

IMPROVED OBJECT MANUFACTURE

TECHNICAL FIELD

This invention lies in the field of object manufacture.

BACKGROUND ART

- 5 It is known to use laser technology to manufacture objects such as parts, which require precision manufacture in order to interact with other parts, and also prototypes. In the past, such parts and prototypes were generally made by skilled craftsman, from wood or plastic or similar material. Alternately, these items were machined from solid metal. Both techniques were time-consuming,
10 required skilled personnel and were relatively expensive.

In laminated object manufacture or laser object machinery ("LOM"), a CAD (computer aided design) programme is used to generate a three-dimensional image of the object and to provide instructions to a computer connected to LOM apparatus, which in turn produces the three-dimensional solid object.

- 15 In more detail, LOM involves providing a single layer of paper, which has been precoated with adhesive, on a horizontal platform. A laminating roller uses heat to cause the paper to adhere to the platform. A laser cutting head emits a laser beam and moves over the layer of paper under the influence of motors adapted to control the motion of the laser head. The laser beam, guided by the
20 CAD generated instructions, precisely cuts a first cross-section of the desired object on the layer of paper. The laser then dices all excess paper outside the cross-sectional area, in effect, freeing the paper outside the cross-sectional boundary.

- The horizontal platform moves downwardly and a second layer of paper is
25 advanced and laminated to the first. The second cross-section of the object is cut out via the laser beam and the excess paper is diced, as before. Each cross-section is cut on an outline which is often slightly different from that on the preceding and following sheets.

- This process is repeated until hundreds of cross-sections have been cut, each
30 consisting of the thickness of a single piece of paper. When all cross sections have been cut, the stack of paper is removed, the excess paper is separated from the cross-sections (facilitated by the laser dicing referred to earlier) and

the desired three dimensional object remains. The product is wood-like in appearance and can be sanded or machined to modify it.

The production of three-dimensional objects via LOM represented a significant advance over the handmade prototypes and patterns previously available, 5 because LOM is capable of producing three-dimensional objects at high speed and relatively low cost, compared to the previous procedures.

However, the production of each sheet of such a laminated object is relatively time consuming, because although the path to be traversed by the laser cutting head above each sheet of paper is reprogrammed into a computer 10 control system, the head must still physically traverse the path of the desired cut in the sheet. Use of such systems can produce good quality laminated models although in the case of a model of average complexity lamination and cutting of all the required sheets may take thirty-six hours or more.

It is accordingly an object of the present invention, inter alia, to provide a 15 system for production of objects formed from laminated sheets wherein the cutting or working of each sheet to or at the required profile is achieved relatively quickly as compared with existing apparatus and does not necessarily require mechanical components to physically traverse the profile to be cut into each sheet.

20 DISCLOSURE OF THE INVENTION

It has now been discovered that three-dimensional objects, both layered and single layer, may be produced in a manner similar to the prior art LOM technique, but without the need to employ a laser. At least in some embodiments, the present invention relates to processes and apparatus which 25 are adapted to quickly transmit a required outline onto a sheet to be laminated and facilitate cutting of successive sheets to differing predetermined outlines without the necessity of any mechanical apparatus having to traverse the precise outline to be cut onto the sheet.

Accordingly, this invention provides an improved process for object 30 manufacture, comprising printing on at least one substrate a desired cross-sectional outline and applying sufficient energy to the printed outline to cause the substrate to weaken at the outline.

In an especially preferred embodiment, this invention provides an improved process for laminated object manufacture, comprising printing on at least some of a number of pieces of substrate a desired cross-sectional outline, binding the substrates and applying sufficient energy to the printed outline to
5 cause each printed substrate to weaken at the outline.

This invention also provides an object and a laminated object manufactured by the processes of the present invention.

This invention also provides apparatus for producing an object, the apparatus including printing means for printing on at least one substrate a desired cross-
10 sectional outline and energy generation means for applying sufficient energy to the printed outline to cause the substrate to weaken at the outline.

This invention also provides apparatus for producing a laminated object, the apparatus including printing means for printing on at least some of a number of pieces of substrate a desired cross-sectional outline, binding means for
15 binding the substrate and energy generation means for applying sufficient energy to the printed outline to cause each substrate to weaken at the outline.

It will be appreciated that the process of the present invention greatly improves on the prior art LOM technique, since it can enable the production of three-dimensional objects by apparatus such as photocopying machines or printers,
20 for example. Preferably, these are guided by a computer in a similar manner to prior art LOM apparatus, so that the computer instructs the deposit of each desired cross-sectional outline on each substrate, to result in a stack of substrates.

It is within the scope of this invention to employ a laser, although a laser is not
25 necessary for the working of the invention in all embodiments, as is the case with the prior art technology described above.

The substrate may be selected from a wide range of materials, including without limitation woven and nonwoven materials, membranes and materials made from cellulose or organic fibres.

30 Optionally, metal or conductive or other material may be incorporated in some or all of the substrate. The substrate may be a collage of pieces. If the substrate is made from a relatively malleable material, such as metal, the object may be modified after manufacture, by using a hammer, for example.

Other choices of suitable substrates will be apparent to persons skilled in the relevant arts.

A preferred material is paper, since it is readily available and inexpensive.

However, the substrate may comprise a single layer of any suitable material, including not only paper but also bulk construction material, material of lattice construction, silicon chips or wafers, or other circuit board material, and so on.

The substrate need not be planar, however: it may be three-dimensional.

Further, the substrate may be multi-layered, for example, to comprise a laminated material, optionally with different compositions through the layers.

10 The substrate may form a "lattice" with areas of different electrostatic charge, so that printing on the substrate reacts differently, depending on location on the substrate.

The substrate may be made from mesoporous silica, in which case the printing material may be sodium, zinc, lead, mercury or biological molecules.

15 It is also contemplated that a substrate may incorporate plating material or that plating material may be inserted between substrates in a stack. By controlling the deposition of plating material, if necessary by use of insulating material, the three dimensional object may be formed on a layer by layer basis. The substrates may be weakened at the outline, for example by dissolving all
20 material except the plated object.

As part of the substrate, or included in the substrate stack, may be material having the ability to provide insulation, reinforcement, electrical conduction, electrical resistance, and so on. The material may further have other qualities; for example, it may be fusible, may be fire retardant or fire accelerant. The
25 material in the substrate or the substrate stack, or the printing itself, may act as an aerial or incorporate electrical contact points or areas. Some or all of the material may act as receiver, transducer, inverter, transponder, anode, cathode, etc.

In one embodiment, a stack of substrates may in effect form a chemical power
30 cell which when activated, for instance by the addition of a suitable liquid or completion of an electrical circuit, can cause a slow reaction in which ions transfer to or from the outline. As an example, the outline may be printed of carbon, some or all of the substrates may comprise or contain magnesium dioxide. Immersion of the stack in an ammonium chloride bath will result in the
35 formation of a Leclanche cell. Activation of this cell will result in electron

transfer to affect the outline and weaken the substrates at the outlines. As will be apparent, other solutions may be substituted for the ammonium chloride bath. Similarly, the outline may be of copper, for example, with the substrates containing zinc; the stack would then be lowered into a sulphuric acid bath.

5 Power cells may be connected in series or in parallel, if desired.

Alternately, a stack of substrates or substrate components may effectively form a dry cell battery or a computer chip. In either case, this can effect weakening at the outline, or may effect the deposit of printing material on the outline. This form of the invention is likely to be slow acting, but may be
10 suitable in cases where the object to be formed is complex.

In another, similar embodiment, the reaction need not be slow: it can be a fast one, for example.

Further, it is an option that ions can transfer from one location or component in a substrate to another location or component.

15 Further, a laminated or multi-component substrate may itself form a battery.

Different pieces of substrate may carry a positive or negative charge, so that the stack can form a capacitor, a battery or circuit (even a complex circuit). Different parts of the outline may also carry a positive or negative charge.

