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FABRICATION DE FEUILLES DE FAIBLE EPAISSEUR
(54) Title: PRODUCTION OF ALUMINUM ALLOY STRIP FOR USE IN MAKING THIN GAUGE FOILS

(57) **Abrégé/Abstract:**

A continuous cast aluminum alloy strip is used in the production of thin gauge or converter foils. The alloy strip contains 0.4 to 0.8 % by weight Fe and 0.2 to 0.4 % by weight Si, has an as cast thickness of less than about 30mm and contains a substantially single intermetallic species of alpha-phase. The strip is cast using a continuous strip caster, e.g. a block or belt caster.





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<p>(21) International Application Number: PCT/CA00/00473 (22) International Filing Date: 26 April 2000 (26.04.00) (30) Priority Data: 09/302,466 29 April 1999 (29.04.99) US (71) Applicant (for all designated States except US): ALCAN INTERNATIONAL LIMITED [CA/CA]; 1188 Sherbrooke Street West, Montreal, Québec H3A 3G2 (CA). (72) Inventors; and (75) Inventors/Applicants (for US only): JIN, Iljoon [CA/CA]; 696 Sussex Blvd., Kingston, Ontario K7M 5B1 (CA). FITZSIMON, John [CA/CA]; 47 Faircrest Blvd., Kingston, Ontario K7L 4V1 (CA). KATANO, Masahiko [JP/JP]; 977-1-1-305, Tatewara, Fuji, Shizuoka 416 (JP). OKAMOTO, Ichiro [JP/JP]; 1-45 Skystage 33-1205, Shinooka, Komaki, Aichi 485 (JP). (74) Agents: EADES, Norris, M. et al.; Kirby, Eades, Gale, Baker, Box 3432, Station D, Ottawa, Ontario K1P 6N9 (CA).</p>	<p>(81) Designated States: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).</p> <p>Published <i>With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p>	
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<p>A continuous cast aluminum alloy strip is used in the production of thin gauge or converter foils. The alloy strip contains 0.4 to 0.8 % by weight Fe and 0.2 to 0.4 % by weight Si, has an as cast thickness of less than about 30mm and contains a substantially single intermetallic species of alpha-phase. The strip is cast using a continuous strip caster, e.g. a block or belt caster.</p>		

PRODUCTION OF ALUMINUM ALLOY STRIP FOR USE IN MAKING
THIN GAUGE FOILS

Technical Field

This invention relates to aluminum alloy sheet products
5 and methods for making them. Specifically, it relates
to a process for manufacturing a new aluminum alloy
foil re-roll strip and foil stock using a continuous
strip casting process.

Background Art

10 Thin gauge or converter foils are generally prepared by
casting an ingot of an aluminum alloy such as AA1145 in
a process known as DC or direct chill casting. The
ingots are generally heated to a high temperature, hot
rolled to a re-roll gauge thickness of between 1 and 5
15 mm, then cold rolled to a "foil-stock" gauge typically
0.2 to 0.4 mm thick. The strip is often subjected to
an interanneal step during the cold rolling process.
The "foil-stock" is then subject to further cold
rolling operations, often using double rolling
20 techniques to produce a final foil thickness of about 5
to 150 microns. When rolled to a thickness of between
5 and 10 microns, the final foil product is frequently
referred to as converter foil and is used in various
packaging applications.

25 There is a cost advantage to using continuous strip
casting as the starting point in manufacture of such
foils since homogenization prior to hot rolling is not
required, and the amount of hot reduction to form re-
roll gauges is greatly reduced. However, continuous
30 strip casting processes apply different cooling

conditions during solidification from those in DC casting, and there is an absence of a high temperature homogenization step prior to hot rolling. Consequently when continuous strip casting processes are used with alloys normally prepared by DC casting and homogenization, this results in the formation of different intermetallic species and shell distortion in the cast product which cause surface defects in the final foil stock product. In continuous strip casting, the cooling rate of the strip during casting is generally higher (in some cases much higher) than the cooling rate in large DC ingots. Thus, such alloys processed in a continuous strip casting process also result in foil stock which has a higher supersaturation of solute elements, and therefore has undesirable hardening and softening properties, resulting in difficulties in rolling the foil stock to the final gauge thickness.

