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(54) **SYSTEM AND METHOD FOR PRODUCING A NANO METAL MESH USING A BRITTLE FILM TEMPLATE FOR LITHOGRAPHY**

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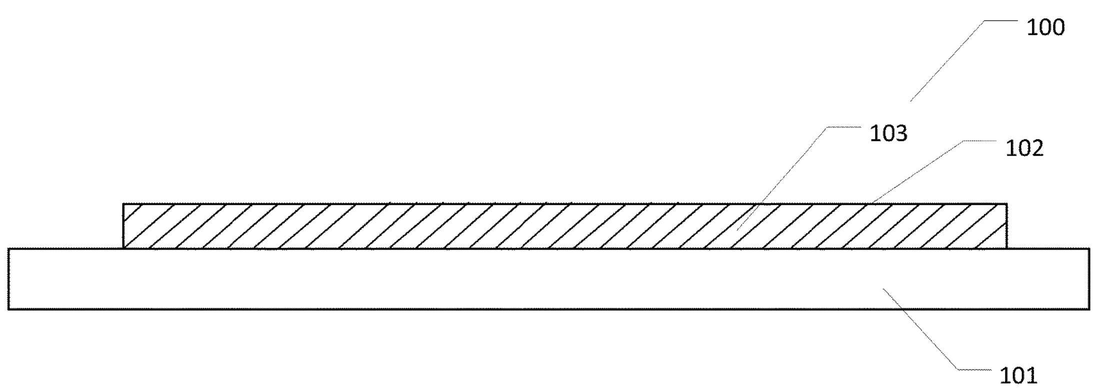
CPC ***G06F 3/044*** (2013.01); *Y10S 977/893* (2013.01); *Y10S 977/857* (2013.01); *Y10S 977/856* (2013.01); *Y10S 148/10* (2013.01); *H01L 21/0331* (2013.01); *G06F 2203/04103* (2013.01); *B82Y 40/00* (2013.01); *B81C 1/00476* (2013.01)

(57) **ABSTRACT**

This disclosure teaches a method for producing a nano metal mesh. A brittle layer can be deposited onto a flexible substrate, the brittle layer having a thickness on the flexible substrate. The flexible substrate can be bent to produce a plurality of gaps on the brittle material. A material can be deposited at the surface of the flexible substrate filling the gaps of the brittle layer. Then, the brittle layer can be etched from the flexible substrate using an etchant, a nano metal mesh formed by the material previously in the gaps. The disclosure also teaches a nano metal mesh made using this method.