One or more pieces of substrate, or material included in the stack, may have
20 electrical contact points; the stack may include facility for power connection or for transmitting of energy.

One or more pieces of substrate may act as a cationic membrane or item of similar use.

The stack of substrates may be composed of photosensitive film or paper or,
25 for example, photographic emulsion on a carrier. As a further development of this concept, different layers in the stack may react differently to light intensity or frequency, which can result in different effects, depending on the aim. This concept can be used to bind the stack, or to bind parts of the stack, or to bind stack components, if some of the substrate or parts of the substrate or
30 components can become adhesive or can melt or set or dissolve or degrade or remain unaffected under particular conditions. In these embodiments, the

printing can be carried out by suitably directed light, including light generated by a laser.

It is within the scope of this invention that one or more of the substrates, but not necessarily all the substrates (including the option of the printed layer),
5 may be laid down by spraying, dusting or vacuum deposition or other suitable methods. The substrate may itself be laid down as part of the printing step. Further, the substrate may comprise a line or profile, for example.

The substrate pieces or individual layers of substrate may be variously coloured, to assist machining or other handling of the object. For example,
10 when the substrate is paper, and a number of substrates is used, the layers of paper may be coloured in one selected colour to a particular depth in relation to the object to be formed, and in a different colour or colours for all or some of the remaining depth. This may assist in locating a particular position on the object for machining during post-production, for example.

15 A surface of each substrate piece, or part thereof, may be variously coloured or refractive, not only to assist machining or other handling of the object, but also to assist identification, for instance.

As another variation, the part of the substrate to be incorporated in the object may be one colour, such as green, while the part of the substrate which will be
20 waste may be another colour, such as red. This can provide a visual distinction between the object and the waste material. The same technique may be used to provide a visual distinction between different parts of an object or between different objects.

The printing step includes printing by hand, painting with a brush, injection into
25 the substrate by a syringe, offset printing and all other useful forms of printing. However, the printing step includes more than traditional printing. For example, printing may be achieved by bubble jet printing or xerography. It is also within the scope of this invention that printing may be achieved by using the copypress process, such as that marketed by the OCE organisation, in a
30 similar way to the xerographic process.

As is known, in xerography, poor electrical conductors, such as selenium, which can absorb light energy to allow a current to flow when a voltage is applied, are used as an insulating layer on a plate. This permits an exposure of an image to be made. The image is made visible by sprinkling over the

exposed plate a toner comprising a special charged powder which carries an opposite charge to the initial charge applied to the plate and insulating layer. The powder adheres to those areas which have retained their charge. A print is obtained by covering the plate with paper and then applying a charge of the
5 same polarity over the back of the paper as the initial charge applied to the photoconductive insulating layer. In this way, the opposite charged powders are transferred to the paper surface. The powder image is then fused onto the paper by exposure to solvent vapour or heat to make the image permanent and fixed to the substrate.

- 10 The toner powder may contain a thermosetting plasticisable element as well as particles which are magnetic or electrically conductive. It is these particles which enable the image to be fused to the paper. At present, these particles are scavenged for reuse.

It is within the scope of the process of the invention that the particles be
15 retained on the substrate to assist in weakening of the substrate at the outline. Indeed, it may be possible to use these particles without the thermosetting plasticisable element to form the outline. Subsequently, the substrate may be sprayed, for example, with a thermosetting plastic dust which will melt upon exposure to heat and cause the substrates to bond together.

- 20 It is to be noted that the substrate may contain selenium and may replace the selenium plate in the conventional xerographic process, obviating the need for the selenium plate.

As another option, the thermosetting plasticisable element may be applied to the substrate first. The electrically conductive or magnetic particles or
25 electrostatically charged particles may then be applied to the substrate to form the required outline. Subsequent application of heat would cause the substrates to bond together.

As a further example, the substrate may be embossed (such as by using a hot metal stamp and a sheet of foil to transfer metal onto the substrate) and this is
30 encompassed by the printing step of the invention.

Further, as well as printing an outline, it is within the scope of the present invention to provide other printing or marking, such as part numbers, etc, or colouring on the object. It will usually be preferred that this other printing or marking is not capable of taking part in the weakening step.

The printing step may also be carried out by electrostatic means and may, for instance, deposit what is in effect an electrical path or circuit board.

Alternately, a separate circuit board or electrical path may be incorporated in the object or stack at any stage in manufacture or after manufacture.

- 5 It is a further option that printing may be effected, for example, by a recording head where the substrate comprises or includes magnetic tape. The recording on a magnetic tape substrate by the recording head may alter or destroy the tape at the outline or permit destruction at the outline at a later stage.

If the substrate comprises or includes magnetic material, the polarity may be
10 altered to cause the substrate to bond to a substrate immediately above or below it. This can take place with the printing step, so that the first substrate is bonded to the second substrate in line with the outline. A laser, for example, may be used to cut the substrate at the outline.

As a further option, the outline may be set in the substrate by an electrical
15 current, for example, with subsequent exposure to light or other influence capable of "setting" the outline or the remainder of the substrate.

The printing and weakening steps of the process of the invention may make use of known photocopy technology. For example, the material to be deposited during the printing step may include magnetic carrier balls made, for
20 example, of iron. Toner may be used to fix the carrier balls on the desired outline.

Subsequently, heat or energy applied to the substrate may be capable of heating the balls to a temperature sufficiently high to destroy the substrate at the outline. The carrier balls can be recovered (e.g., magnetically) and
25 recycled or disposed of.

In a further embodiment, some or all of a substrate may have incorporated in it carrier balls or selenium particles or the like, which can be energised to attract toner particles. The toner particles may also be resident in or between sheets of substrate.

- 30 In some conventional photocopying or laser printing processes, the paper is charged. Exposure to the image to be copied or printed alters the charge which then permits deposition of toner, the toner being attracted to the portions of the paper subject to the charge. It is within the scope of the

invention that the printing step includes the charging of a liquid "toner" and alteration of the charge at the outline. For the purposes of this embodiment, the substrate itself may be liquid.

Preferably, if more than one substrate is used and it is desired to bind them, 5 the substrates are bonded together by suitable means, including those of the prior art: use of a hot roller to melt adhesive with which a substrate is coated. Any other appropriate method of bonding may be used. As an example, the substrate pieces may be bound together by electrostatic force or friction. As another example, an adhesive for the stack can be incorporated by such 10 means as thermosensitive sheets interleaved with the substrate pieces, the thermosensitive sheets melting upon the application of heat and effectively binding the stack together. Further, the method of bonding the stack may not apply to all of each piece of substrate, but only to part, such as the region in which the object is to be formed.

15 The printing step usually involves the deposit of a suitable material on the substrate. The nature of the material to be deposited will depend on the intended purpose of the product, and on any method of causing weakening in the substrate, and suitable choices will be apparent to one skilled in the art. Without limitation, the following may be mentioned as examples: solid, liquid, 20 gel or gaseous material including but not limited to ink or toner which can be activated magnetically, electrically, chemically or by sound, light (visible, infra red and/or ultraviolet), irradiation, temperature change, or other energy, including microwaves, X-rays and electromagnetic vibration, electroplating ink, mixtures, compounds, colloids, aggregates, polymers including polypyrrole 25 and polyaniline, monomers, plastic, metal, alloys, ceramic, magnetic particles, enzymes, proteins, doping agents, organic material, biological material, resins, dielectric material, metalised ink, reflective ink (which may permit focussing of energy), particles or arrays which are photoelectric, photovoltaic, photoemitting, luminescent or radioactive. A further example is a pyroelectric 30 polymer described in US Patent Specification No. 5,604,292 (Stenger-Smith). Yet a further example is a conjugated amino-substituted phenylamine polymer. Super-cooled helium which may be printed on a substrate of mesoporous silica, for instance, is another example.