A previous method of manufacturing aluminum alloy strip suitable for use in the production of thin gauge foils is described in Furukawa, Laid-Open Japanese Application 6-63397, published April 5, 1994. This document indicates that a wide range of iron and silicon concentrations may be present in the aluminum alloy, e.g. 0.2-0.8% Fe and 0.05-0.3% Si. However, the highest concentrations of silicon tested were not above 0.19%.

It is an object of the present invention to provide a continuous strip casting based process for preparing re-roll and foil stock suitable for trouble-free

production of thin foils with no surface defects such as blemishes and streaks.

It is a further object to produce a foil stock in continuous strip form which contains a substantially
5 single intermetallic species of alpha-phase. "Alpha-phase" means an intermetallic phase consisting of Al-Fe-Si where Fe lies in the range of 30 to 33% and Si lies in the range of 6 to 12% (balance Al). The stoichiometry is typically $\text{Fe}_3\text{Si}_2\text{Al}_{12}$ to Fe_2SiAl_8 .

10 Disclosure of the Invention

The present invention in one aspect relates to a method of manufacturing an aluminum alloy strip for use in the production of thin gauge foils. A molten aluminum alloy is prepared containing iron in an amount of 0.4
15 to 0.8% by weight and silicon in an amount of 0.2 to 0.4% by weight, then casting the alloy in a continuous strip caster, e.g. a belt or block caster, to form a cast strip having a thickness of less than about 30 mm, e.g. about 4-30 mm, and containing a substantially
20 single intermetallic species of α -phase. The alloy may optionally also contain less than 0.05% by weight of each of Cu, Mn, Mg, Zn or V, less than 0.03% by weight Ti and the balance aluminum and any incidental impurities. The cast strip may be hot or cold rolled to a desired
25 thickness to provide a re-roll stock.

The re-roll stock obtained by the above process has reduced surface defects, commonly referred to as "fir

tree effect". The fir tree effect is a surface appearance caused by non-uniform intermetallic distributions in cast material where more than one intermetallic phase is present. The non-uniformity is caused by the solidification of different intermetallic species. The absence of the fir tree effect means that the surface quality of the final foil is improved and the pinhole frequency in the final foil is reduced. It has not previously been possible to achieve this surface quality using a continuous strip casting process.

Thus, a further aspect of the invention relates to an aluminum alloy strip product obtained by the above process and suitable for use in the production of thin gauge or converter foils. It comprises a continuous cast aluminum alloy strip containing 0.4 to 0.8% by weight Fe and 0.2 to 0.4% by weight Si, having an as-cast thickness of less than about 30 mm, e.g. about 4-30 mm, and containing a substantially single intermetallic species of alpha-phase. The alloy may optionally also contain less than 0.05% by weight of Cu, Mn, Mg, Zn or V, less than 0.03% by weight Ti and the balance aluminum and incidental impurities.

The strip stock produced according to this invention is typically rolled to form thin gauge foils having a thickness of about 5 to 150 microns, with reduced surface defects such as pinholes, large holes, streaks and tears in the final product.

The combination of alloy composition and continuous strip casting process has been found to result in the

formation, during casting, of substantially 100% alpha-AlFeSi phase. It is this substantially pure alpha-phase that results in fewer surface defects when rolled to the final gauge thin foil products.

5 Best Modes for Carrying Out the Invention

The alloy used in the present process contains Fe in the range 0.4 to 0.8%, preferably 0.4 to 0.6% and most preferably 0.42 to 0.48% by weight and Si in the range

0.2 to 0.4%, preferably 0.2 to 0.3% and most preferably 0.22 to 0.28% by weight. The Si/Fe ratio preferably lies in the range 0.25 to 1.0, preferably 0.4 to 0.7. When Si and Fe are within these ranges, the continuous strip casting conditions result in an as cast slab with substantially 100% alpha-AlFeSi phase. If Si is less than 0.2%, significant amounts of FeAl₆ phase form and the cast strip is susceptible to shell distortion. If Si exceeds 0.4%, there is a tendency to form beta phase which is also detrimental to rolling. If Fe is less than 0.4%, the strip has too little strength. If Fe exceeds 0.8%, FeAl₆ can again form and total amount of intermetallics is also excessive.

