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(54) **A MICROPOROUS LAYER FOR LOWERING FRICTION IN METAL-FORMING PROCESSES**

MIKROPORÖSE SCHICHT ZUR VERMINDERUNG VON REIBUNG BEI
METALLUMFORMUNGSVERFAHREN

COUCHE MICROPOREUSE POUR ABAISSER LE FROTTEMENT DANS DES PROCÉDÉS DE
FORMAGE DE MÉTAL

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EP 2 176 447 B1

DescriptionTechnical Field

[0001] The present invention relates to a microporous layer to be used in low friction metal forming. The invention further relates to a process for producing said microporous layer and the use of the layer as a lubrication carrier for cold forming of metals, particularly for micro-scale components.

Background

[0002] The main objectives of lubrication are to reduce friction and to avoid galling, the latter resulting from i.a. break-down of the lubricant film, metal-to-metal contact between tool and workpiece and pick-up of workpiece material on the tool surface. A thorough lubrication is essential in metal forming in order to obtain products of satisfactory quality.

[0003] The tribological conditions in cold forming of metals, e.g. processes like upsetting, ironing, wire drawing and rod and can extrusion, range from difficult to extremely severe due to large surface expansion and normal pressure in the tool/workpiece interface combined with elevated tool temperatures. With the exception of rather simple cold forming operations, a successful production therefore requires the use of advanced lubrication systems to reduce friction and avoid galling. Such lubrication systems can be based on microporous coatings, cf. the co-pending application No. EP 07388046.

[0004] If these precautions are not met, a direct metal-to-metal contact appears, said contact resulting in very high friction leading to pick-up and galling, which results in a very poor surface quality of the formed components and possibly tool breakdown.

[0005] In metal forming processes, a conversion coating is typically used in order to lower friction and avoid metal-to-metal contact and subsequent galling.

[0006] The function of the conversion coating is dual, i.e. a mechanical function and a chemical function. Due to its topographic nature - with crystal grains of varying orientation and tilt angle - a large surface area is created, said surface area with pockets being suitable for entrapment of lubricant. The conversion coating normally breaks up into separate islands due to surface expansion during the forming operation, and excess lubricant flows into the cracks between these islands, thus preventing metal-to-metal contact between the tool and workpiece surfaces. As regards the second function, many of the lubricants are chosen so as to ensure a chemical reaction with the conversion coating, thus establishing a chemical bonding of the lubricant film to the workpiece surface.

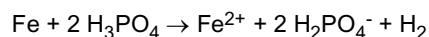
[0007] Lubrication systems for cold forging of steel can be summarised as follows:

Table 1

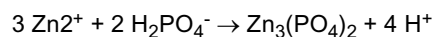
Process	Deformation	Lubrication
Upsetting	light	none Mi + EP + FA
	severe	Ph + SP
Ironing and open-die extrusion	light	Ph + Mi + EP + FA
	severe	Ph + SP
Extrusion	light	Ph + Mi + EP + FA
	severe	Ph + SP Ph + MoS ₂ Ph + MoS ₂ + SP
<i>Mi: mineral oil SP: soap EP: extreme pressure additive Ph: phosphate coating FA: fatty additives</i>		

[0008] The operational sequence for phosphate coating and soap lubrication is cleaning of the workpiece (comprising mechanical cleaning, degreasing, rinsing with cold water, pickling, further rinsing with cold water and subsequent rinsing with warm water containing activators), phosphating, rinsing with cold water, neutralizing, lubrication with soap, MoS₂ etc. and finally drying.

[0009] By the initial reaction, Fe is oxidized, and the H⁺ ions are reduced to hydrogen gas:



[0010] During this pickling, iron is dissolved from the metal surface, and deposition of zinc phosphate on the surface will start. Since H^+ ions are used for the initial process, the balance of the solution near the surface is altered in such a way that the primary zinc phosphate available in the solution is transformed into insoluble tertiary zinc phosphate and free phosphoric acid. The tertiary zinc phosphate precipitates from the solution and appears as a crystalline deposit on the surface:



[0011] This crystalline deposit must subsequently be removed from the surface.

[0012] As regards aluminium alloys, the conversion coatings are conventionally selected among zinc phosphate, calcium aluminate and aluminium fluoride coatings. The lubricants are selected among sodium stearate, zinc stearate and MoS_2 . The choice of lubricant system for cold forging of aluminium alloys depends on the hardness and the surface expansion of the aluminium alloy.

[0013] A process for producing a solid lubricant co-deposited metal film of a self-supplying type is described in US patent No. 3.787.294. In said process a metallic layer, which is deposited by electroplating, is used to reduce friction. Using co-deposition, particles of graphite fluoride are trapped in the layer. The presence of these particles will reduce friction.

Disclosure of the Invention

[0014] Compared to this and other existing methods and products the invention provides lower friction and improved resistance against galling. This fact allows for several benefits such as increased production speed, reduced pick-up and reduced wear on tools implying fewer production stops. Furthermore, the invention allows for products with closer tolerances. All these benefits will reduce costs and/or increase the quality of the products.

[0015] The environmental problems encountered when applying conventional conversion coatings, as described above, are also reduced.

[0016] The invention ensures a lubricant film thickness of significantly smaller size than those normally applied, thereby allowing forming of a wide variety of products ranging from micro-scale products to much larger products with closer tolerances.

[0017] Compared to the existing technology a thinner and more uniform lubricating layer is obtained. The layer will continue to work even when very small metallic parts are being processed.