As an example, the ink may consist or contain of quartz crystals or otherwise 35 tunable crystals, receptive to transmissions, such as fm, am or ultrasound or other frequencies. The ink may have mixtures of crystals, some of which may

be quartz, and some piezoelectric ceramics or polymers, for instance. In this case, waves or vibrations can cause electrical discharge from an outline to another outline or from an outline to a substrate, for instance. The electrical discharge provides energy to alter the outline.

5 As a development of this idea, the outline may be "seeded" with suitable crystals, such as quartz. The substrate containing the outline is lowered into a bath of suitable crystal growing solution, so that the outline grows and weakens the substrate. A suitable environment (for example, as to temperature and pressure) may be required.

10 As another example, the ink or print material may include iron in the first instance and the magnetic or conductive properties of this may be changed in selected areas by forming an alloy.

The outline may consist of a single atom or line of atoms, or a single molecule or line of molecules. This can have important ramifications in the field of
15 microcomputers, for instance.

The outline may be formed from a material such as a semiconductor or an electroconductive plastic. An example of this is polyacetylene which is doped by iodine and/or other suitable impurities. The outline may comprise the material, or the material may be used as a molecular sieve, so that removal of
20 the material from the substrate leaves molecules or atoms of the impurities or other substances, which then form the outline.

The outline may also be formed from a material which is a conductor. In the example of polyacetylene which is doped by iodine or other impurities, it is to be understood that iodine together with other impurities may form the doping
25 agent.

The outline may be formed by any suitable means, including by hand or using a computer. Several different methods of forming the outline are discussed herein.

The outline may also be formed by such techniques as electroless plating or
30 displacement plating. The outline may be worked by those techniques. Further, the outline may be formed or worked by such techniques as electroplating, metal plating or ion plating.

It will be appreciated that the process of the present invention greatly improves - on the prior art techniques, since it can enable the production of products by apparatus such as photocopying machines or printers, for example.

Preferably, these are guided by a computer, so that the computer instructs the
5 deposit of each desired cross-sectional outline on each substrate or stack of substrates.

As a further option, some or all of each substrate may comprise cells filled with liquid. A suitable printing means for such substrates may deposit ink, toner or
doping agent, for example, onto or into the cell or the liquid it contains, similar
10 to a tattooing process, for example. Such substrates may be bonded before or after printing.

By way of further development of this idea, the substrate may comprise a pool of liquid and print may be deposited onto the surface of the liquid. The layer of liquid bearing the deposited print may then be transported, mechanically or
15 electrically, for example, to a location on a stack. This is analogous to the offset printing process. As an alternative, the layer of liquid may be already located on the stack before printing. After printing, if appropriate, the stack may be lowered into the liquid. The deposited print may cause the liquid to cure or set at the outline. Optionally, the liquid apart from the deposited
20 outline may be repelled or removed, leaving the printed outline.

In another related embodiment, an ink may combine with a portion of the liquid and cause it to set, thus forming a sheet or layer of substrate. The outline may be defined by the ink in the same step or in a further step.

The setting can take place by the mixing of the ink with the liquid or by
25 application of energy to the ink. In this regard, the ink may act as a catalyst or a pre-catalyst or a preparatory step in the altering process.

Where a xerographic apparatus is employed, the outline may be formed by attracting electrostatic toner or other print material to the outline, as is the case with known photocopiers. Where feasible, this can be achieved on a micro
30 level.

Further, this invention contemplates selective weakening of the substrate at the outline, for instance by using different types of deposited material. As an example, one type of material may be affected by a field of a particular intensity, such as 150,000 Hz, whereas another type of material on the same

substrate may be affected by a substantially stronger field or a different type of energy. The strength of the fields or energy applied will determine the lines at which weakening occurs. It is to be understood that different substrates and their respective outlines (defining the object or dicing waste material) in a stack may be affected or worked by different energies and modes of delivery.

The nature of the printing materials can be very wide. For example, these can include cells, including foetal cells, mitochondria, DNA, viruses, bacteria, other living organisms (e.g. maggots, leeches), chromosomes, white blood cells which can react with red blood cells, sperm which can react with ova or other symbiotic pairs which can work together to weaken or destroy the substrate at the outline. As will be readily appreciated, some of these may be capable of using the substrate or the outline as food for a colony to be formed, in order to weaken or destroy the substrate at the outline.

The printing material may be a killing agent, a hormone or gene shear, for example. When the printing material is DNA, for example, it may be deposited on or into cellular material which comprises the substrate or printing on a substrate.

To perform the process of the invention, it is not necessary to print on every piece of the substrate. For example, it may be feasible to print only on every second piece of substrate, or even less frequently. If a substrate is multi-layered, it may not be necessary to print on every layer. It may be necessary to use an outline of sufficient reactivity to cause weakening in adjacent or nearby unprinted pieces, in this embodiment.

In connection with the binding of substrates in the process of the invention, it is to be understood that the term "binding" includes mechanical engagement as well as binding by electro-static force, electrochemical force, glue and friction, for example.

The binding step may be carried out before or after the printing step. In addition, the substrate may be printed, bound and then further printed or treated.

The binding step includes joining substrates at selected places and joining substrates in a "lightweight" manner, so that they may be detached.

The binding step may be carried out using through-hole plating or bonding, in which substrates with varying holes or apertures in a chosen pattern are printed with an outline, for example by plating to a cathode. The printing step can combine the binding step by the deposited material seeping through the apertures or holes in the stack, or by the deposited material migrating through the apertures or holes by capillary action, magnetic attraction or repulsion, electric attraction or repulsion, gravity or electrostriction. It may be possible to effect stepped electrical connection of substrates in a stack by this means, although it may not be necessary that each of the substrates be connected to the others electrically. A three dimensional object or, alternatively, the waste material, may be "turned on" layer by layer in this embodiment.

In order to separate the desired three-dimensional object from the surrounding parts of the substrate, various methods may be used. One preferred method is to induce an electric current in the outline, or at least the outer boundary of the cross-sections. This may be achieved via high frequency induction or using a capacitor to which high frequency voltage is applied, for example, and can generate sufficient heat in each outline to cause the substrate to weaken (for example, by burning) at the outline. Where the material to be heated is a poor or non-conductor, use of dielectric heating in a capacitor field may be more appropriate. It is to be further understood that the outline may be adapted to be used as a capacitor or dielectric.

High frequency heating is well known. Heat develops within the material to be heated (in the case of the present invention, the printed outline), with the energy supplied per unit volume of material being as great as the material permits. Heating is localised directly and accurately to the place to be treated and may be carried out at great speed. In the case of dielectric heating, the generation of heat throughout the material is uniform, so far as the material itself is homogeneous.

Examples of printing material which may be suitable for use in conjunction with high frequency heating are inks or toners containing metals or plastics. It is preferred, in this embodiment, that the substrate is substantially inert, so that the application of high frequency heat to the printed outline will generate sufficient heat to burn the outline without burning the remainder of the substrate. In this way, the substrate can be weakened or burnt through at the outline of the desired three-dimensional object, in a manner similar to the prior art LOM method using a laser.

As examples of material suitable to be used in the printing step of the invention, electroplating ink containing platable particles should also be mentioned, as well as organic or inorganic compounds or mixtures, photodegradable, photo-combustive, electrocombustive, soldering, electro-
5 soldering, electrosintering, pyroelectric, photoreactive and photo-synthesising material and material which can act as a lens, such as electrical or magnetic lenses.

The printing step may also be carried out in other ways. Examples are as follows. A mask, such as a masking stencil, may be used to mask what is not
10 to be exposed to subsequent energy. In this embodiment, the exposed area may form the outline or the unexposed area may form the outline. The substrate may be or include a light setting resin. A combination of a mask and a photo setting resin may be used. A printed mask is an option. It may be possible to use electrostriction. The printing step may involve exposure of the
15 substrate several times, using a different mask on each or several occasions. This can be useful, for example, if exposure of the substrate to different wave lengths of light can result in different effects.

