with respect to the transport assembly 24 via a stepped transport. As will be discussed in more detail below, the transport assembly 24 includes a mirror 27 and an objective lens 28 that are also movable to facilitate the engraving process.

[0024] The system 10 requires an input beam 30. A laser assembly 31 is provided to produce the input beam 30, which is incident on the scanner 20 from a first beam direction. The laser assembly 31 includes a laser 32 (preferably a DC excited CO<sub>2</sub> laser), a beam compressor 34 and a modulator 36 driven by a modulator driver 38. Referring to FIG. 1, the laser 32 produces a beam 40 (having a beam width A) that is shaped by the beam compressor 34 to produce a compressed beam 41 (having a beam width B). The compressed beam 41 is modulated by the modulator 36 to produce the input beam 30 (having a beam width C). Preferably, the beam width A of the beam 40 is 8mm, the beam width B of the compressed beam 41 is 1 mm, and the beam width C of the input beam is 1 mm. The input beam 30 is scanned by the scanner 20 to produce a scanning beam 42, which is directed to the beam expander 22. As will be explained in more detail below, the beam expander 22 produces a substantially collimated expanded scanning beam 50 (having a beam width D), which is directed to the mirror 27 and objective lens 28 combination of the transport assembly 24. The mirror 27 reflects the beam 50 to the objective lens 28, which focuses the beam onto the substrate. Preferably, the beam width D of the expanded scanning beam 50 is 20 mm and the mirror 27 is angled at 45 degrees. Essentially, the beam expander 22 expands the scanning beam 42 and relays it to create the expanded scanning beam 50, which has a substantially constant width over an extended distance.

[0025] FIGS. 2 and 3 depict the system 10 in more detail. FIG. 2 is a top plan view of the system 10 and FIG. 3 is a side view of FIG. 2. In a preferred embodiment, the scanner 20 is a polygon scanner having 15 facets and is rotatable in a direction indicated by rotational arrows in FIGS. 2 and 3. In a preferred embodiment, the scanner rotates at either

10,000 rpm or 20,000 rpm, depending on desired resolution. Considering the scanner **20** as a rotating mirror executing  $\pm 10^\circ$  mechanical deflection of the input beam **30**, the input beam **30** is deflected  $\pm 20^\circ$  due to mirror doubling to produce the scanning beam **42**. As shown in **FIGS. 2 and 3**, the beam expander **22** includes a first lens **L1** and a second lens **L2**. Referring to the detailed view of the scanner **20** and the first lens **L1** of the beam expander **22** in **FIG. 4**, the scanning beam **42**, which is a substantially collimated beam having a beam width **C** and deflected  $\pm 20^\circ$ , is directed to be incident on lens **L1**. In a preferred embodiment, lens **L1** has a focal length of 15 mm. The lens **L1** is located one focal length **f1** from the scanner surface and acts telecentrically such that the  $\pm 20^\circ$  beams continue to the right of the lens **L1** and remain substantially parallel to a lens axis **60**, while deflected components of the beams converge to a focal plane **64** one focal length **f1** beyond the lens **L1**. Referring to **FIG. 2**, beyond the focal plane **64**, an upper limit beam **66** and a lower limit beam **68** of the deflected beam components expand. Referring to **FIG. 3**, the focal plane **64** acts as a plane of beam symmetry, as shown in **FIG. 3**.

[0026] The upper limit beam **66** and the lower limit beam **68** expand until they reach a second lens **L2**, which is spaced a focal length **f2** from the focal plane **64** of the first lens **L1**. In a preferred embodiment, the focal length **f2** is 300 mm. Utilizing the preferred pair of lenses **L1** (15 mm focal length) and **L2** (300 mm focal length), the beam expander **22** acts as a 20x beam expander ( $300/15=20$ ). Thus, the beam expander **22** in the preferred embodiment expands the 1mm input beam to a substantially collimated 20mm output beam. A fundamental consequence of beam expansion is a complimentary compression of scan angle of the beam (in the preferred embodiment, compression from  $\pm 20^\circ$  to  $\pm 1^\circ$ ). This reduction in scan angle imparts a practical field angle to the objective lens **28**.