[0018] The aspect of the invention is a novel type of layer in the form of a thin, porous metallic film, which is electrochemically deposited on the workpiece surface. The alloying elements in the film are carefully selected to ensure that a deposit is formed, which consists of fine grains of (two or more) pure metals rather than a solid solution. After the deposition, one of the metals is selectively removed by chemical or electrochemical etching, thereby leaving a micro- or even nanoporous layer on the surface of the workpiece. When a lubricating film subsequently is applied to said surface, the lubricant will be trapped in the pores, whereby an ideal surface for lowering friction by enhancing lubricant entrapment during one or more subsequent metal forming process steps is created.

[0019] More specifically, the invention concerns a microporous layer for metal forming, said layer being (a) a thin metallic film, which has been electrochemically deposited on the surface of a metal substrate, and (b) due to subsequent etching, whereby micro- or nanopores are created in the layer, being capable of capturing a lubricant in these pores, thereby providing an ideal surface for lowering friction in metal forming processes.

Brief Description of the Drawings

[0020] The invention is explained in detail below with reference to the drawings, in which

Fig. 1 is an illustration of the set-up for electroplating as described in Example 2,

Fig. 2 shows Scanning Electron Micrographs of the deposited layer (copper substrate) after etching. A: 8% Zn etched for 30 minutes. B: 40% Zn etched for 30 minutes. C: 40% Zn etched for 4 hours. D: 40% Zn etched for 24 hours,

Fig. 3 and 4 show the surface of the porous coating deposited on an aluminium rod (Fig. 4 is a cross section), after etching,

Fig. 5 is a schematic drawing of a system for sample preparation (deposition of SnZn alloys with well defined

agitation) as described in Example 3, and

Fig. 6 illustrates the friction measurement as described in Example 4.

Detailed description of the Invention

[0021] As mentioned above, the invention concerns a layer in the form of a thin, porous metallic film, which is electrochemically deposited on a workpiece surface. Further, the invention concerns a process for producing a microporous layer for lowering friction in metal forming processes on such a metal substrate, wherein the following steps are carried out:

(1) selecting one or more alloys, each consisting of two or more phases capable of providing a thin metallic film consisting of a mixture of fine grains rather than a solid solution,

(2) electrochemically depositing the alloy(s) on the metallic substrate and

(3) selectively removing one of the metals or phases by chemical or electrochemical etching,

leaving a microporous layer on the substrate surface.

[0022] The electrochemically deposited alloy is selected among FeIn, SnZn, AgCo, AgBi, AgFe, AgNi, InZn, BiCo, BiCu, BiSn, BiZn, PdCu, PdCo, CoCu, AgCu, AuCu and AuCo based-alloys. Preferably the electrochemically deposited alloy is a SnZn based-alloy.

[0023] By selecting one or more alloys, each consisting of two or more phases capable of providing a thin metallic film it becomes possible to regulate the number of pores per area unit as well as the depth of the individual pores.

[0024] The chemical or electrochemical etching is carried out by means of a solution dissolving a selected metallic phase, said solution being a concentrated or diluted inorganic acid, organic acid, inorganic base, organic base or mixtures thereof. Preferably, the etching is carried out with diluted hydrochloric acid, especially when the electrochemically deposited alloy is SnZn.

[0025] The etching time may be accelerated by increasing the acid concentration, by using electrochemical etching, by increasing the temperature, by applying ultrasonic agitation (or other types of agitation) or by combinations of these accelerating measures.

[0026] The surface of the porous coating after etching appears from the photographs in Fig. 2 - 4, where

Fig. 2 shows the surface of a copper ring electroplated with SnZn and subsequently etched (various compositions and etching times) with diluted HCl,

Fig. 3 shows the surface of an aluminium rod electroplated with SnZn and subsequently etched with diluted HCl, and

Fig. 4 is a cross section of the aluminium rod, the surface of which is shown in Fig. 3.

[0027] The invention may be used not only for the treatment of workpieces in macro-scale, but also as a lubrication carrier for cold forming of micro-scale components, such as potentiometer axles for hearing aids. As regards the forming of micro-scale components, the conventional solid film lubrication with phosphate coating and soap lubrication often is inappropriate due to (a) packing of dies with excess lubricant and (b) inability to obtain close tolerances, as film thickness of lubricant is of the same order of magnitude as component detailed being formed. Liquid lubricants are preferred, but because galling problems can be expected, a combination of an ultra-thin, porous metallic film and a liquid lubricant is used to overcome these problems.

[0028] The invention is illustrated in more details in the following examples.

Example 1

[0029] This example describes the electroplating and etching of a copper substrate.

[0030] The copper substrate (a Cu-plate) was degreased cathodically in an alkaline solution and activated (pickled) in a commercial acidic solution. Then the SnZn alloy was electrodeposited on the copper plate at an applied current density of 1 A/dm² at a bath temperature of 40 °C with magnetic stirring (up to 500 rpm) in a commercial electrolyte for 12 minutes.

[0031] The commercial electrolyte had the following composition: 0.6 l/l SLOTOLOY ZSN 21; 0.013 l/l FS 20; 0.04 l/l SLOTOLOY ZSN 22; 0.0015 l/l SLOTOLOY ZSN 23; 70 g/l ZnCl₂; 45 g/l KCl, and 30 g/l H₃BO₃.

[0032] The thickness of the electrodeposit was 5 µm, and the Zn content in the deposit may vary from 10 to 40 at. %

depending on the agitation.

[0033] A selective etching of the zinc in the SnZn alloy deposit was carried out at room temperature with diluted HCl (1 part concentrated 37% hydro chloric acid and 9 parts distilled water) for 0.5; 1; 4 and 24 hours, respectively.