Optionally, substrates and stack components may be masked. In addition, a mask may act like a filter or shield against one type of energy, or frequency of
20 light. A mask may be a good conductor or may permit exposure of the underlying material to light of a different frequency or energy, such as infrared or ultraviolet, or x-rays, for example. A mask may be lead based and provide shielding so that unshielded surfaces of the substrate may be destroyed, for example, by x-rays. A mask may be permanent or removable. A mask may
25 be used in connection with editing. A mask may insulate. It is possible to dope a mask into or onto a substrate. It is further possible to use a mask as a shield to permit angled cuts of the substrate - for example, to permit 45 degree cuts by a laser but not 90 degree cuts. A mask may be temporary; it may be effective for a chosen period and then start to break down. The mask may
30 have a variation in thickness from one place to another. This can be useful in controlling layer weakening or cutting and could be used to produce patterned finishes. In connection with the weakening step of the process, in one embodiment destruction of the outline may generate light of sufficient intensity to weaken the substrate, much like a contact laser.

35 The process of the present invention involves weakening along the outline. As a variation, a change can be induced in the nature or composition of some of

the substrate - for example, by converting some of the substrate into a brittle form, while the rest remains elastic. The term "weakening" as used herein encompasses "altering" in this sense.

This invention is not limited to weakening of the substrate from above the
5 stack, as is the case with the prior art LOM system. For example, it may be possible to cause the weakening step to commence from below the stack, or from some location on the interior of the stack.

As a further development, the material printed on the substrate may be capable of acting as an anode or cathode, including an anode or cathode in an
10 electrolytic cell, so as to attract deposited metal or other substance, for instance. As electrolysis proceeds, the outline grows and the substrate is weakened at the outline, ultimately forming the object. The concept of weakening the substrate at the outline encompasses other techniques of "growing" on the outline, such as crystallisation.

15 It is to be understood that the substrate may alternately repel deposited metal or other substance, for example. When electrolysis proceeds and material is attracted to the outline, the outline grows by deposition of attracted metal or other substance. The weakening of the outline can be compared to the breaking of rock by invading tree roots, the rocks being the substrate and the
20 printing representing the tree roots.

The cross-sectional outline, which may, of course, include interior printing, including complex interior patterns or solid block printing, may be printed on both sides of the substrate, which in addition may be of double or extra thickness, in which case the weakening process may operate from each side
25 of the substrate.

The outline need not be continuous; it is within the scope of the invention that the outline is comprised of dots or dashes, for instance. Optionally, the outline may be formed from particles, including atoms or molecules or parts of these, of metal or other suitable material which may be attracted to the desired
30 outline (e.g., cathode or anode) formed by electroconductive plastic or other material or materials which can hold a charge, for instance. It is within the scope of this invention to use compounds or elements which can migrate to the desired outline under electric, magnetic, chemical or mechanical influences.

If desired, the object or parts thereof formed by the process of this invention may act as an anode or cathode with individual layers of substrate having different degrees of resistance, if required. In this way, the object may be plated in a plating bath, or other plating environment, resulting in different
5 effects, depending on the resistance in the layers of substrate. This is especially useful in moderating the throwing power in the plating process.

It is to be understood that the process of the invention includes the printing on or in a substrate surface.

A stack of substrates may be gas permeable so as to form, for example, a
10 fluorescent or neon tube, the weakening step being effected by gas-borne deposition of suitable material, including ions, elements, compounds, colloids to the printed outline. Alternately, the stack of substrates may be liquid permeable in much the same way.

The weakening of the outline may be carried out on a particular substrate after
15 that substrate has been bound to the stack. In prior art LOM, for example, that marketed by Helisys Corp, of California, USA, each sheet is bound to the stack and the profile cut. Successive sheets are treated the same way. The process of the present invention can be carried out in the same way, in that each sheet of substance is bound to the stack, printing takes place before or
20 after binding, and weakening of the outline on that sheet of substrate follows. Another sheet is advanced, bound, and so on.

The energy used to weaken the substrate at the outline may be supplied by electromagnetic radiation or by microwaves or radiowaves, for example.

As well as the possibility that the outline may be formed by one or more
25 streams of electrons beamed at the substrate, the outline may be further worked by these means. The electron beam may perform either the printing or weakening steps or both together, effectively burning through or working the substrate as the outline is traced.

In a further development, using known technology relating to printing pixels or
30 blinding pixels, the substrate may be printed with a series of excitable "dots", which can be excited by an electron beam, for example, which can effect weakening or destruction of the substrate at the desired outline or which can enable joining of the substrates.

In connection with the formation of the outline from a doping agent, weakening of the substrate may occur upon application of the doping agent or after the application of appropriate energy or other means to the doping agent or doped substrate, or to the undoped part of the substrate (if any).

- 5 Electrostriction may be mentioned as another method of weakening the substrate.

The energy to weaken the substrate at the outline may be applied to the outline or to the substrate.

- It will be recalled that, in order to facilitate removal of excess material from a
10 three-dimensional object formed by prior art LOM techniques, it is usual to use the laser to dice the paper outside the outline. A similar technique may be used in connection with the process of the present invention, by printing the excess substrate, for example, in a cross-hatched or dicing pattern, at the same time as printing the outline.

- 15 Application of a suitable energy in the form of, for example, high frequency heat will not only weaken the substrate at the outline, but also weaken or alter the excess substrate in sections, facilitating removal of excess substrate at the desired time, which may be during or after binding and/or stacking.

- Prior art LOM techniques typically produce a 300 mm high object over about
20 three days. It is estimated that the process of the present invention, at least in some embodiments, will be able to produce 24 metres of object/s per day. This in itself is a significant improvement over the prior art. However, there are further ramifications. The speed of which the process of the present invention is capable will permit LOM methods to be used to produce large scale objects
25 in a timely and economical manner. Further, several printers may cooperate to provide a large scale printed outline on a substrate or the required printed outlines on several substrates (at the same time) and this would further reduce manufacture time.

- The accuracy of which the process of the invention is capable will establish a
30 new standard, especially when it is considered that the outline may be microscopically small, to consist of single atoms, for example. This is a considerable advantage over prior art LOM techniques, where the accuracy is dependent on the minimum cross-section of the laser beam.



It is to be understood that the process of the present invention is not limited to the use of high frequency heating. For example, it may be possible to achieve the desired result by applying an electric current to an outline which outline which has been marked by a suitable toner or ink such as MICR (magnetic
5 image character recognition) toner, which is capable of carrying an electric current. Because of the resistance of the outline, the substrate (e.g., paper) should be destroyed or weakened at the outline.

As another option, the desired result may be achieved by using a printing material containing aluminium, for example, or metal ions, similar to
10 electroplating solutions.

It is within the scope of the method of this invention to apply the required energy to each substrate or outline after printing and/or binding, or to apply the energy to a stack of substrates or outlines after printing and binding.

In addition, the energy may be supplied by an electromagnetic coil, or by an
15 oscillating or direct current or by light or by chemicals, for example. In one embodiment, the print material is activated by an accelerator or similar substance, or by infra-red or ultra-violet light. In another embodiment, the substrate is printed with a material which is photosensitive, so that planned and timed exposure to light weakens or destroys or alters the substrate at the
20 outline.

In another embodiment, the outline may be earthed (or alternately, the substrate may be earthed) and a current applied to weaken the substrate at the outline.

In yet another embodiment, the outline may be formed by one or more
25 streams of electrons or particles beamed at the substrate, in an environment similar to that used in a cathode ray tube (a vacuum). The electron or particle beam may perform either the printing or weakening steps or both together, effectively burning through the substrate as the outline is traced. The substrate may be located inside the vacuum environment or outside it, with the electron
30 or particle beam having sufficient energy to achieve the desired effect of tracing and/or weakening. It is within the scope of this invention that the printing and weakening steps are carried out simultaneously, by means other than a laser beam.