Elements such as Mg, Mn, Cu, V, Zn should preferably all be less than about 0.05% by weight. Ti should preferably be less than 0.03%, and the incidental impurities should preferably not exceed 0.15%.

The strip casting process is preferably carried out in a continuous strip casting process where the strip thickness is less than 30 mm. Preferably the strip thickness is greater than or equal to about 4 mm. The strip casting process should preferably provide an average cooling rate through the thickness of the cast strip of between 20 and 200°C/sec. A cooling rate of less than 20°C/sec results in the formation of surface segregation which results in poor surface quality in the final strip. A cooling rate greater than 200°C/sec results in excessive shell distortion. The actual

cooling rate depends on the strip thickness and the mould cooling ability.

The strip casting process preferably is carried out using a block or belt caster. Most preferably a twin
5 belt caster is used, with the casting carried out on textured steel belts.

The as cast slab typically has a secondary dendrite arm spacing of between 8 and 15 microns when cast under the above conditions. The secondary dendrite arm spacing
10 is described along with standard methods of measurement, for example, in an article by R.E. Spear, et al., in the Transactions of the American Foundrymen's Society, Proceedings of the Sixty-Seventh Annual Meeting, 1963, Vol. 71, Published by the
15 American Foundrymen's Society, Des Plaines, Illinois, USA, 1964, pages 209 to 215.

The as cast slab is preferably hot rolled to a re-roll gauge without any homogenization step or other
20 additional heating. Preferably a hot rolling process is used with an entry temperature of between about 400°C and 550°C and an exit temperature of between about 200°C to 320°C to produce a re-roll strip thickness of between 1 and 3 mm, preferably 1 to 2 mm.
25 This re-roll strip is normally coiled and allowed to cool to ambient temperatures before additional processing.

The re-roll strip can then be further processed by cold rolling to form a foil stock. The preferred process

involves first cold rolling to one or more intermediate gauges with interannealing steps, then cold rolling to a foil stock. The thickness of the foil stock product is typically from 0.2 to 0.4 mm.

- 5 It is particularly preferred that the cold rolling process include a two step interannealing. The interannealing comprises heating an intermediate gauge strip at 350 to 450°C for at least 0.5 hours, but preferably less than 12 hours and then cooling the
10 strip to 200 to 330°C and holding for at least 0.5 hours, but preferably less than 12 hours. A cold reduction of at least 40% prior to the interanneal is preferred.

Brief Description of Drawings

- 15 The invention is illustrated by the appended drawings in which:

Fig. 1 is a photograph of the etched surface of a rolled strip outside the composition range of the invention; and

- 20 Fig. 2 is a photograph of the etched surface of a rolled strip within the composition range of the invention.

Example 1

- Two aluminum alloys were cast on a laboratory scale
25 twin belt caster. Alloy 1 contained 0.96 wt.% Fe, 0.05 wt.% Si, and the balance essentially aluminum. Alloy 1 composition was therefore outside the range of the

present invention. Alloy 2 contained 0.45 wt.% Fe and 0.25wt. % Si which was within the range of the present invention. The slab thickness was 19 mm and the casting speed was 3 m/min. The resulting slabs were hot rolled to 3 mm and then cold rolled to 0.3 mm. The rolled sheets were then anodized in sulphuric acid solution to reveal the intermetallic phase distribution. This treatment causes dark areas where FeAl₆ intermetallics are formed. The results are shown in Figures 1 and 2. Alloy 1 (Fig. 1) has a mixture of dark and light areas, indicating that this alloy has a mixture of at least two intermetallic phases. On the other hand, alloy 2 (Fig. 2) shows only a white area, indicating that intermetallics in this alloy are uniform (and of a single type).