[0034] The geometry of the porous coating of the etched SnZn alloy depends on the composition and the etching conditions. The number and size of holes in the etched SnZn alloy increases with the Zn content. A Zn content of about 10 at.% in the alloy deposit is too low for fabricating a porous coating.

Example 2

[0035] This example presents results obtained by using a friction test known as the ring compression test.

[0036] In the ring compression test, friction is measured by the relationship between height reduction and decrease of inner diameter of a ring of specified geometry being upset between planar anvils. In the test carried out for this example, rings of electrolytically pure copper with well specified geometry, height:inner diameter:outer diameter ratio of 2:3:6, were used. Combinations of rings with and without said coating were tested in combination with a lubricant.

[0037] The Zn content decreases with increasing agitation speed in the cell, as shown in the table 2 below. The composition varies depending on the position of the sample. Also the geometry of the sample may give rise to this problem.

Table 2: Zn content for various positions (up, down, right, left) of samples

	Up	Right	Down	Left
600 rpm	1.7	4.9	14.6	16.0
500 rpm	2.3	1.8	13.5	1.2
400 rpm	22.1	21.6	46.0	31.4
300 rpm	38.5	25.2	53.5	39.2

[0038] For the electroplating with SnZn a 1 l beaker was used as electrochemical cell as shown in Fig. 1. Providing the test specimens, i.e. the copper rings, with said coating has significant impact on the friction between anvils and plane surfaces of test specimens, as it appears from Table 3. In order to obtain identical coatings on both sides, the copper ring was located in the centre between two tin anodes. Agitation was conducted by means of a magnetic stirrer.

[0039] The friction of a sample coated with a porous coating (SnZn alloy with 40 at.% Zn deposited with magnetic stirring at 400 rpm and a current density of 1 A/dm² and then subsequently etched in diluted HCl for 4 hours) and a lubricant was measured. As reference an untreated copper ring was used. The surface of the porous coating after etching is shown in Fig. 2C.

[0040] Using a commercial lubrication paste (Molykote) on uncoated as well as coated rings, the ring test gave a friction factor of $f = 0.25$ in the former case and $f \approx 0.16$ in the latter case, i.e. the porous layer caused a decrease in friction of 36 %.

[0041] Three combinations of said coating and the lubricant paste were applied. Table 3 below shows the combinations and a qualification of friction between anvils and plane sides of test specimens, ranked with lower friction being preferable.

Table 3

Coating	Lubricant	Ranked results	Friction
none (reference)	applied	worst	highest
coated	not applied	better	lower
coated	applied	best	lowest

[0042] As can be seen from the table above, application of lubricant in combination with said coating results in the lowest friction between test specimen and anvils.

Example 3

[0043] For an alternative friction test (described in the next example) a wire with a diameter of 1.88 mm was provided. To make a homogeneous composition of the deposited alloy a rotating set-up involving planetary gears was installed in the system for SnZn alloy electrodeposition as shown in Fig. 5. Ten wires, each with a diameter of 1.88 mm and a length of 13 cm, were attached to the rotating set-up.

[0044] The problem of heterogeneous composition could be improved with this system compared to conventional systems. The Zn contents of the deposits appeared to be much lower (from 1.6 ± 0.2 to 3.7 ± 0.8 at.%), regardless of the agitation speed. Then the amount of tin concentrate FS 20 was decreased, while the amount of ZnCl_2 was increased. Now the electrolyte had the following composition: 0.6 l/l SLOTOLOY ZSN 21; 0.009 l/l FS 20; 0.04 l/l SLOTOLOY ZSN 22; 0.0015 l/l SLOTOLOY ZSN 23; 98 g/l ZnCl_2 ; 45 g/l KCl, and 30 g/l H_3BO_3 . The current density was 1 A/dm^2 and the temperature 40°C .

[0045] The compositions of the deposits for the modified electrolyte were analyzed, both at the top and at the bottom of the samples. The composition distribution was homogeneous.

Table 4: Zn content (at.%) in deposits from the modified electrolyte

	1 (top)	2 (top)	3 (bottom)	4 (bottom)
800 rpm	30.9	30.2	27.2	31.1
500 rpm	35.0	34.8	34.0	36.7
400 rpm	36.0	35.3		
300 rpm	49.5	43.3	44.2	44.9

[0046] The geometry of the porous coating of the etched SnZn alloy is clearly different (see Fig. 3) from one deposited from the previous system: It is more like a three-dimensional network (and may affect the friction).

Example 4

[0047] This example presents results obtained by using a friction test known as the double cup extrusion test, see Fig. 6.

[0048] In the double cup extrusion test, the cylindrical slug is inserted in a container with the same nominal diameter. The upper punch is moving downwards while the container and the lower punch are kept stationary, see Fig. 6. In case of zero friction along the container wall the upper and lower cup will develop identically, i.e. $h_u/h_l = 1$, whereas increasing friction will cause an increasing ratio between the upper and the lower cup height. The test is carried out in a $\varnothing 27\text{mm}$ container with a reduction $r = (D_p/D_0)^2 = 0.69$. The shape of punch nose was chosen according to the recommendations of ICFG. The height/diameter ratio of the billets is chosen as $h_0/d_0 = 1$. The test principle is illustrated in Fig. 6.

[0049] The experiments were performed in pure silver with a stress-strain curve: $\sigma = 295 \varepsilon^{0.27} [\text{N/mm}^2]$ determined by uni-axial compression testing. Three different surface treatments were tested: The new porous coating lubricated with MoDX paste (commercial product called Molykote) or mineral oil or MoDX paste added directly on a clean surface. The relative punch travel z/h_0 is aimed at 20, 40 and 60%. In the table below, the friction values determined are shown.