In a further embodiment, the outline may be traced by one or more streams of electrons or particles beamed at the substrate, substrate bearing a grid of suitable energy sensitive dots. Each dot may be selectively excited by the timed and controlled exposure to the electron or particle beam. The outline is thus formed; the reaction of the dots to the beam causes weakening of the substrate at the outline.

In a further embodiment, the outline may be formed from a doping agent. Weakening of the substrate may occur upon application of the doping agent, or after the application of appropriate energy or other means.

10 In yet a further embodiment, the outline may be formed using a substance capable of reacting with a second substance or causing a chain reaction to result in combustion or an explosion, sufficient to at least weaken the substrate at the outline. For example, the first substance may be printed on a first piece of substrate. The second substance may be printed on the next
15 piece of substrate in such a way as to penetrate the second piece and allow the first substance to contact the second substance. Depending on the nature of the first and second substances, combustion or an explosion may occur immediately on contact, or after activation by a suitable catalyst or detonator. Alternately, the first piece of substrate may be overlaid by a sheet which is
20 impregnated with the second substance, and which causes the combustion or explosion, either on contact or after activation, in a way sufficient to weaken both the first piece of substrate at the outline and the second piece of substrate in the region of the same outline.

A specific example of this type of embodiment is as follows. The substrate is a
25 sheet of carbon fibre. The outline is printed in magnesium in a non-oxygen or reduced oxygen atmosphere. Oxygen is then fed to the outline. The resultant chemical reaction weakens the substrate at the outline. This example applies both the forming an object from a single sheet of substrate and to forming an object from a plurality of sheets of substrates.

30 As another illustration, the outline formed may be light sensitive and the substrate will weaken at the outline upon exposure of the outline to a laser, even though the laser beam may not be limited to the outline. This enables laser technology to be employed without the need for accurate guidance of the laser. An accurate laser guidance system may also be used, of course, to
35 weaken the substrate at the outline.

Various features may be introduced to LOM techniques, using the process of the present invention. For example, the laminated object to be formed may be "edited", such as by a laser or drill or by hand or other known means, during manufacture or after manufacture.

5 Thus, furrows, grooves, excavations and similar changes may be effected to the object.

In addition, it is within the scope of this invention to form the object and cast additional material as the object is formed or as the substrate is weakened at the outline. In one embodiment, the object being formed by the process of the
10 invention may be used as a mould or added to with different material. A specific example of this is the formation of an object in a honeycomb pattern. Material can be incorporated in the spaces in the honeycomb as the waste substrate is removed, so that the resulting object is a composite or is reinforced, for instance.

15 The laminated object formed by the process of the invention may be further modified and this aspect is included in the scope of the invention. For instance, part or all of the object may be caused to compact. For example, a gas introduced into the interior of a hollow object may be caused to explode, thus compressing the material of the object, and making it more solid, either
20 totally or in the region bordering the interior.

As a further development of this aspect, the interior of the object may include force lines or weaknesses, so that the explosion will have a particular, desired effect.

These options may be especially suitable for use on an object made wholly or
25 principally of cellulose, for example.

In another, related option of the process of the invention, where the laminated object is formed with a hollow core or other cavity, it is within the scope of the invention to insert in the hollow core or cavity a fine particulate material and to apply pressure, so that at least some of the particulate material is forced into
30 the object. The purpose of this may be to strengthen the object, or to add some desired characteristic.

In yet another option, the hollow core or cavity may have inserted therein a diaphragm or other deformable cover which can be caused to balloon within

the core or cavity, upon the application of pressure, and enable part or all of the object to be compacted.

In some cases, the object produced by the process of the invention will have a male and a female component (or more than one of each). It may be desired
5 to make each male component or each female component more dense or solid. It is within the scope of this invention to crush or compact the female component around the male component, thus making the female component more dense or solid. Equally, it is within the scope of this invention to crush or compact any of the male components within the female components, thus
10 making each such male component more dense or solid. As a further option, material in the male component may be introduced into the female component, or vice versa, in order to harden the male and/or the female component. The desired result may be male and female components of differing densities.

As another method of making the object, or certain surfaces of it, more solid,
15 liquids containing setting agents or cement may be poured into or onto the object, in order to harden a desired surface or make the object more solid. The object may then be able to attract or repel certain substances, such as water but not oil, for example.

As yet another aspect of changing characteristics of the object after
20 manufacture, a liquid medium may be used to carry solids or ions which may be caused to migrate to selected parts of the object upon application of an electric current to the substrates, the outlines or the object.

If desired, liquid or suitable gas may be introduced into one or more cavities of the object of the invention, which is subsequently subjected to centrifugal
25 force, to urge the liquid or gas into the object, even to its outer boundaries in some cases.

The outline printed by the xerographic process may be used as an electrostatic sieve. For example, a suitable hydrocarbon may be poured into the object after manufacture to increase density of some or all of the object, by
30 filling up any voids. The hydrocarbon may carry metalised particles, or carbon, or plastic particles, for example, and deposit these in regions of the object or on part or all of its surface.

If desired, heat may be applied to homogenise or stabilise the resulting product or the deposited material.

The material may be deposited in or on some layers of substrate or some regions or parts of the object. The aim may be to produce an object with different physical properties in the different parts. For example, some parts of the object may be harder or more dense than others. Some parts may absorb 5 shock more easily than others.

An object may be filled with a substance such as a suitable resin which, upon setting, substantially increases the density and strength of the object, for example.

On the other hand, all or substantially all of the object may be hardened 10 because of the intended purpose for the object. For instance, the object manufactured in accordance with the process of the invention may be used for die sets, mandrels, press tools and other tools. The object may itself be a working part.

It is within the scope of the process of the invention that sprues or channels 15 are formed within an object or stack, either during manufacture or after manufacture. If the channels are to be incorporated during manufacture, tubes or similar conduits may be laid down during the process. If the channels are to be formed later, this may be achieved by drilling the manufactured object for example.

20 Similarly, the object of the invention may contain veins or highways providing electrically conductive paths or electromechanical passageways. An object may have one or more of these. They may be capable of acting as an anode or cathode, for example. Such paths may be useful in enabling more detailed and thorough electroplating of the object. for instance. Such processes as 25 electroplating may be facilitated by selectively applying pressure or vacuum to an object in a similar way to that disclosed above in connection with particulate material. For example, all or part of an object made according to the invention may act as a cathode for the deposit of chrome, the object being at least partly permeable and pressure or vacuum being applied to assist in 30 penetration of the chrome into part or all of the object.

The veins or highways referred to above may permit the passage of light, nutrients, fluid, suspension or electrolytic solution, for example.

In the description above, frequent reference is made to the treatment of an object. It is to be understood that many of these treatments can be applied to the stack of substrates.

In addition to this, a destroyed and excavated outline may be used as a
5 mould.

In addition, more than one object may be formed in a stack at once. Each object may be formed on or in an already existing structure or stack.

Structural components may be added or incorporated before, during or after manufacture, so that, for example, it may be possible to manufacture a three
10 dimensional object which has a part wholly captive inside the object. In addition, protrusions or braces, handles, hinges, bearings or other components may be added to the object or stack. The object may even be formed on an already existing structure.

Structural reinforcing can be added during manufacture, for instance to brace
15 a particularly high object and prevent it from toppling over. If desired, structural reinforcing can be in-built into the substrate pieces.

Structural reinforcing can be used not only to brace a particularly high object and prevent it from toppling over, but also to prevent it being crushed by its own weight. Structural or other features of substrates may cooperate with
20 features in other substrates, for example in the manner of hooks and eyes.

Where the outline is "grown" by deposition, such as by crystallisation, it may be desirable to alter the substrate outside the outline, so that the waste substrate (which can form a jelly, for example) can be pushed aside by the growth.

25 In a particularly preferred embodiment of the process of the invention, the substrate is paper and the outline comprises a thin narrow film which is affected by microwaves, preferably by exhibiting high microwave loss, the paper having a low microwave loss characteristic. In this embodiment, the application of sufficient microwave energy results in weakening of the
30 substrate at the outline.