[0027] Another consequence of this configuration in the preferred embodiment is the relaying of a 1mm beam aperture at the scanner **20** to a 20 mm beam aperture at the 300 mm focal distance of lens **L2**. Thus, as shown in **FIG. 2**, although the beams shift laterally (due to deflection) in the long region between the scanner **20** and the objective lens **28**, the beam shift reduces to zero at a distance **E** beyond lens **L2** (300 mm in a preferred embodiment). In other words, the stability of the 1 mm beam at the scanner **20** (scanning beam **42**) is transferred as a stable 20 mm beam (expanded scanning beam **50**) at the objective lens **28**. As explained in more detail below, in a preferred embodiment, the 300 mm distance is a nominal beam travel length for the objective lens **28** with respect to its movement on the transport assembly **24** along a beam axis **70** of the expanded scanning beam **50**.

[0028] Referring again to **FIGS. 2 and 3**, the transport assembly **24** facilitates movement of the mirror **27** and the objective lens **28** along the beam axis **70** of the expanded beam **50**. The mirror **27** and the objective lens **28** combination are movable within the transport assembly **24** in both directions for a distance **F** along the beam axis from the nominal position, for a total travel of 2**F**. In a preferred embodiment, the transport assembly **24** facilitates movement of the mirror **27** and the objective lens **28** for 4 inches (**F**=4 inches) in each direction for a total range of travel of 8 inches (2**F**), which corresponds to a dimension of an image format size, which is 8"x10" in a preferred embodiment. Of

course, other format sizes could be accommodated through adjustment of the system in accordance with the principles of the present invention.

[0029] Referring to **FIG. 3**, the expanded scanning beam **50** is intercepted by the mirror **27** and reflected, thereby folding the beam **50** so that it is incident on a principal plane **80** of the objective lens **28**. The beam **50** is intercepted by the mirror **27** at a nominal position of **G**, folding the remaining length (**E-G**) to complete the nominal distance **E** (300 mm in a preferred embodiment) to the principal plane **80** of the objective lens **28**. At the objective lens **28**, the beam width of beam **50** (20 mm in a preferred embodiment) is converged over a focal distance (**f3**) of the lens **28** to an energetic focal point to engrave the surface of the substrate material. The transport assembly **24** transports the mirror **27** and the objective lens **28** over a dimension of the format size (2**F**). For simplicity of illustration, the limit positions of the mirror **27** and the objective lens **28** are represented in **FIG. 3** by the two mirrors shown in phantom lines. It is understood that the mirror **27** and the objective lens **28** move in combination.

[0030] Referring to the right side of **FIG. 2**, it is noteworthy that with a collimated beam incident on the objective lens **28**, even though the beam position in the aperture of the lens **28** shifts slightly during transport, the fundamental criterion for accurate placement of the engraving focal point, which is the angle of the collimated beam with respect to the lens axis, remains a constant of the system. As explained below, this establishes uniformity of a width dimension of each of a plurality of substrates of data engraved to form, in combination, an engraved image.

[0031] The present invention utilizes a method of engraving the substrate wherein a plurality of data substrates are engraved to form individual swaths, which, in combination form a complete raster of data representing an image to be engraved. Referring to the schematic diagram of **FIG. 5**, a byte and bit layout of a sampling of data sets **102** of a substrate in a sample 1200 dpi scan is shown in accordance with the principles of the present invention. Each data bit of the data sets **102** represents a point, or dot, of the image to be engraved. As shown in **FIG. 5**, each substrate **104** comprises a plurality of data sets in a width dimension of the substrate. In the 1200 dpi resolution example, each data set **102** comprises 40 dots across the width dimension of the substrate (5 sets of 8 dots). In a 2400 dpi example (not shown), each data set comprises 80 dots across the width dimension of the substrate (10 sets of 8 dots). The expanded scanning beam **50** engraves each data set across the substrate width as the transport assembly **24** moves the mirror **27** and objective lens **28** combination in a direction along the length dimension of the substrate **104** (denoted by **X** in **FIG. 5**) until the substrate **104** is completed. The objective lens and mirror combination returns to its starting position and the receptor assembly **26** incrementally translates the substrate in a direction along the width dimension of the substrate **104** (denoted by **Y** in **FIG. 5**) to initiate engraving of a subsequent substrate. The translation increment is equal to the width dimension of the substrate **104**. In a preferred embodiment, the width dimension of each substrate is about 33.3 mils and a total of 300 substrates are utilized to form the raster. Although the movement of the objective lens and mirror combination is described herein in various phases or steps of the engraving process, it is understood that move-

ment of these components is continuous throughout the engraving process. Table 1 below shows the data point content for both 1200 dpi and 2400 dpi images in an 8"×10" image format.