[0050] From the results obtained it is clear, that the coating has no influence when lubricated with MoDX but seems to perform very well when lubricated with mineral oil, where rather low friction is obtained especially for large punch travel $z/h_0 = 0.6$.

[0051] Friction coefficients and friction factors found by double cup extrusion test:

	No coat. + MoDX	Coat. + MoDX	Coat. + oil
Friction coefficient (μ)	> 0.2	> 0.2	< 0.05
Friction factor (m)	> 0.6	> 0.6	0.05-0.4

[0052] In conclusion, it has been shown that the porous surface geometry of an etched SnZn alloy deposit is determined by the composition of the alloy. About 40 at.% Zn appears to be reasonable. Further, it is possible to control the composition by changing the agitation in the cell (but it is difficult to obtain identical and reproducible compositions). The friction is improved with a porous coating of etched SnZn alloy with 40 at.% Zn.

Claims

1. A process for producing a microporous layer for lowering friction in metal forming processes on a metal substrate, said layer being

- a thin metallic film, which has been electrochemically deposited on the surface of a metal substrate, and

- capable of capturing a lubricant film in its pores,

wherein the following steps are carried out:

- (1) selecting one or more alloys, each consisting of two or more phases capable of providing a thin metallic film consisting of a mixture of fine grains rather than a solid solution,
- (2) electrochemically depositing the alloy(s) on the metallic substrate, and
- (3) selectively removing one of the metals or phases by chemical or electrochemical etching,

leaving a microporous layer on the substrate surface and thereby providing an ideal surface for said metal forming.

2. The process according to claim 1, wherein the electrochemically deposited alloy is selected among FeIn, SnZn, AgCo, AgBi, AgFe, AgNi, InZn, BiCo, BiCu, BiSn, BiZn, PdCu, PdCo, CoCu, AgCu, AuCu and AuCo.

3. The process according to claim 2, wherein the electrochemically deposited alloy is SnZn.

4. The process according to any of the claims 1 - 3, wherein the chemical or electrochemical etching is carried out by means of a solution dissolving a selected metallic phase, said solution being a concentrated or diluted inorganic acid, organic acid, inorganic base, organic base or mixtures thereof.

5. The process according to any of the claims 1 - 4, wherein the chemical etching of the Zn phase is carried out with diluted hydrochloric acid.

6. The use of a microporous layer as a lubrication carrier for cold forming of metals, wherein the microporous layer originates from a ZnSn alloy having a Zn-content of between 10 and 40%.

7. The use of a microporous layer according to claim 6 as a lubrication carrier for cold forming of metallic micro-scale components.

8. The use according to claims 6 or 7 for the electroplating of a copper substrate, wherein the electrochemically deposited alloy is SnZn and the chemical etching of the Zn phase is carried out with diluted hydrochloric acid.

9. Use of a microporous layer for lowering friction in metal forming processes, wherein the microporous layer originates from a ZnSn alloy having a Zn-content of between 10 and 40%.

10. Use according claim 9, wherein the microporous layer, is lubricated with a liquid, such as a mineral oil or an organic oil, with a viscosity low enough to penetrate into the pores of the porous coating.

Patentansprüche

1. Verfahren zum Herstellen einer mikroporösen Schicht zur Verminderung von Reibung bei Metallformungsverfahren auf einem Metallsubstrat, wobei die Schicht

- ein dünner metallischer Film ist, der elektrochemisch auf der Oberfläche eines Metallsubstrats abgeschieden worden ist, und
 - in der Lage ist, einen Schmiermittelfilm in ihren Poren aufzunehmen,
- wobei die folgenden Schritte durchgeführt werden:

- (1) Auswählen einer oder mehrerer Legierungen, die jeweils aus zwei oder mehr Phasen bestehen und in der Lage sind, einen dünnen metallischen Film bereitzustellen, der aus einer Mischung aus feinen Körnern statt einer festen Lösung besteht,
- (2) elektrochemisches Abscheiden der Legierung(en) auf dem metallischen Substrat und
- (3) selektives Entfernen eines der Metalle oder einer der Phasen durch chemisches oder elektrochemisches Ätzen,

sodass eine mikroporöse Schicht auf der Substratoberfläche zurückbleibt und dadurch eine ideale Oberfläche für das Metallformen bereitgestellt wird.

2. Verfahren gemäß Anspruch 1, worin die elektrochemisch abgeschiedene Legierung ausgewählt ist aus FeIn, SnZn, AgCo, AgBi, AgFe, AgNi, InZn, BiCo, BiCu, BiSn, BiZn, PdCu, PdCo, CoCu, AgCu, AuCu und AuCo.
3. Verfahren gemäß Anspruch 2, worin die elektrochemisch abgeschiedene Legierung SnZn ist.
4. Verfahren gemäß einem der Ansprüche 1 bis 3, worin das chemische oder elektrochemische Ätzen mittels einer Lösung durchgeführt wird, die eine ausgewählte metallische Phase auflöst, wobei die Lösung eine konzentrierte oder verdünnte anorganische Säure, organische Säure, anorganische Base, organische Base oder Mischung davon ist.
5. Verfahren gemäß einem der Ansprüche 1 bis 4, worin das chemische Ätzen der Zn-Phase mit verdünnter Salzsäure durchgeführt wird.
6. Verwendung einer mikroporösen Schicht als Schmiermittelträger für das Kaltformen von Metallen, worin die mikroporöse Schicht aus einer ZnSn-Legierung mit einem Zn-Gehalt zwischen 10 und 40 % herrührt.
7. Verwendung einer mikroporösen Schicht gemäß Anspruch 6 als Schmiermittelträger für das Kaltformen von metallischen kleinmaßstäbigen Komponenten.
8. Verwendung gemäß den Ansprüchen 6 oder 7 für das Galvanisieren eines Kupfersubstrats, worin die elektrochemisch abgeschiedene Legierung SnZn ist und das chemische Ätzen der Zn-Phase mit verdünnter Salzsäure durchgeführt wird.
9. Verwendung einer mikroporösen Schicht zum Vermindern von Reibung in Metallformungsverfahren, worin die mikroporöse Schicht von einer ZnSn-Legierung mit einem Zn-Gehalt zwischen 10 und 40 % herrührt.
10. Verwendung gemäß Anspruch 9, worin die mikroporöse Schicht mit einer Flüssigkeit wie etwa einem Mineralöl oder einem organischen Öl mit einer Viskosität, die niedrig genug ist, um in die Poren der porösen Beschichtung einzudringen, geschmiert wird.