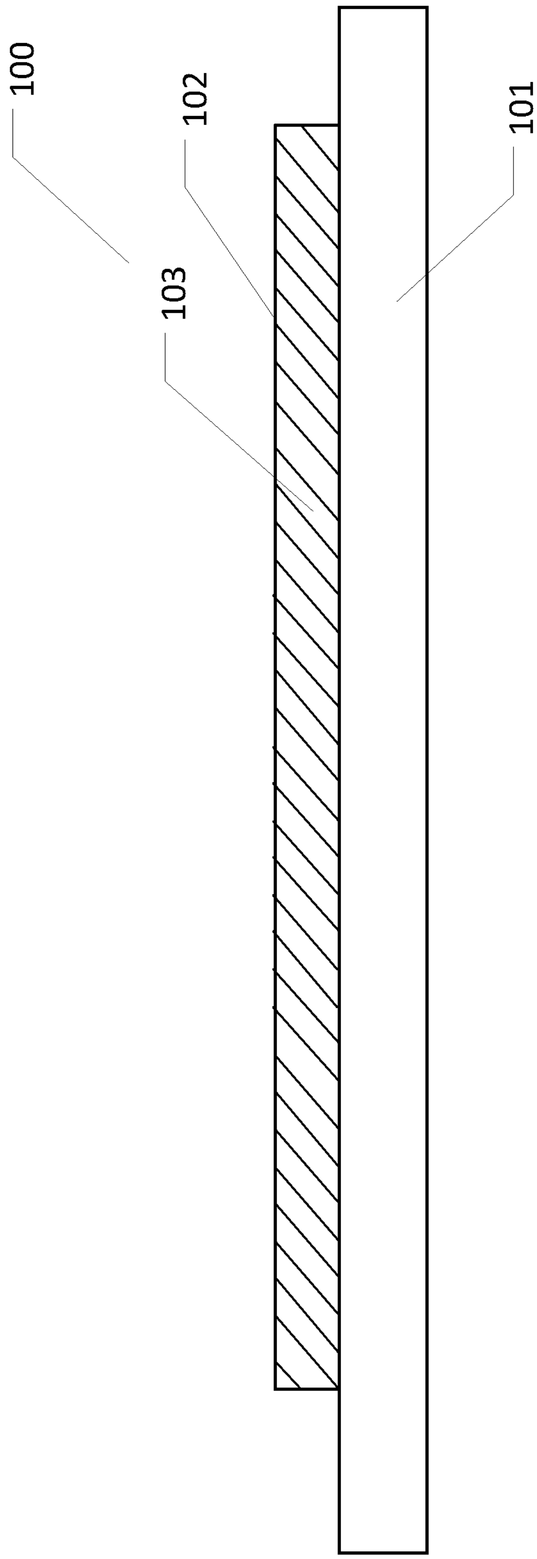


Fig. 1

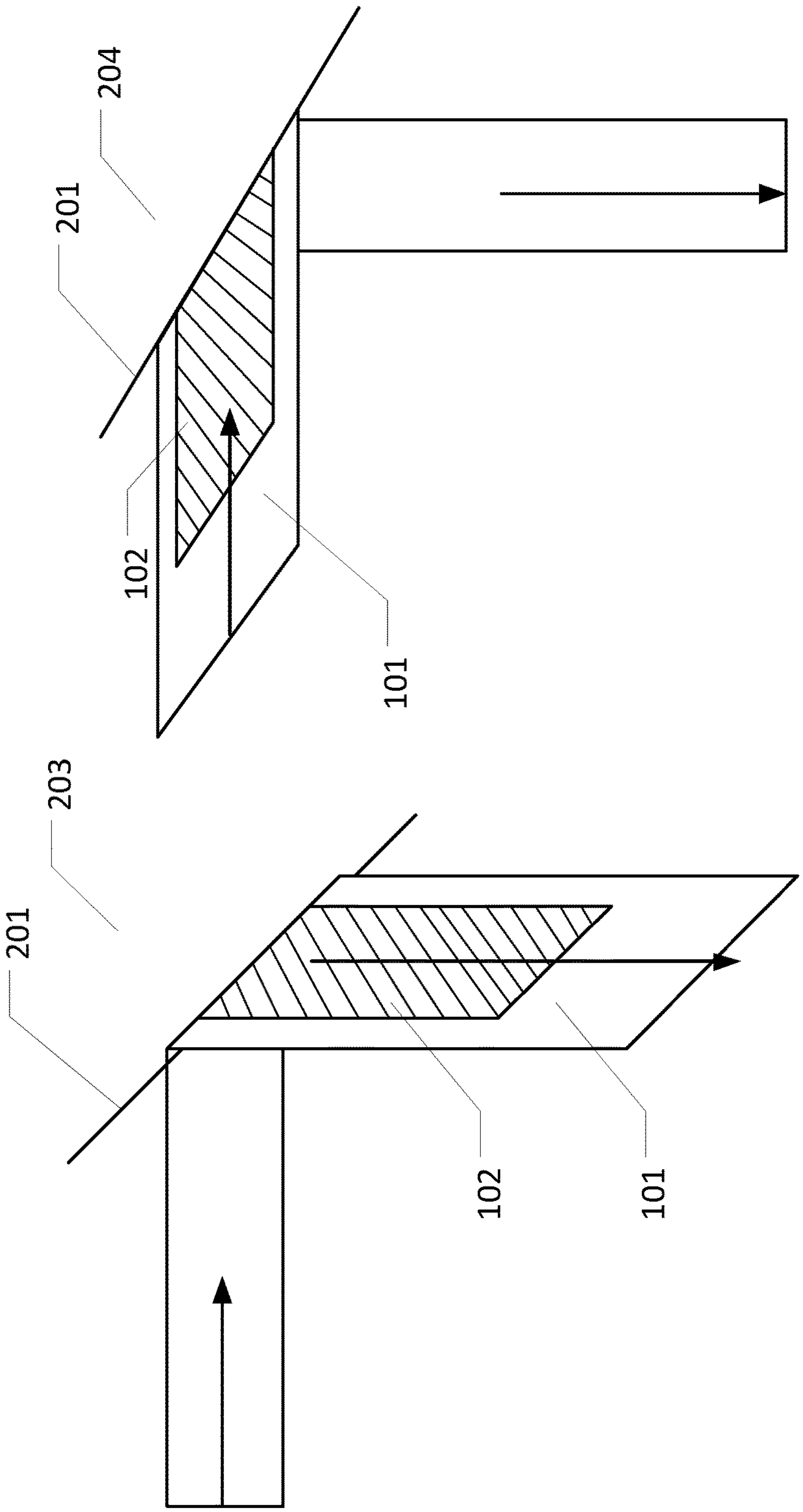


Fig. 2

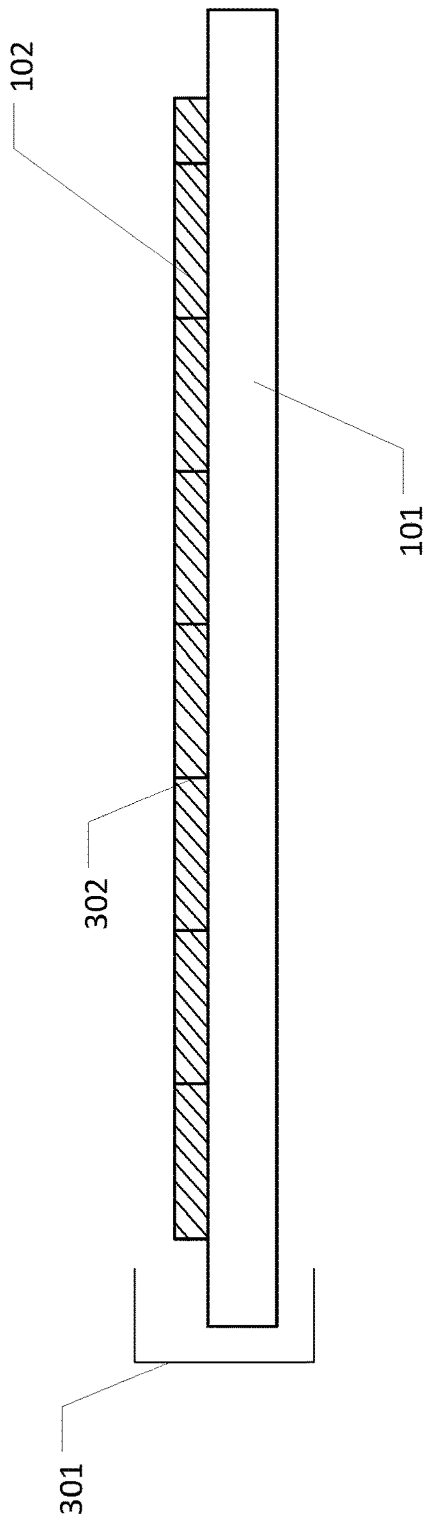


Fig. 3

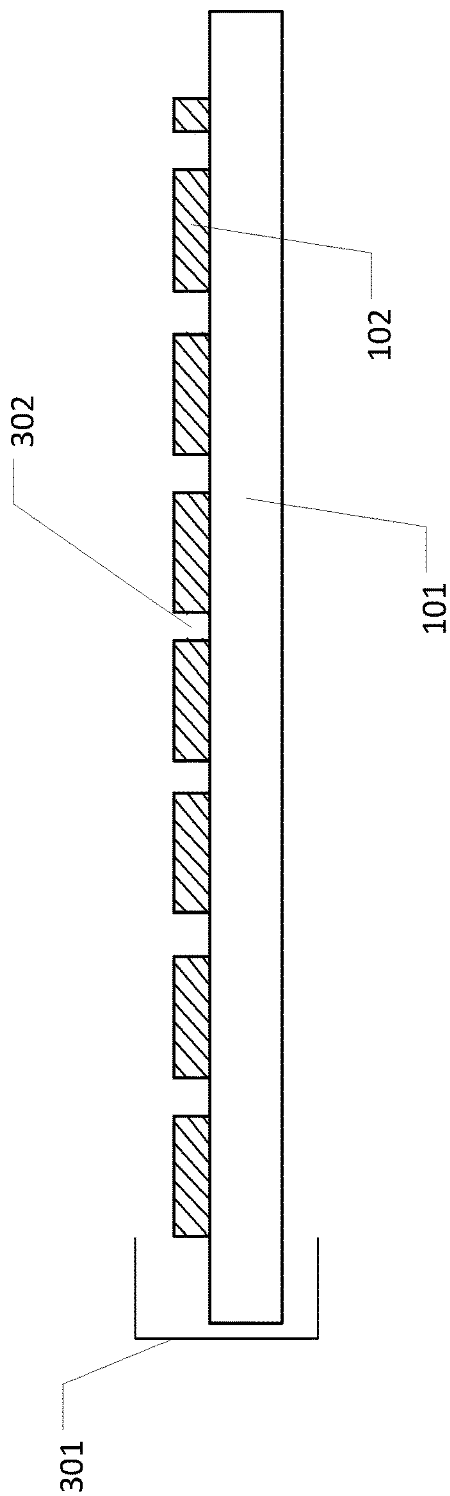


Fig. 4A

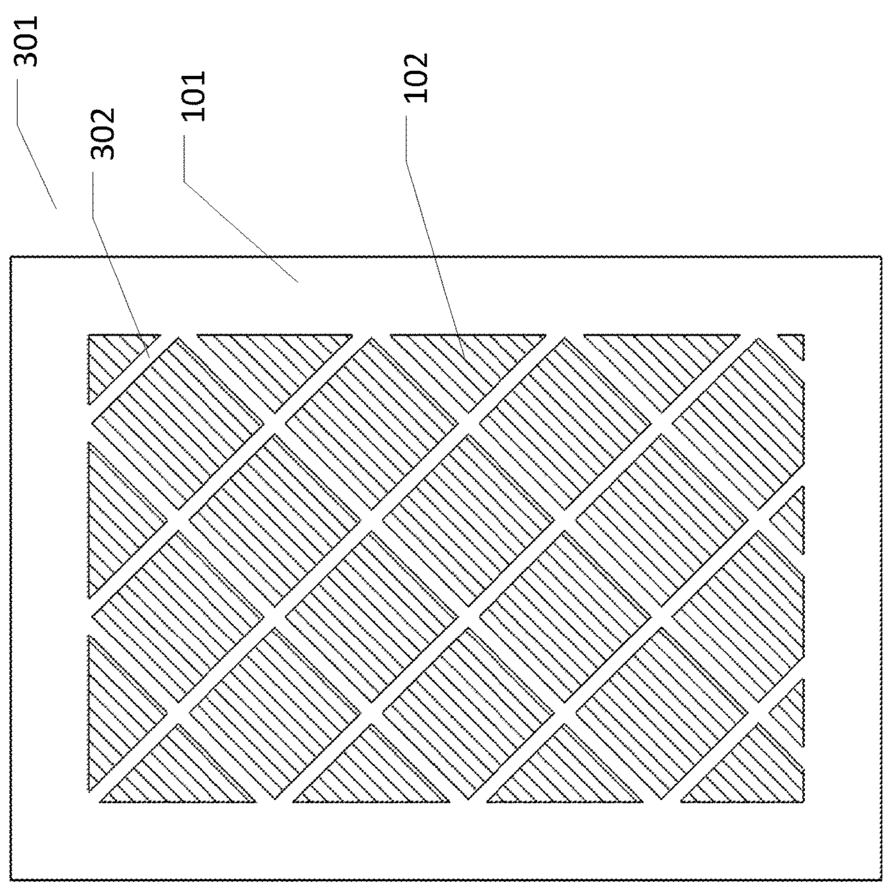


Fig. 4B

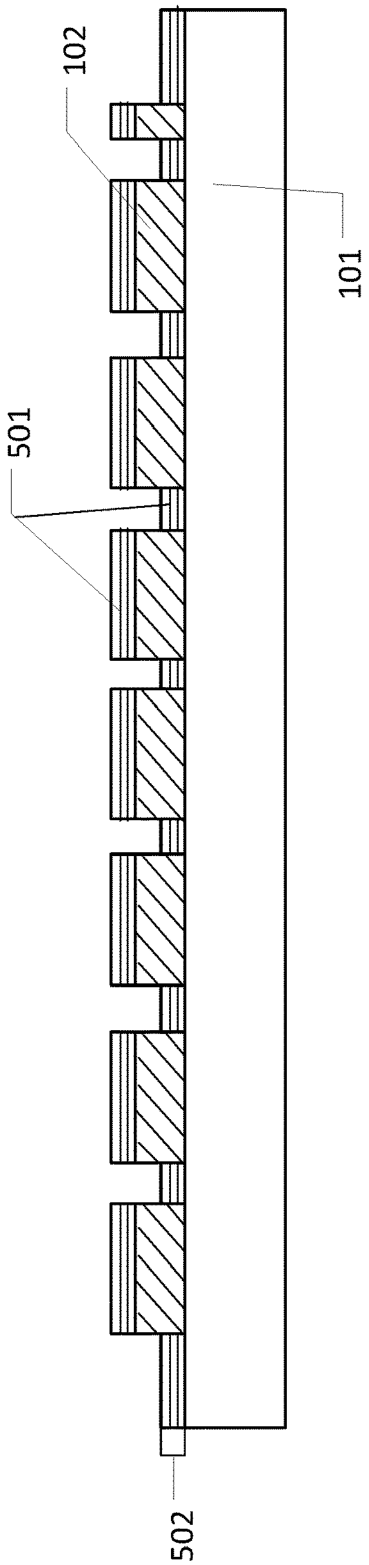


Fig. 5

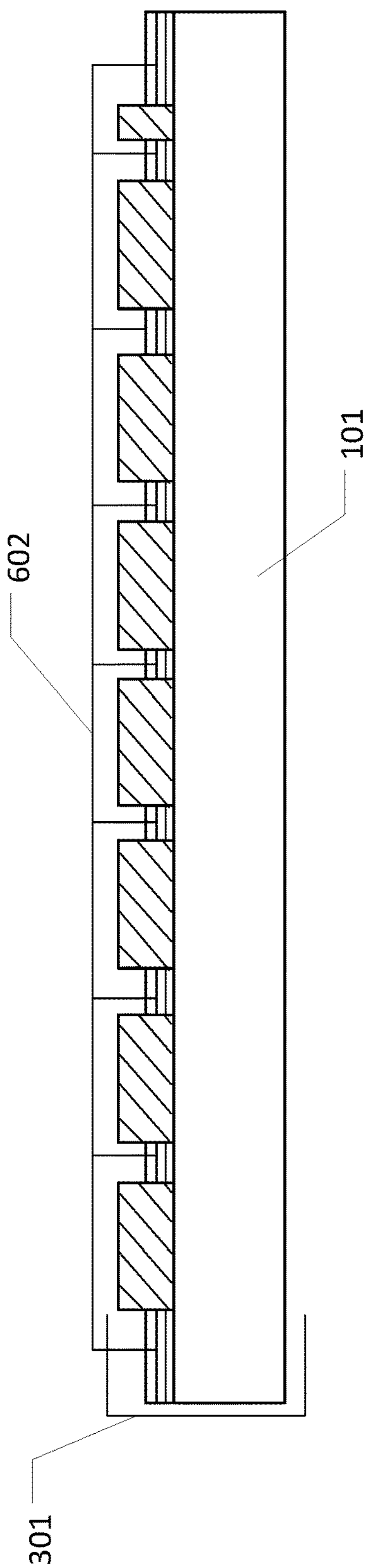


Fig. 6

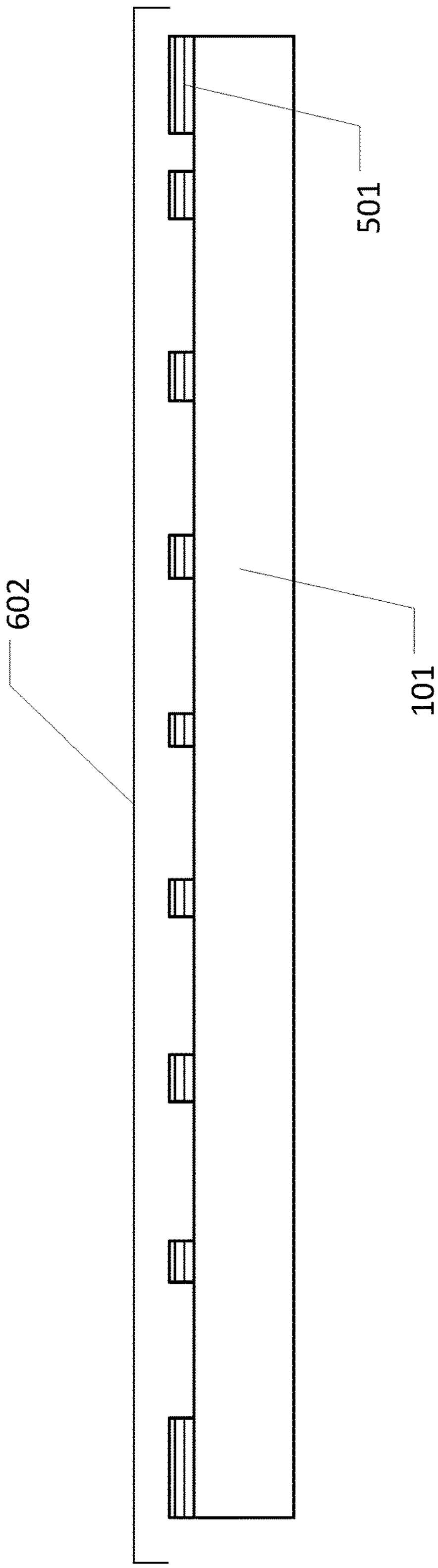


Fig. 7A

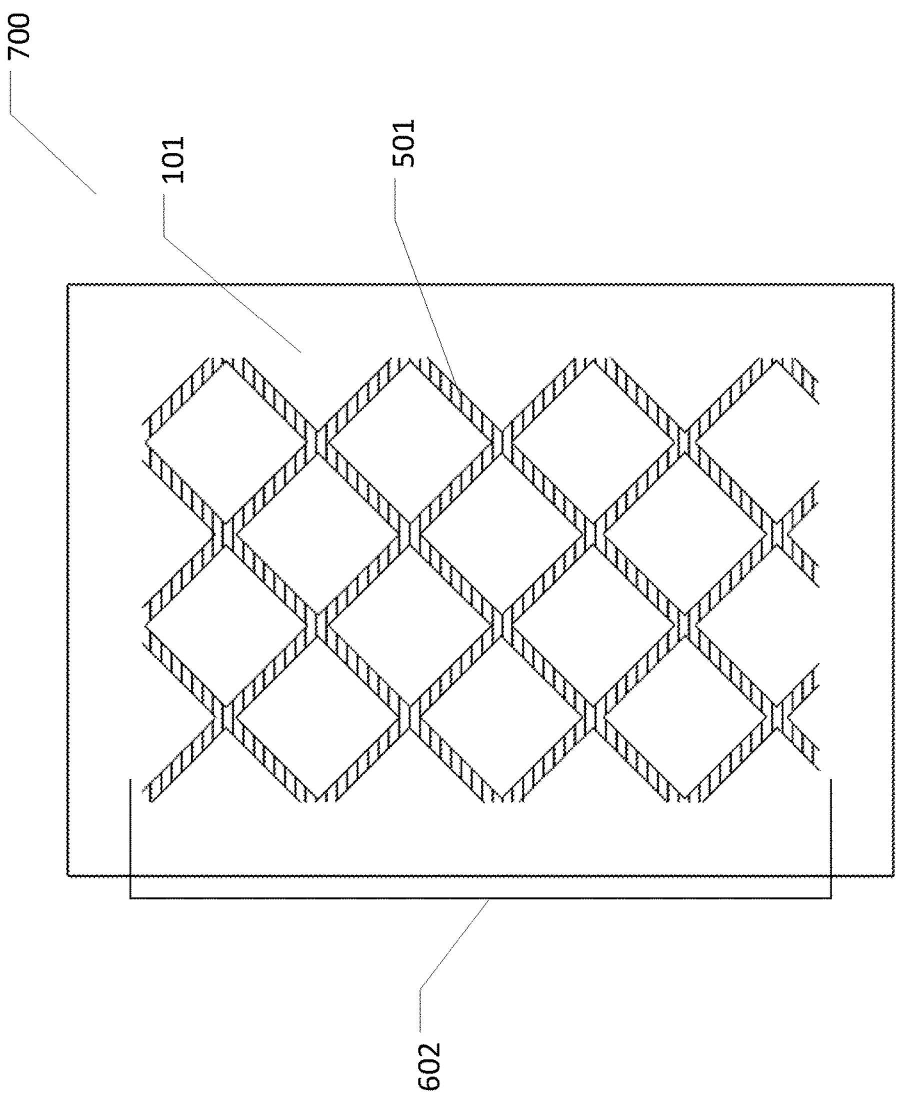


Fig. 7B

SYSTEM AND METHOD FOR PRODUCING A NANO METAL MESH USING A BRITTLE FILM TEMPLATE FOR LITHOGRAPHY

BACKGROUND

[0001] This application is a continuation of pending utility application entitled, "Method for Producing a Nano Metal Mesh using a Brittle Film Template for Lithography" by Ethan Pfeiffer filed Sep. 21, 2015.