TABLE 1

Operational Data Point Content for 8" × 10" Image Format				
Each Data Subraster				
Resolution	Data Points	Data Sets	Total Data Points Per Subraster	Total Data Points 300 Subrasters
1200 dpi	40	9,600	384,000	115,200,000
2400 dpi	80	19,200	1,536,000	460,800,000

[0032] During engraving, the laser 32 remains on. Instead of turning the laser 32 on and off, the modulator 36 shifts the beam 30 to a position analogous to ON. An unshifted beam position is analogous to OFF. During engraving, this shift happens at a very high rate. In the OFF position, the beam 30 exits the modulator 36, strikes a dump mirror (not shown), and deflects into a beam dump (not shown) to absorb unwanted laser power. When the modulator 36 shifts the beam 30 in an ON position, the shifted beam 30 bypasses the dump mirror and impinges on the scanner 20. Based on these ON and OFF positions, each data point or dot can represent an engraved point (ON) or an unengraved point (OFF) on the surface of the substrate.

[0033] FIG. 6 depicts a functional block diagram of data handling of the system. As shown in FIG. 6, a master clock 200 operates at 480 kHz, which is the data rate for 2400 dpi resolution. The master clock 200 is stepped down to 120 kHz for 1200 dpi resolution. The data rate clocks clock an X-Y transport logic 210, which in turn drives an X-Y transport controller 212 for the transport assembly 24 (which moves the mirror 27 and objective lens 28 in the X-direction) and the receptor assembly 26 (which incrementally translates the substrate in the Y-direction). The data rate clocks also clock a modulation logic 310, which in turn operates the modulator driver 38 that drives the modulator 36. The master clock 200 is stepped down further to provide a motor control, as shown in FIG. 6. The scanner 20 rotates at either 10,000 rpm (1200 dpi) or 20,000 rpm (2400 dpi). A motor controller 410 is clocked at 6 kHz for 20,000 rpm and 3 kHz for 10,000 rpm to control a motor 412 that drives the scanner 20. An encoder signal is provided back to the motor controller from the scanner 20. S.O.S (Start of Scan) pulses from the scanner 20 and are fed to the modulation logic 310 and the X-Y transport logic 210. Each S.O.S. pulse initiates the first data point of each data set in the width dimension of the subrasters. Each S.O.S pulse also triggers the modulation sequence for each data set.

[0034] As already mentioned, a particular advantage of the system 10 is its ability to provide two different resolutions with the same optical system (1200 dpi and 2400 dpi in a preferred embodiment). This is accomplished by narrowing the modulation pulse width at 2400 dpi to half of the modulation pulse width at 1200 dpi, while doubling its repetition rate, which doubles the dot count along the subraster width from 40 to 80. Correspondingly, the motor speed of the scanner is doubled from 10,000 rpm to 20,000 rpm, which provides a full double-resolution dot array (data set) across the width dimension of the subraster. The modu-

lation pulse width is narrowed by reducing the intensity of the beam. Since the dots are formed by a Gaussian focused beam contour, reducing the pulse duration by one half reduces the dot exposure (intensity) on the substrate, which, in turn, sufficiently reduces the dot width to facilitate the double-resolution engraving. The repetition rate of the modulation pulse width is changed via software control. Since the exposure (intensity) is reduced at the 2400 dpi resolution, the total energy remains the same as that at 1200 dpi resolution. Since the total energy is the same, the total engraving duration is the same. Thus, the system is capable of doubling its engraving resolution without increasing engraving time.

[0035] From the foregoing description, it is apparent that changing the resolution of the system is rapidly accomplished without the need for critical mechanical changes, such as changing the objective lens to focus to a smaller dot size, which can be very costly. Furthermore, two different resolutions can be engraved with the same optical system, which creates the same subraster format to cover the same total area during the same total time, and the same laser providing the same optical power.