Example 2

The procedure of Example 1 was repeated using aluminum alloys containing a range of iron and silicon concentrations. The alloy compositions in wt. % and the resulting intermetallics are shown in Table 1

TABLE 1

Alloy No.	Fe (wt.%)	Si (wt.%)	Intermetallics
3	0.31	0.09	Mixed
4	0.52	0.05	Mixed
5	0.46	0.14	Mixed
6	0.54	0.27	Single

Notes: Mixed intermetallics mean more than one species present. Single intermetallic means substantially all alpha phase.

The results shown in Table 1 demonstrate that the alloy number 6, which has Fe and Si concentrations within the range of the present invention, is free of fir tree image and has a single phase intermetallic.

Claims:

1. A process for manufacturing an aluminum alloy strip suitable for use in the production of thin gauge foils, in which a molten aluminum alloy containing iron and silicon is cast in a continuous strip caster to form a cast strip,

comprising providing the molten aluminum alloy containing 0.4 to 0.8% by weight of iron, 0.2 to 0.4% by weight of silicon, less than 0.03% by weight Ti, optionally less than 0.05% by weight of each of Cu, Mn, Mg, Zn or V, the balance aluminum and incidental impurities not exceeding 0.15% by weight, and casting the alloy by belt or block casting to form a strip having an as-cast thickness of about 4-30 mm with an average cooling rate through the thickness of the cast strip during casting in the range of about 20 to 200°C/sec., thereby obtaining a cast strip containing substantially 100% alpha-AlFeSi phase.

2. A process according to claim 1, wherein the aluminum alloy contains the Si and Fe in the Si:Fe ratio of 0.25 to 1.0.

3. A process according to claim 2, wherein the aluminum alloy contains 0.42 to 0.48% Fe and 0.22 to 0.28% Si.

4. A process according to any one of claims 1 to 3, wherein the as-cast strip is hot rolled to a thickness of about 1 to 3 mm.

5. A process according to claim 4, wherein the hot rolling of the as-cast strip is carried out with an entry temperature of between 400 and 550°C and an exit temperature of between about 200 and 320°C.

5 6. A process according to claim 4, wherein the hot rolling is carried out without homogenization or additional heating.

7. A process according to any one of claims 1 to 3, wherein the as-cast strip is cold rolled to form a foil
10 stock having a thickness of about 0.2 to 0.4 mm.

8. A process according to claim 4, 5 or 6, wherein the hot rolled aluminum alloy strip is cold rolled to form a foil stock having a thickness of about 0.2 to 0.4 mm.

15 9. A process according to claim 7 or 8, wherein at least two cold rolling procedures are carried out with an interannealing step.

10. A process according to claim 9, wherein the interannealing step includes first heating the strip at
20 350 to 450°C for at least 0.5 hours, then cooling and holding the strip at 200 to 330°C for least 0.5 hours.

11. An aluminum alloy strip suitable for use in the production of thin gauge foils which comprises a continuous cast aluminum alloy strip containing iron and
25 silicon,

characterized in that the aluminum alloy contains 0.4 to 0.8% by weight iron, 0.2 to 0.4% by weight

silicon, less than 0.03% by weight Ti, optionally less than 0.05% by weight of each of Cu, Mn, Mg, Zn or V, the balance aluminum and incidental impurities not exceeding 0.15% by weight, and has been cast by belt or block
5 casting to form a strip having an as-cast thickness of about 4 to 30 mm and containing substantially 100% alpha-AlFeSi phase.

12. An aluminum alloy strip according to claim 11, wherein the Si and Fe are in the ratio of Si:Fe of 0.25
10 to 1.0.

13. An aluminum alloy strip according to claim 12, wherein the alloy contains 0.42 to 0.48% Fe and 0.22 to 0.28% Si.

14. An aluminum alloy strip according to any one
15 of claims 11 to 13, characterized by having a thickness of about 1 to 3 mm after being hot rolled.