This invention is also concerned with etching, printing or marking procedures.

It is well known to etch an intaglio plate, for example. The plate is prepared by coating it with a wax or other acid-resistant layer. The desired path is engraved in the wax, using a sharp instrument to expose the metal. The metal plate is immersed in an acid bath. The acid eats away the exposed metal, etching the desired path into the plate.

It is known to etch or otherwise mark substrates such as silicon chips or wafers in order to produce printed circuit boards and similar products. Laser beams can be employed in this regard.

For convenience, the term "print" and its derivatives will be used hereunder to encompass the procedures of etching, marking, printing and similar procedures where a track or path or pattern or marking or outline is applied to or worked into a substrate.

The term "mark" and its derivatives will be used to include outline, track, path and pattern.

It has now been discovered that printed substrates may be produced without the need to follow intaglio printing procedures and without the need to employ a laser. Accordingly, this invention also provides an improved printing process, comprising printing on a substrate, and treating the printing to form a mark.

This invention also provides an object manufactured by the improved printing process of the present invention.

The substrate may be selected from the wide range of materials referred to above. Different areas of substrate or printing may carry a positive or negative charge. One or more areas of substrate or printing may have electrical contact points.

The substrate may be composed of photosensitive film. As a further development of this concept, different parts of the substrate may react differently to light intensity, which can result in different effects, depending on the aim.

It is within the scope of this invention also that the substrate may be laid down by spraying, dusting or vacuum deposition or other suitable methods. Further, the substrate may comprise a line or profile, for example.

Further, as well as printing the desired line(s), it is within the scope of the present invention to provide other printing or marking, such as part numbers, etc, on the substrate.

The printing step may also be carried out by electrostatic means and may, for instance, deposit what is in effect an electrical path or circuit board.

Two or more substrates may be bonded together by suitable means, including those of the prior art: use of a hot roller to melt adhesive with which a substrate is coated. Any other appropriate method of bonding may be used. As an example, the substrate pieces may be bound together by electrostatic force. As another example, an adhesive for a stack of substrates can be incorporated by such means as thermosensitive sheets interleaved with the substrate pieces, the thermosensitive sheets melting upon the application of heat and effectively binding the stack together. Further, the method of bonding the stack may not apply to all of each piece of substrate, but only to part.

The printing step usually involves the deposit of a suitable material on the substrate. The nature of the material to be deposited will depend on the desired further treatment and suitable choices will be apparent to one skilled in the art.

Without limitation, the examples already listed above may be applicable to this invention also.

As an illustration, a metal atom or particle, or other conductive material, for example, carbon, may be deposited on a ceramic or silicon substrate. A second substrate of the same or a different material may be laid over the first substrate. The atom or particle can form a track or conductive location in the assembly, to act as a printed circuit, for example.

The printing may be formed from a material such as those already mentioned above.

Further, this invention contemplates selective altering of lines on the substrate, for instance by using different types of deposited material; examples have already been given, above, and are applicable here.

In order to treat the printing to form the mark, various methods may be used. One preferred method is to apply energy to the printing, such as by inducing an electric current in the printing. This may be achieved via high frequency

induction or using a capacitor to which high frequency voltage is applied. Other methods include application of light, exposing the printing to a reactive compound or exposing the printing to a plasma.

In order to cause the mark to be etched, various methods may be used. One preferred method is to induce an electric current in the mark, or at least parts of it. This may be achieved via high frequency induction or using a capacitor to which high frequency voltage is applied, for example, and can generate sufficient heat in each mark to cause the etching (for example, by burning) of the mark. Where the material to be heated is a poor or non-conductor, use of dielectric heating in a capacitor field may be more appropriate.

The printing need not be continuous; it is within the scope of the invention that the printing is comprised of dots or dashes, for instance. Optionally, the printing may be formed from particles, including atoms or molecules, of metal which may be attracted to the desired line formed by electroconductive plastic or other material which can hold a charge, for instance. It is within the scope of this invention to use compounds which can migrate to the desired line under electric, magnetic, chemical or mechanical influences.

The substrate with printing may be exposed to a compound which reacts with the printing to form the mark, such as an oxidising atmosphere. Alternatively, the substrate with printing may be placed in an inert atmosphere and exposed to electromagnetic radiation to energise the printing. As a further alternative the substrate with printing may be exposed to a plasma.

The mark, which may, of course, include interior printing, including complex interior patterns or solid printing, may be printed on both sides of the substrate, which in addition may be of double or extra thickness.

The effect of the printing on different areas of the substrate when treated may be varied by varying the physical dimensions of the printing or the chemical composition of the printing may be varied, so that sections with higher printing have a greater effect on the substrate compared to the lower sections. Similarly, the width may be varied of printed lines. In a similar manner, the chemical composition may be varied so that the efficiency with which the exiting energy is absorbed varies. Thus one section may absorb the applied energy to a higher degree than another section and so have a greater effect on the substrate.

The accuracy of which the process of the invention is capable will establish a new standard, especially when it is considered that the mark may be microscopically small, to consist of single atoms, for example. This is a considerable advantage over prior art techniques.

- 5 As an option, the desired result may be achieved by using a printing material containing aluminium, for example, or metal ions, similar to electroplating solutions.

It is within the scope of the method of this invention to apply the required energy to each substrate after printing, or to apply the energy to a stack of
10 substrates after printing.

In addition, the energy may be supplied by an electromagnetic coil, or by an oscillating or direct current or by light or by chemicals, for example. One embodiment, the print material is activated by an accelerator or similar substance, or by infra-red or ultra-violet light. In another embodiment, the
15 substrate is printed with a material which is photosensitive, so that planned and time exposure to light alters the substrate at the mark.

In yet another embodiment, the mark may be formed by one or more streams of electrons beamed at the substrate, in an environment similar to that used in a cathode ray tube (a vacuum). The electron beam may perform the printing
20 step, effectively burning through or into the substrate as the mark is traced. The substrate may be located inside the vacuum environment or outside it, with the electron beam having sufficient energy to achieve the desired effect of tracing. In a further embodiment, the mark may be formed from a doping agent.

- 25 In yet a further embodiment, the mark may be formed using a substance capable of reacting with a second substance to result in an explosion, sufficient to at least etch the substrate with the mark. For example, the first substance may be printed on a first piece of substrate. The second substance may be printed on the next piece of substrate in such a way as to penetrate
30 the second piece and allow the first substance to contact the second substance. Depending on the nature of the first and second substances, an explosion may occur immediately on contact, or after activation by a suitable catalyst or detonator. Alternately, the first piece of substrate may be overlaid by a sheet which is impregnated with the second substance, and which
35 causes the explosion, either on contact or after activation, in a way sufficient to

etch both the first piece of substrate with the mark and the second piece of substrate in with the same mark.

As another illustration, the mark formed may be light sensitive and will etch upon exposure to a laser, even though the laser beam is not limited to the
5 mark. This enables laser technology to be employed without the need for accurate guidance of the laser.

Various features may be introduced to the process of the present invention. For example, the product may be "edited", such as by a laser or drill or other known means, during manufacture or after manufacture. Thus, furrows,
10 grooves, excavations and similar changes may be effected to the product.

In addition, the product of this invention may be treated to add, for example, texture such as a quilt pattern. For example, a cup may be treated to have a textured surface. An instance of this is the production of a three dimensional product in the shape of a cone, from thin layers of substrate such as paper.
15 Each piece of paper is marked with a circle, subsequent pieces of paper having circles of increasingly smaller diameter to form a cone. Around the circumference of each circle there may be placed dots, for example, which when the cone is formed may be activated to result in a quilting pattern, or crocodile print, around the surface of the cone. It will be apparent to one
20 skilled in the art that many variations of this are possible.

As another example, the cone could be clad with a separate substrate, carrying the desired pattern.