[0036] As yet another aspect of the present invention, it has been found that the use of a thermoset plastic material as the substrate substantially eliminates unwanted slag formation around the engraved points of the substrate. The thermoset plastic material substantially vaporizes in response to the impinging laser beam that engraves points of the substrate, thereby substantially eliminating the formation of the slag material. Desirable results have been achieved by including a mineral filler with the thermoset material. Preferably, the mineral filler has a grain size smaller than a smallest feature of the engraved portions of the substrate. Preferably, the grain size is in the range of about 3 to 5 microns. However, the grain size can be varied to match a particular resolution. The filler adds strength to the substrate material, thereby maintaining the accuracy and detail of the engraved portions of the substrate. In a preferred embodiment, silica is utilized as a filler for the thermoset material. Additionally, a flame retardant can be included to minimize flame and smoke formation from the impinging laser beam.

[0037] Thermoset plastics provide for more accurate laser engraving due, in part, to their strength and resistance to flow. The polymer component consists of molecules with permanent cross-links between linear chains that form a rigid three-dimensional network structure which cannot flow. The tightly cross-linked structure of thermosetting polymers immobilizes the molecules, providing hardness, strength at relatively high temperature, insolubility, good heat and chemical resistance, and resistance to creep. The use of a thermoset plastic material for a substrate has a significant impact on the cost of printing processes that utilize such substrates. Thermoset plastic substrates are much less expensive than copper or steel substrates and they do not sacrifice engraving accuracy, and hence, printing accuracy.

[0038] It is contemplated that a variety of thermoset plastic materials can be utilized in accordance with the principles of the present invention. Such materials include epoxies, unsaturated polyesters, phenolics, amino resins (such as urea- and melamine-formaldehyde), alkyds, allyl family (such as diallylphthalate), silicone molding compounds, and polyimides (such as bismaleimides).

[0039] In cases where durability is a priority, it has further been found that a substrate having an inorganic ceramic material is suitable for a printing process, and particularly suitable for use in the system and process described herein. In an embodiment as shown in FIG. 7, a substrate 400 comprises a base material 402 and an inorganic ceramic material 404 disposed on, and preferably bonded to, the base material 402. Preferably, the base material 402 comprises a metal, such as, for example, steel, aluminum, copper, iron or any other metal suitable for use in a printing substrate. The ceramic material 404 provides a surface for formation of an image to be printed to a medium during a printing process. It is to be understood that other additional materials or layers may be incorporated into the substrate 400, with the ceramic material 404 providing the printing surface.

[0040] An inorganic ceramic material component, layer or coating of a printing substrate provides excellent resistance to abrasion encountered during the printing process. Among other things, ink ingredients used in printing processes can cause wear to the substrate. The ceramic material of the substrate is more resistant to abrasion than the thermoset substrates, while offering excellent engraving accuracy. The substrate incorporating the inorganic ceramic material provides an excellent alternative to the thermoset substrates. It has been found that an inorganic ceramic material that is vitreous in nature offers particularly excellent resistance to abrasion and is particularly suitable for use in a printing substrate.

[0041] By way of background and example, a particular inorganic ceramic material for use in a substrate for a printing process will now be described with the understanding that the particular example is but one embodiment of many as understood by one of ordinary skill in the art that can be utilized in accordance with the principles of the present invention. In this particular example, the inorganic ceramic material is in the form of a porcelain enamel disposed on a metallic substrate, such as a steel or iron substrate. Porcelain enamels for steel and iron substrates are typically classified as either ground-coat or cover-coat enamels. Ground-coat enamels contain metallic oxides, such as cobalt oxide and/or nickel oxide, that promote adherence of the glass/enamel to the metal substrate. Cover-coat enamels are applied over fired ground coats to improve the properties of the coating. In addition, cover-coat enamels may be applied over unfired ground coats, with both coats being fired at the same time. This is referred to as a two-coat/one-fire system. Cover coats may also be applied directly to properly prepared decarburized steel substrates. Porcelain enamels for aluminum substrates are typically one-coat systems that are applied by spraying. However, two-coat systems can also be utilized. It should be understood, however, that any number of application systems, alone or in combination, can be utilized on various substrate materials to achieve a porcelain-coated substrate.