[0002] This disclosure relates to a system and method for producing a nano metal mesh using a brittle film template for lithography.

[0003] In the recent years, the growth of touch related devices and touch related applications made a huge impact in the development of transparent conductive film. Currently, the transparent conductive film market is dominated by Indium-tin-oxide (ITO) film. ITO film is widely known in the market because of its electrical conductivity, optical transparency, and ease of application when being used as a thin film. However, due to the limited supply of indium and expensive cost in production of ITO film, alternative transparent conductive films are continuously being developed. Some of the known alternatives are carbon nanotubes, graphene, and conductive polymers. However, these alternatives are still expensive, and cannot provide sufficient low resistance. The leading ITO alternative is nano metal mesh, which has the capability to provide high conductivity, and high optical transmission that is commercially competitive with ITO. Most nano metal mesh processes uses lithography, sintering, or other high defect methods. However, these methods are still costly especially when it involves high volume production. As such it would be useful to have an improved system and method for producing a nano metal mesh using a brittle film.

SUMMARY

[0004] This disclosure teaches a method for producing a nano metal mesh. A brittle layer can be deposited onto a flexible substrate, the brittle layer having a thickness on the flexible substrate. The flexible substrate can be bent to produce a plurality of gaps on the brittle material. A material can be deposited at the surface of the flexible substrate filling the gaps of the brittle layer. Then, the brittle layer can be etched from the flexible substrate using an etchant, a nano metal mesh formed by the material previously in the gaps. The disclosure also teaches a nano metal mesh made using this method.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] FIG. **1** illustrates a side view of a strip comprising a flexible substrate coated with a brittle film.

[0006] FIG. **2** illustrates the bending process of a strip using a turnbar.

[0007] FIG. **3** illustrates a side view of a strip after the bending process.

[0008] FIG. **4**A illustrates a side view of a strip after heating.

[0009] FIG. **4**B illustrates a top view of a strip after heating.

[0010] FIG. **5** illustrates a material deposited at the surface of a strip.

[0011] FIG. **6** illustrates a water solution deposited onto the surface of a strip.