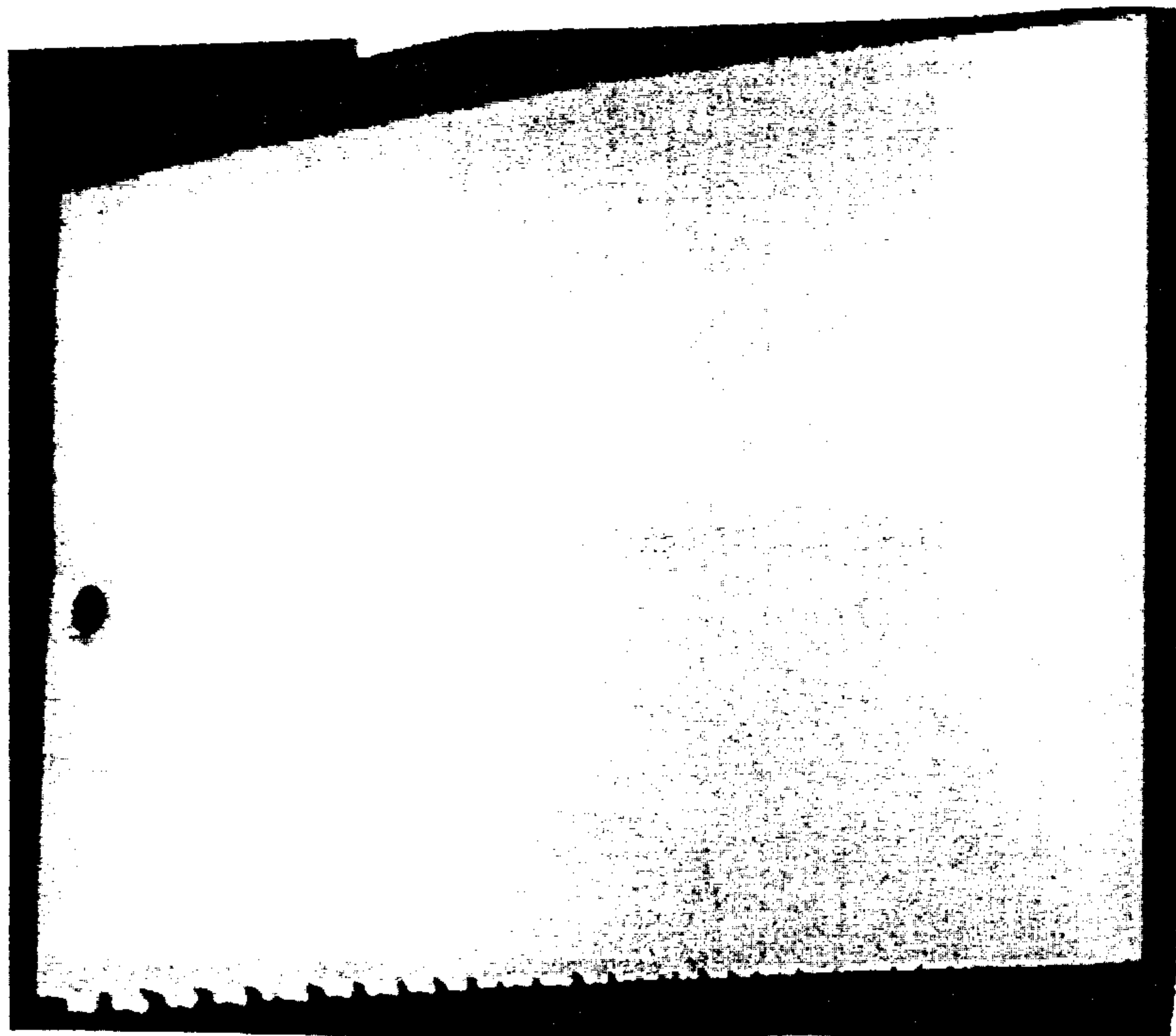


FIG. 2

