structures on the metal surface. However, this process also involves a sacrificial process of removing the resist, again limiting the resolution of the structures that can be formed on the metal surface.

[0007] The currently available methods for producing fine structures in metals are thus limited in terms of resolution and in the need to remove sacrificial materials to obtain the final structure.There is therefore a need to provide a method for making an imprint on a metal substrate that overcomes or at least ameliorates, one or more of the disadvantages described above.

Summary of Invention

[0008] There is provided a method for making an imprint on a metal substrate comprising the steps of; (a) providing a mold having a defined imprint surface pattern in the nano-sized or micro-sized range; and (b) pressing the metal substrate against the mold at hot working temperature to form a nano-sized or micro-sized imprint thereon.

[0008a] In an aspect, there is provided a method for making an imprint on a metal substrate comprising the steps of: (a) providing a mold having a defined imprint surface pattern in the nano-sized or micro-sized range; and (b) pressing the metal substrate against the mold at hot working temperature to form a nano-sized or micro-sized imprint thereon, wherein the metal is selected from the group consisting of indium, tin, bismuth, cadmium, lead, antimony, and any mixture thereof, and the hot working temperature is in the range of 5 °C to 200 °C.

[0009] Advantageously, the method may enable the imprinting directly onto a metal substrate without the need for using sacrificial materials or any sacrificial processes. That is, the method may eliminate the extra processing steps of adding the sacrificial material and/or removing the sacrificial material, therefore speeding up the imprinting process and reducing waste that is formed from the imprinting process.

[0010] Further advantageously, the method may enable large surface area structuring of metals as well as metal films on substrates such as silicon, which is otherwise not possible with traditional techniques that require the use of sacrificial materials, such as photolithography and electron beam lithography.

[0011] Further advantageously, the structuring of the metal substrate may be carried out at hot-working temperatures. More advantageously, because the method may be carried out at hot-working temperatures, the method may not rely on extreme high temperatures. Additionally, the method may not require extremely high pressures or the use of sharp features on the mold to generate large localized pressures to enable metal flow. The method may enable the imprinting of nano-sized or micro-sized sharp and blunt features on the metal.

[0012] More advantageously, the method may be a combination of the principles of an imprinting process and principles of hot working in metallurgy. Advantageously, this may enable direct imprinting of structures on a metal substrate at high resolution on the micro- or nano-size range. Advantageously, this may overcome the issue of conventional techniques where micro- or nano-sized structures were not able to be directly imprinted on the metal substrate.

[0013] Further advantageously, the method may be useful in imparting hydrophobicity to

Claims

Claims:

[Claim 1] A method for making an imprint on a metal substrate comprising the steps of:
(a) providing a mold having a defined imprint surface pattern in the nano-sized or micro-sized range; and
(b) pressing the metal substrate against the mold at hot working temperature to form a nano-sized or micro-sized imprint thereon, wherein the metal is selected from the group consisting of indium, tin, bismuth, cadmium, lead, antimony and any mixture thereof, and the hot working temperature is in the range of 5 °C to 200 °C.

[Claim 2] The method of claim 1, wherein the method does not comprise the use of a sacrificial material.

[Claim 3] The method of claim 2, wherein the sacrificial material may be selected from the group consisting of binder, resist, protective films and any combination thereof.

[Claim 4] The method of any one of the preceding claims, wherein the metal substrate comprises a metal or metal alloy.

[claim 5] The method of claim 1, wherein the metal alloy comprises elements selected from the group consisting of bismuth, lead, tin, cadmium, indium and any mixture thereof.

[Claim 6] The method of claim 1, wherein the metal alloy comprises 40 to 50 wt% bismuth, 20 to 30 wt% lead, 5 to 15 wt% tin, 0 to 12 wt% cadmium and 0 to 25 wt% indium, wherein the total wt% of bismuth, lead, tin, cadmium and indium combined is 100 wt%.

[Claim 7] The method of any one of the preceding claims, wherein the metal substrate is supported on a silicon substrate.

[Claim 8] The method of claim 7 wherein the metal substrate is deposited on the silicon substrate by a method selected from the group consisting of sputtering, melt deposition, thermal evaporation and a combination thereof.

[Claim 9] The method of any one of the preceding claims, wherein the pressing step may be performed at a pressure in the range of 40 to 250 bars.

[Claim 10] The method of any one of the preceding claims, wherein the hot working temperature, in degrees Celsius (°C), is greater than $0.5T_m$, wherein the T_m is the melting point of the metal substrate in absolute temperature scale.

[Claim 11] The method of claim 1, wherein the hot working temperature is in the range of 20 °C to 200 °C.

[Claim 12] The method according to any one of the preceding claims, wherein the method is performed under an inert atmosphere or a reducing atmosphere.

[Claim 13] The method according to claim 12, wherein the inert atmosphere is a nitrogen atmosphere or argon atmosphere or a reducing atmosphere consisting of small amount of hydrogen gas.

[Claim 14] The method of any one of the preceding claims, wherein the mold is made of a mold material selected from the group consisting of nickel, palladium, platinum, iron, steel, cobalt, tungsten, molybdenum, tantalum, high carbon steel, nickel-titanium-aluminium alloys, graphitic carbon, glassy carbon, silicon carbide, silicon nitride, cermets and any mixture thereof.

[Claim 15] The method of claim 14, wherein the mold further comprises a coating of 1*H*,1*H*,2*H*,2*H*-perfluorodecyltrichlorosilane, diamond-like carbon or graphitic carbon.

[Claim 16] The method of any one of the preceding claims, wherein the formed imprint is a structure selected from the group consisting of a hemisphere, pillar, trench, cone, prism and pyramid.

[Claim 17] The method of claim 16, wherein the structures are hierarchical.

[Claim 18] The method of claim 16, wherein the structure is hollow and embedded in the surface of the metal substrate.

[Claim 19] The method of claim 16, wherein the structure is solid and protruding from the surface of the metal substrate.

[Claim 20] The method of claim 16, wherein the structure has a width of less than 1 μm.

[Claim 21] The method of claim 20, wherein the structure has a width of less than 500 nm.

[Claim 22] The method of any one of the preceding claims, wherein the structure has a height of less than 1 μm.

[Claim 23] The method of any one of the preceding claims, wherein the structure has an aspect ratio in the range of 1 to 3.

[Claim 24] The method of any one of the preceding claims, further comprising the step of removing the mold from the metal substrate after the pressing step.

[Claim 25] A metal having a nano-sized or micro-sized range pattern imprinted thereon according to the method of claim 1.

[Claim 26] A hydrophobic metal comprising a metal surface having a nano-sized or micro-sized ranged pattern imprinted thereon according to the method of claim 1.