Revendications

1. Procédé de production d'une couche microporeuse pour diminuer le frottement lors de processus de formage de métal sur un substrat métallique, ladite couche étant
 - une mince couche métallique, qui a été déposée de manière électrochimique sur la surface d'un substrat métallique, et
 - capable de capturer une couche de lubrifiant dans ses pores,
 dans lequel les étapes suivantes sont réalisées :
 - (1) sélection d'un ou plusieurs alliages, chacun se composant de deux ou plusieurs phases capables de fournir une mince couche métallique se composant d'un mélange de grains fins plutôt que d'une solution solide,
 - (2) dépôt électrochimique du(des) alliage(s) sur le substrat métallique, et
 - (3) retrait sélectif d'un des métaux ou phases par attaque chimique ou électrochimique,
 laissant une couche microporeuse à la surface du substrat et fournissant ainsi une surface idéale pour ledit formage de métal.
2. Procédé selon la revendication 1, dans lequel l'alliage déposé de manière électrochimique est choisi parmi FeIn, SnZn, AgCo, AgBi, AgFe, AgNi, InZn, BiCo, BiCu, BiSn, BiZn, PdCu, PdCo, CoCu, AgCu, AuCu et AuCo.
3. Procédé selon la revendication 2 dans lequel l'alliage déposé de manière électrochimique est SnZn.
4. Procédé selon l'une quelconque des revendications 1 à 3, dans lequel l'attaque chimique ou électrochimique est réalisée au moyen d'une solution dissolvant une phase métallique sélectionnée, ladite solution étant un acide inorganique, un acide organique, une base inorganique, une base organique concentré(e) ou dilué(e), ou leurs

mélanges.

- 5 **5.** Procédé selon l'une quelconque des revendications 1 à 4 dans lequel l'attaque chimique de la phase Zn est réalisée avec un acide chlorhydrique dilué.

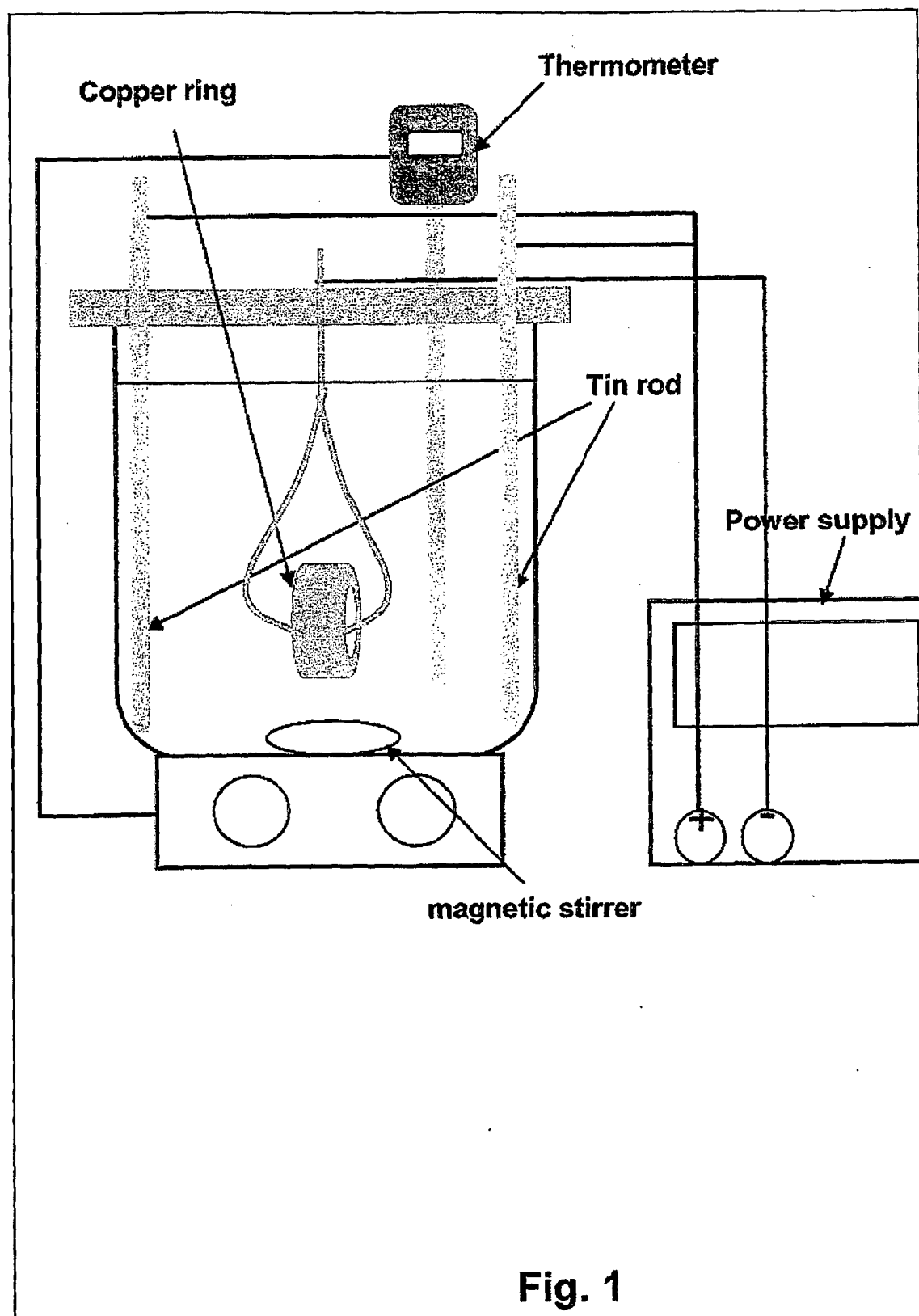
- 10 **6.** Utilisation d'une couche microporeuse en tant que support de lubrification pour le formage à froid de métaux, dans laquelle la couche microporeuse provient d'un alliage ZnSn présentant une teneur en Zn comprise entre 10 et 40 %.