This invention includes the concept of conducting multiple print runs, and/or using lines of different thicknesses. The latter feature could be used, for
25 instance, to build in a fuse into a circuit, the electrical path being thinner at the fuse location.

It is to be understood that the mark may constitute the electrical path in the case of conductive products, or some or all of the remainder of the substrate may comprise the path.

30 The invention also provides an ability to cut the substrate. For example, a line may be printed onto a substrate and then excited to melt, vaporise or react with the substrate so as to cut through the substrate whenever the printing is

in place. Thus complicated cutting may be achieved by printing and then exposing the substrate to a suitable energising source.

The variations which have been described in relation to the first invention herein may be applicable to the improved printing process, and vice versa.

- 5 The improved printing process has the potential to enhance and improve present circuit board and microcomputer chip manufacture.

Further, as well as printing a mark, it is within the scope of the present invention to provide other printing or marking, such as part numbers, etc.

- It will be appreciated by one skilled in the art that many of the processes
10 referred to above may be used in combination.

The process of the invention lends itself the provision of "kits", containing for example a complete set of substrates preprinted with the desired outlines, as well as any materials needed to cause weakening of the outlines and binding material if required.

- 15 The process of the invention can be carried out in discreet steps, even at different locations. For example, a set of paper substrates may be printed with the required information (outline) by a printer. The set may then be sent to a binder for binding. The weakening step may be carried out subsequently by an end user, for example.

- 20 According to one embodiment of the present invention there is provided apparatus for producing a laminated three dimensional object, comprising printing means adapted to print a predetermined outline on each of successive sheets of substrate, each outline being printed on a sheet of substrate with an ink having a valence different from that of the substrate onto which it is printed;
25 means for laminating successive sheets of substrate; means for subjecting each laminated sheet so printed to a collapsing induction field, the intensity of the induction field and the nature of the ink on the sheets being such that the heat generated by the induced current in the ink on the sheets causes the sheets to be cut at the areas printed with such ink, thereby defining the object
30 or waste material surrounding the object.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, Figures 1 to 5 describe the production of a laminated object in accordance with the process of the invention.

Figure 1 is a plan view of a first sheet of substrate to be incorporated in the
5 laminated object;

Figure 2 is a plan view of a second sheet of substrate to be superimposed on the sheet of Figure 1;

Figure 3 is a plan view of a third sheet of substrate to be superimposed on the sheet of Figure 2;

10 Figure 4 is a plan view of a fourth sheet of substrate to be superimposed on the sheet of Figure 3;

Figure 5 is a cross-section taken along the lines IV-IV of Figure 4;

Figures 6 to 19 illustrate the production of an object, not necessarily laminated, in accordance with the process of the invention;

15 Figure 6 is a perspective view of one embodiment of a step in the production of an object of the invention, while Figure 7 is a side elevation of the drawing of Figure 6;

Figure 8 is a perspective view of a further embodiment relating to the invention, while Figure 9 is a side elevation of the drawing of Figure 8;

20 Figure 10 shows a perspective view of the sheet of Figure 8 after weakening at the outline and Figure 11 is a cross-sectional view of the sheet in Figure 10;

Figure 12 is a perspective view of the sheet of Figure 8, in a different embodiment, while Figure 13 is a cross-sectional view;

Figure 14 is a perspective view of a further embodiment of the invention, while
25 Figure 15 is a side elevation of the sheet in Figure 14;

Figure 16 is a variation of the drawing of Figure 14, in perspective view, while Figure 17 is a side elevation;

Figure 18 shows a substrate to be used in the process of the invention, having a honeycomb pattern;

Figure 19 shows the substrate of Figure 18 after it has been printed;

Figures 20 to 29 illustrate embodiments of apparatus for producing the object of the invention;

Figures 20 to 22 show one embodiment of such apparatus, Figure 20 being a perspective view, Figure 21 being a plan view and Figure 22 being a side elevation;

Figures 23 to 25 show a second embodiment of such apparatus, Figure 23 being an isometric view, Figure 24 being a perspective view from above, omitting some of the cowlings in Figure 23 and Figure 25 being a side elevation of the apparatus in Figure 24;

Figures 26 and 27 show a third embodiment of such apparatus, Figure 26 being a perspective view and Figure 27 a side elevation;

Figures 28 and 29 show a further embodiment of such apparatus, Figure 28 being a perspective view, partly broken away, while Figure 29 is a side elevation, partly broken away;

Figure 30 shows how a stack of substrates may act as a battery;

Figure 31 shows three batteries of Figure 30 connected in series;

Figure 32 shows three batteries of Figure 30 connected in parallel;

Figure 33 shows in section a side elevation of an embodiment of the invention; and

Figures 34 and 35 show sectional side views of a further embodiment.

Referring first to Figures 1 to 5, Figure 1 shows a sheet of paper 10 upon which there is printed an outline 20 intended to become part of a pyramid-like three dimensional model 30 depicted in Figure 5. Apart from printed outline 20, a matrix of lines 11 has been additionally printed onto sheet 10, dividing much of the remainder of sheet 10 into square segments. It will be appreciated that dicing of sheet 10 along lines 11 will enable ready removal of waste parts of sheet 10, surrounding outline 20.

Figure 2 shows a second sheet 12 on which is printed an outline 22, being of slightly larger dimensions than outline 20 on sheet 10. Sheet 12 is also

printed with a matrix of lines 13, dividing much of the area of sheet 12 outside -
outline 22 into small squares.

Outline 24 on sheet 14 in Figure 3 is slightly larger again. Matrix of lines 15 is
similar to matrix of lines 13 in Figure 2, for example. Figure 4 shows sheet 16
5 having printed outline 26 and matrix of lines 17.

Each of outlines 20, 22, 24 and 26 encloses a void 18, 19, 21 and 23
respectively, each void being successively larger than the last. In the case of
sheets 12, 14 and 16, matrix of lines 13, 15 and 17 respectively are extended
into the voids.

10 During manufacture and in accordance with the process of the invention, sheet
12 is laminated over the top of sheet 10, sheet 14 is laminated over the top of
sheet 12 and sheet 16 is laminated over the top of sheet 14. The waste
material in voids 18, 19, 21 and 23 and surrounding each of outlines 20, 22,
24 and 26 is removed progressively as each sheet is laminated to the next, by
15 reason of the destructive force applied to each sheet which severs the outline
in each case from the remainder of the sheet.

Figure 5 shows the three dimensional article so formed. The stepped sides of
the object in Figure 5 are exaggerated for the purposes of pictorial
representation. In practice, a pyramidal object of about 100mm in height may
20 be comprised of hundreds of sheets of substrate. Consequently, the outline of
each successive sheet would differ from the immediately preceding one by
perhaps only a small fraction of a millimetre.

Turning now to Figures 6 and 7, substrate 32 has printed thereon an outline
34. On each side of outline 34 are insulating lines 35 and 36. (As an alternate
25 construction, outline 34 could be replaced by an insulating line, while
insulating lines 35 and 36 could be replaced by outlines). Outline 34 is
carbon, while insulating lines 35 and 36 are fire retardant ceramic material. It
is to be understood that insulating lines 35 and 36 may, in another
embodiment, spread over the surface of substrate 32, to extend to its edges.
30 It should also be understood that the fire retardant ceramic material could be
incorporated into the substrate itself.

Turning now to Figures 8 and 9, substrate 38, of magnesium impregnated
material, has printed on it outline 40, from carbon, to form the letter "R" in this
illustration. The printing step is carried out under a controlled atmosphere.

Oxygen or other suitable accelerant is fed to substrate 38 to result in a burning away of outline 40. Figures 10 and 11 show how, in this example, outline 40 is removed from the whole thickness of substrate 38, leaving a portion 42. Of course, if the magnesium in substrate 38 is sufficiently reactive, substrate 38 may be completely consumed during the weakening step. The result of this procedure will be an object shaped in the letter "R".