[0012] FIG. **7**A illustrates a side view of a strip after the etching process.

[0013] FIG. **7**B illustrates a top view of a nano metal mesh.

DETAILED DESCRIPTION

[0014] Described herein is a system and method for producing a nano metal mesh using a brittle film template for lithography. The following description is presented to enable any person skilled in the art to make and use the invention as claimed and is provided in the context of the particular examples discussed below, variations of which will be readily apparent to those skilled in the art. In the interest of clarity, not all features of an actual implementation are described in this specification. It will be appreciated that in the development of any such actual implementation (as in any development project), design decisions must be made to achieve the designers' specific goals (e.g., compliance with system- and business-related constraints), and that these goals will vary from one implementation to another. It will also be appreciated that such development effort might be complex and time-consuming, but would nevertheless be a routine undertaking for those of ordinary skill in the field of the appropriate art having the benefit of this disclosure. Accordingly, the claims appended hereto are not intended to be limited by the disclosed embodiments, but are to be accorded their widest scope consistent with the principles and features disclosed herein.

[0015] FIG. **1** illustrates a side view of a strip **100** comprising a flexible substrate **101** coated with a brittle film **102**. In a preferred embodiment, flexible substrate **101** can be a bendable Optical grade Poly-ethylene Terephthalate (PET) film. In one example, PET film can be 75 um thick with a 25 um thick protective layer to prevent scratching and optical transmission defects during bending 10 cm wide. Brittle film **102** can comprise a brittle material **103**, which can include but are not limited to salt, ceramic, or silica glass substance. An example of brittle film **102** is a spin-on-glass (SOG) liquid glass, which is a type of glass that can be applied as a liquid and cured to form a layer of glass having characteristics similar to those of SiO_2.

[0016] The process of producing a nano mesh metal can initiate by depositing brittle material **103** to coat a surface of flexible substrate **101**. Flexible substrate **101** can be coated through coating method that can include but is not limited to Mayer rod coating. In a preferred embodiment, a size #9 Mayer rod can be used to produce about .**4** micron glass coating. After coating, brittle film **102** must be dry before proceeding to a bending process.

[0017] FIG. **2** illustrates a bending process of strip **100**, in one embodiment, using a turnbar **201**. For large and upscale production, a roll-to-roll manufacturing operation using modified turnbars **201** (turnbars are commonly used to change direction of the roll to roll webs(PET)) as the bending bars can be used for perpendicular cracking of strip **100**. Furthermore, the bending process can be done for crack propagation on brittle film **102**. Strip **100** can be bent using a motor rewinder to pull it around turnbar **201**. Strip **100** can be mounted on turnbar **201** at an angled position **202**. In a preferred embodiment, angled position **202** is at a 45-degree angle. Angled position **202** of turnbar **201** can ensure that strip **100** remains at the same bending position, which can prevent horizontal movements on the turnbar plane. Moreover, turnbar **201** can be fixed and stationary to prevent movements on the turnbar plane. In a preferred embodiment, turnbar **201** can be a PTFE (Teflon) turnbar. PTFE (Teflon) turnbar is known to have a low coefficient of friction, which can minimize the chances of strip **100** from sticking to turnbar **201**. Moreover, PTFE (Teflon) turnbar can provide uniform speed and a minimization of crack propagation defects.

[0018] In one embodiment, strip **100** can be bent using one turnbar **201** at a time. In this embodiment one end of strip **100** can be mounted on turnbar **201** at a first bend **203** and the other side of strip **100** mounted on the other side of turnbar **201** at a second bend **204**. In another embodiment, strip **100** can be pulled through a pair of turnbars **201**, to achieve perpendicular cracking. Further in one example, weight of first bend **203** can be 2.5 lbs. while weight of second bend **204** can be 4.5 lbs., the weight on first bend **203** and second bend **204** can produce tension in strip **100**. In a preferred embodiment, first bend **203** can have a ⅝" diameter rod, while second bend **204** can have a $\frac{3}{16}$" diameter rod. Such radiuses and the tension on turnbar **201** for first bend **203** and second bend **204** can produce a preferred template for a nano metal mesh.

[0019] FIG. **3** illustrates a side view of strip **100** after the bending process. The radius of turnbar **201**, and tension applied on strip **100** for first bend **203** and second bend **204** are necessary to generate a sufficient nano-gap template **301**. Nano-gap template **301** can be a preset format of nanoscale gap patterns made on brittle layer **102**. Moreover, nano-gap template **301** is produced from the propagated cracks during the bending process. Nano-gap template **301** can comprise a plurality of nano-gaps **302**. For purposes of this disclosure, a nano-gap **302** is a gap of **200** nanometers or less. In an embodiment wherein roll-to-roll manufacturing is used, strip **100** can be reduced in size through a slitting method. As an example, strip **100** can be cut into 10 cm×15 cm portions similar to the size of that of a conventional touchscreen smartphone.