- 15 **7.** Utilisation d'une couche microporeuse selon la revendication 6 en tant que support de lubrification pour le formage à froid de composants à micro-échelle métalliques.

- 20 **8.** Utilisation selon les revendications 6 ou 7 pour le dépôt électrolytique d'un substrat de cuivre, dans laquelle l'alliage déposé de manière électrochimique est SnZn et l'attaque chimique de la phase Zn est conduite avec de l'acide chlorhydrique dilué.

- 25 **9.** Utilisation d'une couche microporeuse pour diminuer le frottement lors de processus de formage de métal, dans laquelle la couche microporeuse provient d'un alliage ZnSn présentant une teneur en Zn comprise entre 10 et 40 %.

- 30 **10.** Utilisation selon la revendication 9, dans laquelle la couche microporeuse est lubrifiée par un liquide, tel qu'une huile minérale ou une huile organique, avec une viscosité suffisamment faible pour pénétrer dans les pores du revêtement poreux.



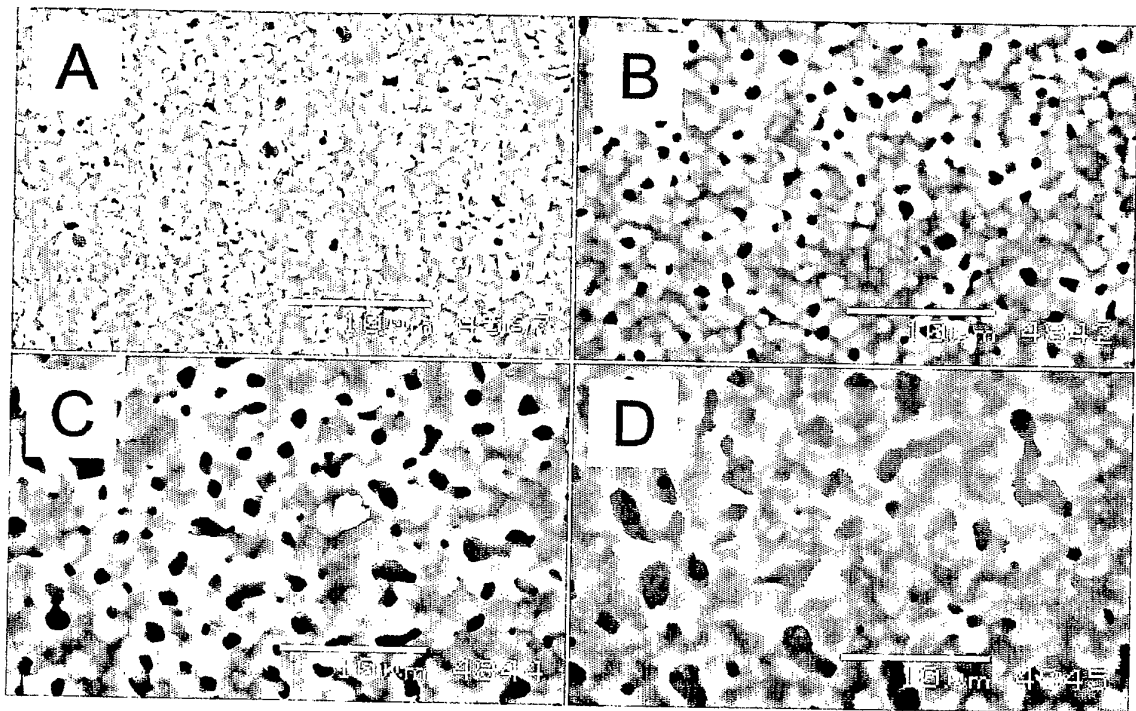


Fig. 2

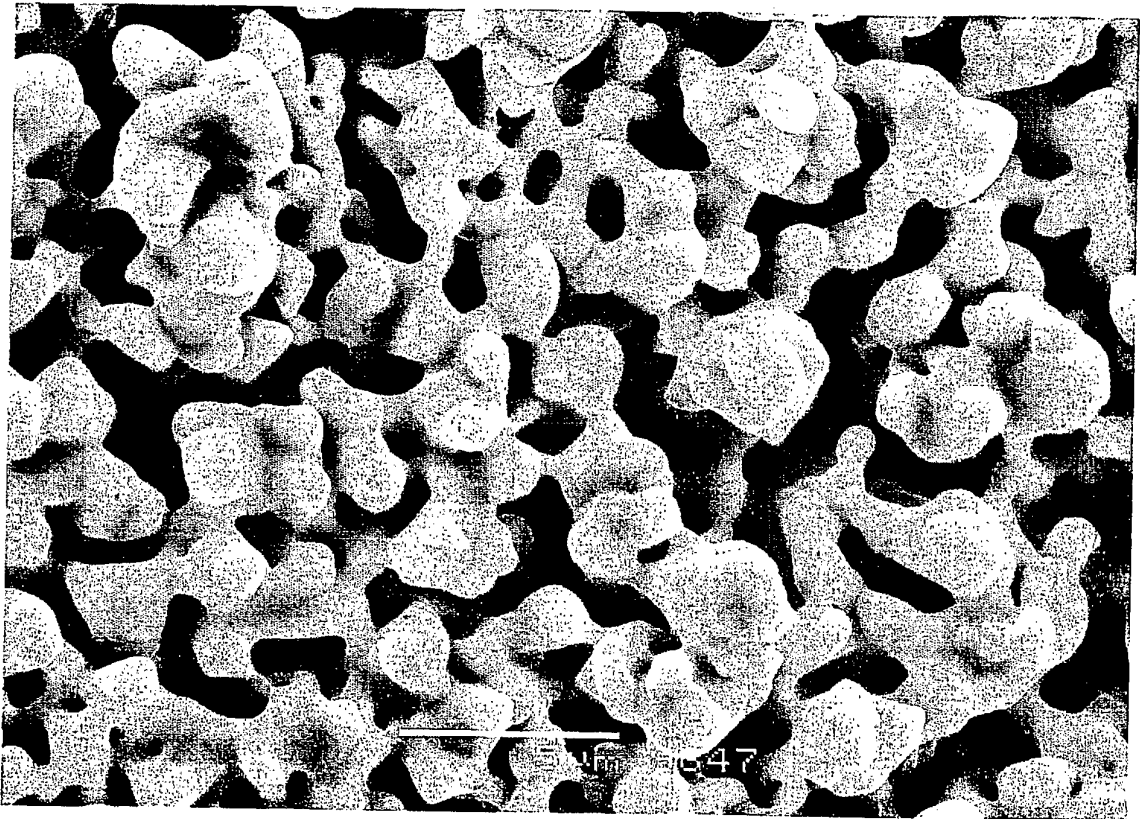


Fig. 3

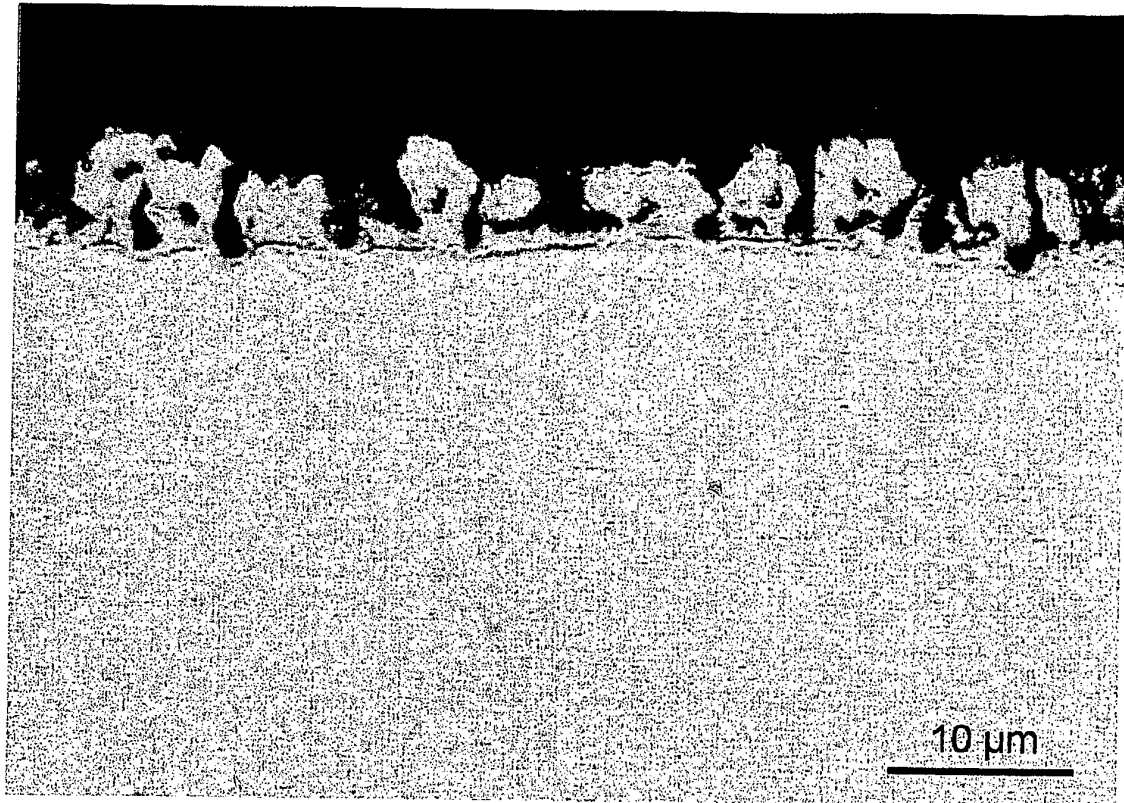
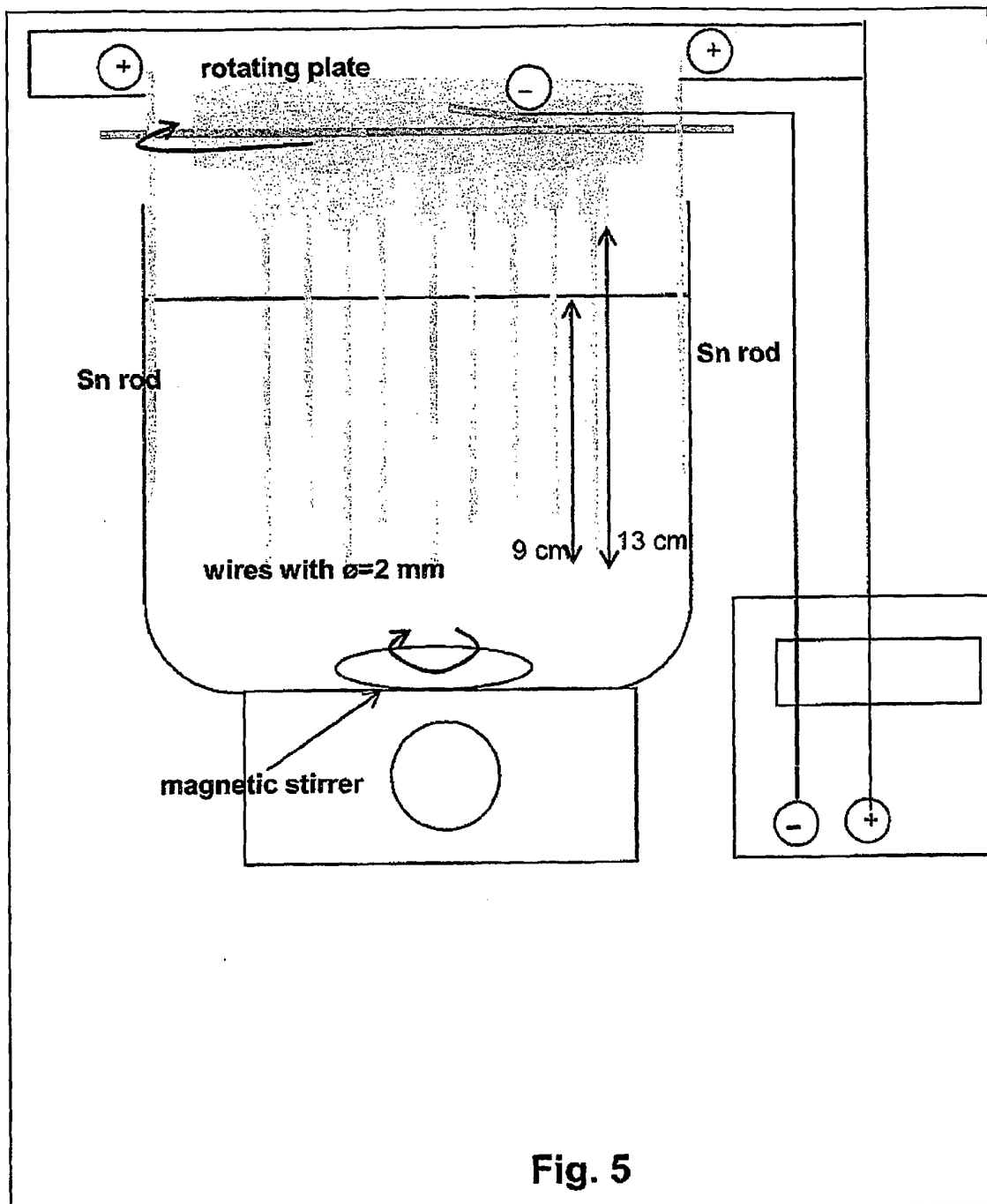


Fig. 4



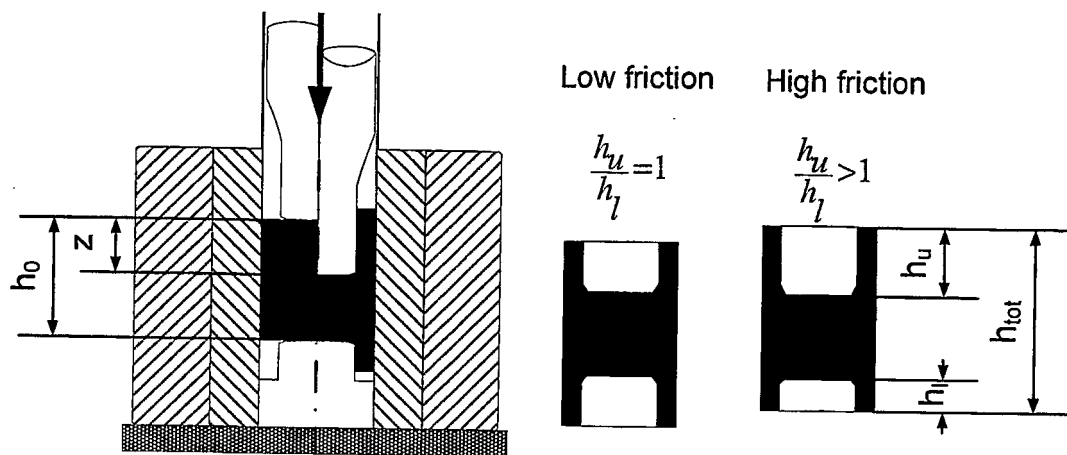


Fig. 6

REFERENCES CITED IN THE DESCRIPTION

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