If substrate 38 in Figures 8 and 9 were to be paper, for example, and outline 42 were to be carbon, for example, subsection of substrate 38 to an induction field would weaken outline 40 so that it could be separated from substrate 38 but without cutting completely through substrate 38, as shown in Figure 13.

In Figures 14 and 15, substrate 44 is made of suitable organic fibres and outline 46 is printed from copper. Clip 48 is intended to facilitate attachment to an electrical source. There may in fact be two identical clips 48, one on each of legs 45 and 47. The energising of outline 46 from an electrical source (not shown) can cause heating of the outline 46 and burning of substrate 44 at the outline. This operates in a similar manner to an incandescent light.

Figures 16 and 17 are basically the same as Figures 14 and 15, except that two clips 48 and 50 are shown and the shape of outline 46 is a little different. It will be readily appreciated that clips 48 and 50 would need to be supported by an extension of substrate 44 or by some other means (not shown).

In Figure 18, substrate 52 is made of a honeycomb structure of fibrous material, with each cavity filled with an unset resin. Substrate 18 thus has a plurality of honeycomb elements 54. Substrate 18 is mounted on a thermo setting film base 56 to enable substrate 52 to be joined to another substrate layer if desired.

As can be seen from Figure 19, certain of the honeycomb elements 54 have been printed in the shape of an "R". In this embodiment, printing is achieved by setting the resin in the chosen honeycomb elements. This setting can at the same time enable the unset honeycomb elements to be separated from the set elements, so that the object 58 results. If it is desired to bind substrate 52 to other, similar substrates, this may be achieved by heating film based 56.

Turning now to Figures 20 to 22, apparatus 60 has a web 62 of paper substrate 64 which is fed under guide roller 65 to pass beneath laser printing head 66. In this illustration, the outline 67 being printed is that of a V8 engine

block. Substrate 64 bearing outline 67 (and dicing lines for waste material, not shown) pass under magnetrons 68 which generate sufficient microwave energy to excite outline 67 and dicing lines (not shown), so that outline 67 is separated from the waste part of substrate 64. Outline 67 is then laminated or bound onto stack 70 on table 71 (which can be raised or lowered in accordance with requirements). The remainder of web 62, from which outline 67 and waste material (not shown) have been severed, winds onto roller 72. Guide rollers 73, 74 and 75 assist in control of web 62.

Turning now to Figures 23 to 25, in this embodiment, instead of a web of substrates, a stack of substrates 76 is supported by table 77. As each sheet of substrate 76 is drawn off the stack, it is drawn (by means, not shown) under printing head 78 and roller 80 and between guide rollers 81 and 82. Although the means of drawing substrate 76 from the stack are not shown, there may be mentioned such means as electrical means, the use of air and the use of gravity if the stack is vertical. In this embodiment, substrate 76 is paper having a layer of aluminium oxide, for example, and insulating material to insulate each sheet of substrate from the stack. The insulating layer may be thermo reactive plastic for example. Table 77 is raised as the stack of substrate 76. Each substrate 76, after printing with outline 84, passes under microwave or induction field chamber 86, in which a standing wave is set up by magnetron or other suitable source 88. Outline 84 is thus excited and substrate 76 is caused to weaken at the outline, producing, in this case, a layer for a V8 engine block. This layer is bonded to previously made layers on table 89, which is progressively lowered as the block is formed. Cowling 90 and 91 in Figure 23 has been omitted from Figures 24 and 25 for clarity.

Turning now to Figures 26 and 27, these illustrate apparatus of the invention which enables the printing onto liquid. Consequently, substrate 92 is a layer of liquid, such as catalysable resin. An outline 94 is printed on the surface of the catalysing resin by bubble jet printhead 96. The orientation of printhead 96 is adjustable along track 98. As outline 94 is printed, the resin is also set. The printed substrate 92 is then drawn across to stack 99 supported on table 100, where substrate 92 is bonded (for example, by exposure to light) to the underlying stack. Table 100 sinks correspondingly into the liquid of which substrate 92 formed part before setting.

Turning now to Figures 28 and 29, the whole of the apparatus of the invention is enclosed in a cathode ray tube 102. The apparatus is similar to that in

Figures 23 to 25, except that instead of chamber 86 and energy source 88, outline 84 is excited by electron bombardment, the electrons being controlled into a desired pattern, to result in weakening of substrate 76 at the outline 84. Outline 84 may be comprised of pixels.

5 Turning now to Figures 30 to 32, in Figure 30 two substrates 103 and 104 are shown and one outline 106. All are immersed in a bath of electrolytic material 107, to form a battery 108. Three such batteries are shown connected in series in Figure 31 and three such batteries are shown connected in parallel in Figure 32.

10 Shown in Figure 33 is a stack of substrates 110 (of paper), on some of which has been printed copper outline 112 (in this case resembling a head). Stack of substrates 110 are immersed in an electroforming bath 114. Cathode 116 is inserted as shown, to connect with outline 112. Completion of the circuit can cause weakening of substrates 110 at outline 112. Other additives or
15 wetting agents may be added to bath 14 or the substrates 110 if desired.

Turning now to Figures 34 and 35, substrate 118, which is backed with insulating (and optionally thermosetting) sheet 120 carries an outline 122, which has masking qualities in relation to light. Laser source 124 directs a beam at outline 122, perpendicular to substrate 118. Because of the profile of
20 outline 122, the laser beam has an unequal penetration through outline 122 into substrate 118. As can be seen from Figure 35, the result is an angled excavation of substrate 118.

As will be appreciated from the above, this invention includes the burning or other destruction of the outline by way of weakening the substrate.

25 INDUSTRIAL APPLICABILITY

It will be appreciated by one skilled in the art that the selection of substrate, print material and energy source will enable a vast number of techniques to be used in the process of the invention, while remaining within the spirit and scope of the invention.

30 Further, using at least some embodiments of this invention, it is possible to produce low cost rapid prototyping apparatus having low consumable cost and capable of generating much larger models than are presently possible. In

addition, models can be produced more rapidly and require less preparation to be useable.

CLAIMS

1. An improved process for object manufacture, comprising printing on at least one piece of substrate a desired cross-sectional outline and applying sufficient energy to the printed outline to cause the or each
5 substrate to weaken at the outline.
2. An improved process for laminated object manufacture, comprising printing on at least some of a number of pieces of substrate a desired cross-sectional outline, binding the substrates and applying sufficient energy to the printed outline to cause each substrate to weaken at the
10 outline.
3. The process claimed in claim 1 or 2 wherein the substrate is paper.
4. The process as claimed in claim 1, wherein the substrate comprises a single layer of material chosen from the group consisting of carbon, metal, silicon, chip and material of lattice construction.
- 15 5. A processes claimed in claim 2, in which the substrate incorporates plating material or plating material is inserted between layers of substrate in the stack.
6. The processes claimed in claim 2, wherein there is included in the substrate stack material having the ability to provide insulation,
20 reinforcement, electrical conduction or electrical resistance.
7. The processes claimed in claim 2, wherein each substrate comprises photosensitive film or paper and the outline on each substrate is formed by exposure to light.
8. The processes claimed in claim 1 or 2, are in the printing step is carried
25 out using xerography or bubble jet printing.
9. The processes claimed in claim 1 or 2, wherein the weakening step is effected by the application of energy to the outline.
10. The processes claimed in claim 9, wherein the energy takes the form of heat energy, high frequency heating, microwaves or electromagnetic
30 radiation.

This Sheet Has Been Replaced



11. The process claimed in claim 2, in which the binding step is carried out before the printing step.
12. The processes claimed in claim 1 or 2, in which, at the same time as the outline is printed, unwanted material around the object to be formed is
5 also printed.
13. An object made by the process of claim 1.
14. A laminated object made by the process of claim 2.
15. An improved printing process, comprising printing on a substrate and treating the printing to form a mark as herein defined.

10

This Sheet Has Been Replaced