[0020] FIG. **4**A illustrates a side view of strip **100** after heating. In one embodiment, brittle film **102** can be heated for a period of time to widen nano-gaps **302** of up to, but not limited to, around **200** nanometers wide. The heating process can cause the solvent in brittle film **102** to evaporate drying and increasing the nanogap distance. In a preferred embodiment, brittle film **102** can be heated at 65 degrees Celsius for 15 seconds.

[0021] FIG. **4**B illustrates a top view of strip **100** after heating. In this embodiment, widened nano-gaps **302** can divide brittle film **102**. The patterned structure of nano-gaps **302**, which is formed at a surface of strip **100** creates a nano gap template **301** for nano metal mesh.

[0022] FIG. **5** illustrates a material **501** deposited at the surface of strip **100**. In one embodiment, material **501** can include but is not limited to metals. In this embodiment, material **501** can be silver (Ag). Material **501** can have strong adherence to flexible substrate **101**. This property can be essential to ensure that deposit material **501** can withstand the etching liftoff process of Nano mesh template **401**. As shown in FIG. **5**, material **501** can be evaporated onto the surface of strip **100** at a specific thickness **502**, using an evaporator device such as an E-beam evaporator. This process can cover the surface of sections **301** and fill gaps **302** with material **501**. In this embodiment, thickness **502** can be **1000** angstroms. Furthermore, after the deposition of material **501** if strip **100** is going to be stored for more than **10** minutes, brittle film **102** can be heated to prevent tarnishing of silver (Ag). The highest temperature applicable for heating after deposition can be **119** degrees Celsius just before the glass transition temperature. This is to ensure that flexible substrate **101** does not warp.

[0023] FIG. **6** illustrates a water solution **601** deposited onto the surface of strip **100**. Water solution **601** can be deposited onto the surface of brittle film **102**. In a preferred embodiment, water solution **601** can be a Sodium Chloride (NaCl) water solution. This NaCl stripping method, can liftoff or strip material **501** that was placed onto the surface of brittle film **102**. Furthermore, this process can leave a silver (Ag) mesh **602** intact with nano mesh template **301**.

[0024] FIG. **7**A illustrates a side view of PET strip **100** after the etching process. After the NaCl stripping process, an etching process can be performed on brittle film **102** using an etchant **701**. Etchant **701** can include but is not limited to water or various acids. In this embodiment, etchant **701** can be a Hydrofluoric (HF) acid solution. Brittle material **103** that is within nano-gaps **302** can be etched from strip **100**, which can expose or leave Ag mesh **602** intact with flexible substrate **101**. The result of etching process can then produce a nano metal mesh **700**. For purposes of this disclosure, NaCl water solution can be used as water solution **601** so that Silver (Ag) material **501** can be recycled without having to filter Ag out of HF acid solution, which can be dangerous and costly.

[0025] FIG. **7**B illustrates a top view of nano metal mesh **700**. Nano metal mesh **700** can comprise of Ag mesh **602** attached to the surface of flexible substrate **101**. Further for purposes of this disclosure, results may vary according to the different bending radius, tension, after bend heat, and thickness of metal applied.

[0026] Various changes in the details of the illustrated operational methods are possible without departing from the scope of the following claims. Some embodiments may combine the activities described herein as being separate steps. Similarly, one or more of the described steps may be omitted, depending upon the specific operational environment the method is being implemented in. It is to be understood that the above description is intended to be illustrative, and not restrictive. For example, the above-described embodiments may be used in combination with each other. Many other embodiments will be apparent to those of skill in the art upon reviewing the above description. The scope of the invention should, therefore, be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled. In the appended claims, the terms "including" and "in which" are used as the plain-English equivalents of the respective terms "comprising" and "wherein."

1. A nano metal mesh manurfactured by

depositing a brittle layer onto a flexible substrate, said brittle layer having a thickness on said flexible substrate;

bending said flexible substrate to produce a plurality of gaps on said brittle material;

depositing a material at the surface of said flexible substrate filling said gaps of said brittle layer;

etching said brittle layer from said flexible substrate using an etchant, a nano metal mesh formed by said material previously in said gaps.

2. The nano metal mesh of claim **1** wherein said flexible substrate is a bendable Optical grade Poly-ethylene Terephthalate (PET) film.

3. The nano metal mesh of claim **1** wherein said brittle layer comprises a Spin On Glass (SOG) liquid glass.

4. The nano metal mesh of claim **1** wherein said water solution is a Sodium Chloride (NaCl) water solution.

5. The system of claim **1** wherein said etchant is a hydrofluoric acid solution.

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