[0042] The basic material of the porcelain enamel coating is called frit, which is a smelted complex borosilicate glass. Frits are produced by quenching a molten glassy mixture that is compounded from numerous components, sometimes more than 20 different components, depending upon the application. Thus, the composition of the frit can be customized and optimized to exhibit certain desired properties for a particular application. As already mentioned, in cases where increased adherence to a steel substrate is desired, for

example, cobalt oxide and/or nickel oxide may be included in the frit. In accordance with the principles of the present invention, the frit can be optimized for properties conducive to use as a printing substrate, including, but not limited to, hardness, abrasion resistance, strength at relatively high temperature, heat and chemical resistance, etc. Examples of oxide components that may be utilized include, but are not limited to,  $\text{SiO}_2$ ,  $\text{B}_2\text{O}_3$ ,  $\text{Na}_2\text{O}$ ,  $\text{K}_2\text{O}$ ,  $\text{Li}_2\text{O}$ ,  $\text{CaO}$ ,  $\text{ZnO}$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{ZrO}_2$ ,  $\text{TiO}_2$ ,  $\text{CuO}$ ,  $\text{MnO}_2$ ,  $\text{NiO}$ ,  $\text{Co}_3\text{O}_4$ ,  $\text{P}_2\text{O}_5$ ,  $\text{MgO}$ ,  $\text{PbO}$ ,  $\text{Sb}_2\text{O}_3$ ,  $\text{Sb}_2\text{O}_5$ ,  $\text{ZrO}_2$ ,  $\text{BaO}$  and  $\text{F}_2$ . Additives may be added to the frit to further influence various properties of the enamel, such as clay, bentonite, electrolytes, fluxes, and coloring oxides.

[0043] In a preferred embodiment, the porcelain enamel has a low glass content, i.e., less than 50% by weight, preferably in the range of 35-40% by weight. However, other percentages can also be utilized, as long as the glass content is not too low, which weakens the enamel. Typical porcelain enamels have a glass content between 50% and 60% by weight.

[0044] The porcelain enamel may be applied to the substrate by either a wet process or a dry process. Wet process methods include manual spraying, electrostatic spraying, dipping, flow coating, and electrodeposition (electrophoresis). Dry process methods include electrostatic dry powder spraying and sprinkling onto a heated substrate. In a preferred embodiment, the porcelain enamel is applied electrostatically.

[0045] Since subsurface abrasion resistance varies with processing variables that affect the bubble structure of the enamel (i.e., gas bubbles that get trapped in the enamel during cooling), it is preferable that gas bubbles are minimized. Enamel compositions may contain crystalline particles (from mill additions or devitrification heat treatment) that can increase abrasion resistance by as much as 50%. In a preferred embodiment, calcium carbonate is included as a filler additive, which increases abrasion resistance.

[0046] It should be understood that any inorganic ceramic material can be utilized in accordance with the principles of the present invention. However, it is preferable to utilize a porcelain enamel, particularly one having low glass content and exhibiting excellent abrasion resistance.

[0047] While some substrate materials—such as thermoset plastics—can accommodate and take advantage of the faster engraving speeds and fast trolley return speeds associated with the system 10 depicted in FIGS. 1-6 (wherein only the objective lens and the mirror are carried on the trolley assembly and moveable rapidly in the X direction while the substrate is stepped short distances moveable in the Y direction) other materials cannot be optimally engraved at higher speeds. In such cases, an alternate embodiment system 600 may be utilized as shown in FIG. 8, which is substantially identical to the system 10, with the primary difference residing between the beam expander 22 and the receptor assembly 26, wherein the mirror 27 and the objective lens 28 (also referred to as “mirror/objective lens combination”) remain in a fixed position within the system 600. To simplify the descriptions herein, elements that are identical in system 10 and system 600 share the same reference indicia.

[0048] Referring to FIG. 8, the mirror/objective lens combination are in a fixed position and remain at a fixed distance

with respect to the beam expander **22** within the system **600**. In this embodiment, the receptor assembly **26** supports the substrate to be engraved and is capable of incrementally translating the substrate with respect to the mirror/objective lens via a stepped transport in both the X and Y directions. Thus, the engraving process is facilitated by translating the substrate in both directions while the mirror/objective lens combination remains fixed to direct a fixed beam onto the substrate. This embodiment has been found to be effective with certain materials dictating slower engraving speeds.

[0049] Software that facilitates the system to skip over non-engraved areas of the substrate at higher speeds can be incorporated into controls of both systems, the system having a moveable objective lens and the system having a fixed objective lens, to compensate for the slower engraving speeds dictated to these embodiments by the materials they are engraving.

[0050] It is understood that, given the above description of the embodiments of the invention, various modifications may be made by one skilled in the art. Such modifications are intended to be encompassed by the claims below.