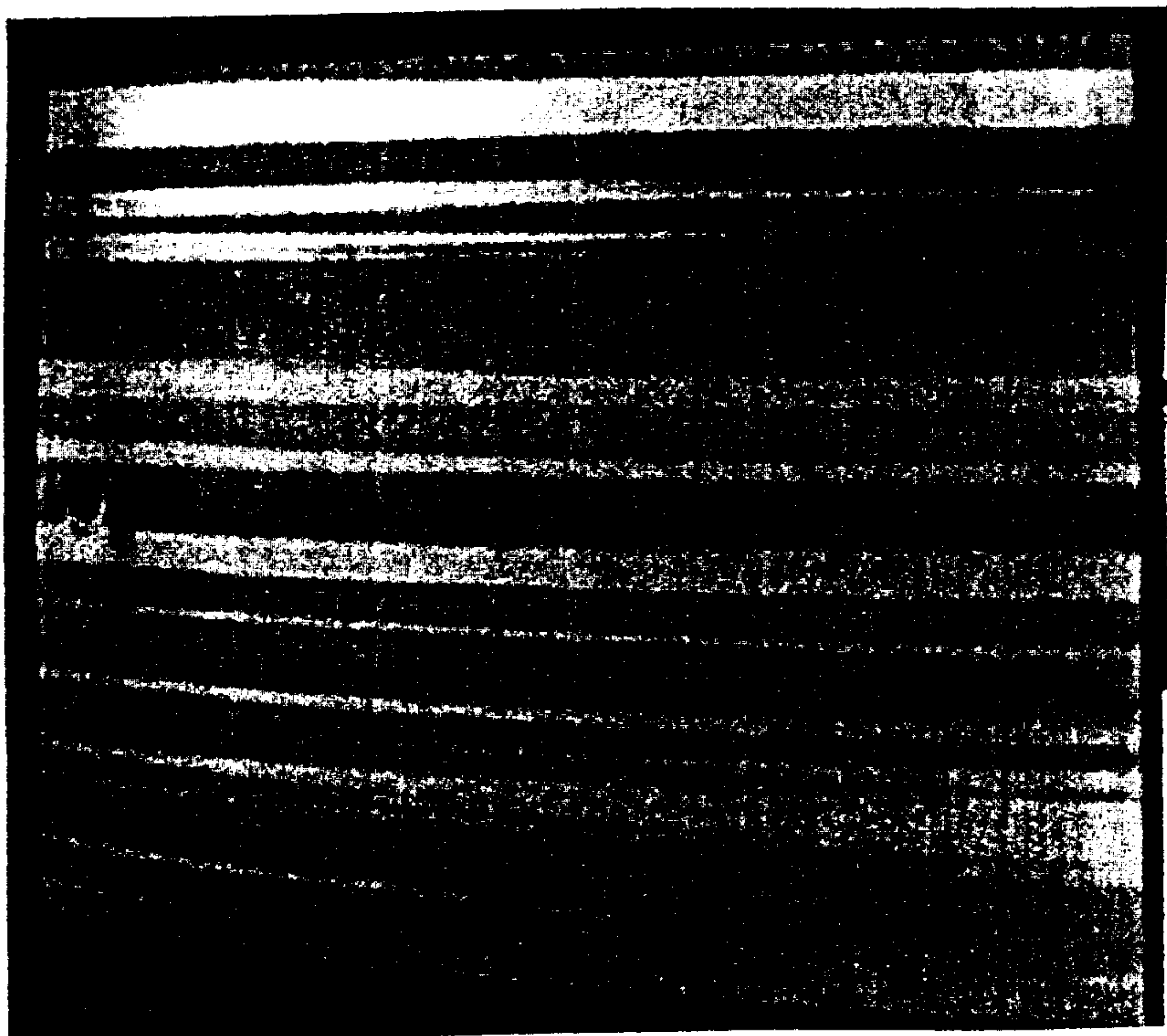


FIG. 1 (Prior Art)