What is claimed is:

1. A substrate for use with a direct laser engraving process to create a printing substrate, the substrate comprising:

a base material; and

an inorganic ceramic material disposed on the base material.

2. The substrate of claim 1, wherein the base material comprises a metal.

3. The substrate of claim 1, wherein the inorganic ceramic material is vitreous.

4. The substrate of claim 1, wherein the inorganic material is bonded to the base material.

5. The substrate of claim 1, wherein the base material is selected from the group consisting of steel, aluminum, copper and iron.

6. The substrate of claim 1, wherein the inorganic ceramic material comprises a porcelain enamel.

7. The substrate of claim 6, wherein the porcelain enamel has a glass content less than 50 percent by weight.

8. The substrate of claim 6, wherein the porcelain enamel has a glass content generally between 35 to 40 percent by weight.

9. The substrate of claim 6, wherein the porcelain enamel comprises an oxide selected from the group consisting of SiO<sub>2</sub>, B<sub>2</sub>O<sub>3</sub>, Na<sub>2</sub>O, K<sub>2</sub>O, Li<sub>2</sub>O, CaO, ZnO, Al<sub>2</sub>O<sub>3</sub>, ZrO<sub>2</sub>, TiO<sub>2</sub>, CuO, MnO<sub>2</sub>, NiO, Co<sub>3</sub>O<sub>4</sub>, P<sub>2</sub>O<sub>5</sub>, MgO, PbO, Sb<sub>2</sub>O<sub>3</sub>, Sb<sub>2</sub>O<sub>5</sub>, ZrO<sub>2</sub>, BaO and F<sub>2</sub>.

10. The substrate of claim 6, wherein the porcelain enamel includes a mineral filler.

11. The substrate of claim 10, wherein the mineral filler comprises calcium carbonate.

12. A printing substrate comprising:

a base material; and

an inorganic ceramic material disposed on the base material and having a formation defining an image to be printed on a medium during a printing process.

13. The substrate of claim 12, wherein the base material comprises a metal.

14. The substrate of claim 12, wherein the inorganic ceramic material is vitreous.

15. The substrate of claim 12, wherein the inorganic material is fused to the base material.

16. The substrate of claim 12, wherein the formation defining the image is a laser-engraved formation.

17. The substrate of claim 12, wherein the base material is selected from the group consisting of steel, aluminum, copper and iron.

18. The substrate of claim 12, wherein the inorganic ceramic material comprises a porcelain enamel.

19. The substrate of claim 18, wherein the porcelain enamel has a glass content less than 50 percent by weight.

20. The substrate of claim 18, wherein the porcelain enamel has a glass content generally between 35 to 40 percent by weight.

21. The substrate of claim 18, wherein the porcelain enamel comprises an oxide selected from the group consisting of SiO<sub>2</sub>, B<sub>2</sub>O<sub>3</sub>, Na<sub>2</sub>O, K<sub>2</sub>O, Li<sub>2</sub>O, CaO, ZnO, Al<sub>2</sub>O<sub>3</sub>, ZrO<sub>2</sub>, TiO<sub>2</sub>, CuO, MnO<sub>2</sub>, NiO, Co<sub>3</sub>O<sub>4</sub>, P<sub>2</sub>O<sub>5</sub>, MgO, PbO, Sb<sub>2</sub>O<sub>3</sub>, Sb<sub>2</sub>O<sub>5</sub>, ZrO<sub>2</sub>, BaO and F<sub>2</sub>.

22. The substrate of claim 18, wherein the porcelain enamel includes a mineral filler.

23. The substrate of claim 22, wherein the mineral filler comprises calcium carbonate.

24. A substrate for use with a direct laser engraving process to create a printing substrate, the substrate comprising:

a metal layer; and

a porcelain enamel layer bonded to the metal layer.

25. The substrate of claim 24, wherein the porcelain enamel has a glass content less than 50 percent by weight.

26. The substrate of claim 24, wherein the porcelain enamel has a glass content generally between 35 to 40 percent by weight.

27. The substrate of claim 24, wherein the porcelain enamel includes an oxide selected from the group consisting of SiO<sub>2</sub>, B<sub>2</sub>O<sub>3</sub>, Na<sub>2</sub>O, K<sub>2</sub>O, Li<sub>2</sub>O, CaO, ZnO, Al<sub>2</sub>O<sub>3</sub>, ZrO<sub>2</sub>, TiO<sub>2</sub>, CuO, MnO<sub>2</sub>, NiO, Co<sub>3</sub>O<sub>4</sub>, P<sub>2</sub>O<sub>5</sub>, MgO, PbO, Sb<sub>2</sub>O<sub>3</sub>, Sb<sub>2</sub>O<sub>5</sub>, ZrO<sub>2</sub>, BaO and F<sub>2</sub>.

28. The substrate of claim 24, wherein the porcelain enamel includes a mineral filler.

29. The substrate of claim 28, wherein the mineral filler comprises calcium carbonate.

30. A printing substrate comprising:

a metal layer; and

a porcelain enamel layer bonded to the metal layer and having a laser-engraved image to be printed on a medium during a printing process.

31. The substrate of claim 30, wherein the metal layer is selected from the group consisting of steel, aluminum, copper and iron.

32. The substrate of claim 30, wherein the porcelain enamel layer has a glass content less than 50 percent by weight.

33. The substrate of claim 30, wherein the porcelain enamel layer has a glass content generally between 35 to 40 percent by weight.

**34.** The substrate of claim 30, wherein the porcelain enamel layer includes an oxide selected from the group consisting of SiO<sub>2</sub>, B<sub>2</sub>O<sub>3</sub>, Na<sub>2</sub>O, K<sub>2</sub>O, Li<sub>2</sub>O, CaO, ZnO, Al<sub>2</sub>O<sub>3</sub>, ZrO<sub>2</sub>, TiO<sub>2</sub>, CuO, MnO<sub>2</sub>, NiO, Co<sub>3</sub>O<sub>4</sub>, P<sub>2</sub>O<sub>5</sub>, MgO, PbO, Sb<sub>2</sub>O<sub>3</sub>, Sb<sub>2</sub>O<sub>5</sub>, ZrO<sub>2</sub>, BaO and F<sub>2</sub>.

**35.** The substrate of claim 30, wherein the porcelain enamel layer includes a mineral filler.

**36.** The substrate of claim 35, wherein the mineral filler is calcium carbonate.

**37.** The substrate of claim 30, wherein the porcelain enamel layer has been electrostatically applied to the base layer.

**38.** The substrate of claim 30, wherein the porcelain enamel is formulated to be abrasive resistant.

**39.** The substrate of claim 38, wherein the porcelain enamel is formulated to be abrasive resistant by a reduction of formation of gas bubbles within the enamel during application to the metal layer.

**40.** A substrate for use in an intaglio printing process, the substrate comprising:

a metallic base layer; and

a porcelain enamel layer bonded to the base layer and having an engraved image created by laser engraving a plurality of subrasters each having a width and a length, each subraster defined by a plurality of data point sets each scanned across the width of the subraster by a scanning beam incident to the substrate, each of the data point sets having data points that create one of either an engraved point or an unengraved point defined by a state of the scanning beam, the plurality of subrasters combining to form a raster defining the engraved image.

**41.** A method of manufacturing a substrate for use with a direct laser engraving process to create a printing substrate, the method comprising the steps of:

providing a metallic layer; and

disposing an inorganic ceramic layer on the metallic layer.

**42.** A method of making a printing substrate for use in a printing process, the method comprising the steps of:

providing a substrate comprising a metallic layer and an inorganic ceramic layer disposed on the metallic layer; and

forming an image on the inorganic ceramic layer to be printed on a medium during a printing process.

**43.** The method of claim 42, wherein the step of forming the image on the inorganic ceramic layer comprises the step of engraving the image in the inorganic ceramic layer.

**44.** The method of claim 42, wherein the step of forming the image on the inorganic ceramic layer comprises the step of laser engraving the image in the inorganic ceramic layer.

**45.** A method of making a printing substrate for use in a printing process, the method comprising the steps of:

providing a substrate comprising a metallic layer and an inorganic ceramic layer disposed on the metallic layer; and

engraving the inorganic ceramic layer with a plurality of subrasters each having a width and a length, each subraster defined by a plurality of data point sets each scanned across the width of the subraster by a scanning beam incident to the substrate, each of the data point sets having data points that create one of either an engraved point or an unengraved point defined by a state of the scanning beam, the plurality of subrasters combining to form a raster defining the engraved image.

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