June 18, 1963 H. T. FRANCIS 3,094,476

APPARATUS FOR FORMING METAL FIBERS

Filed July 13, 1960

FIG. 1

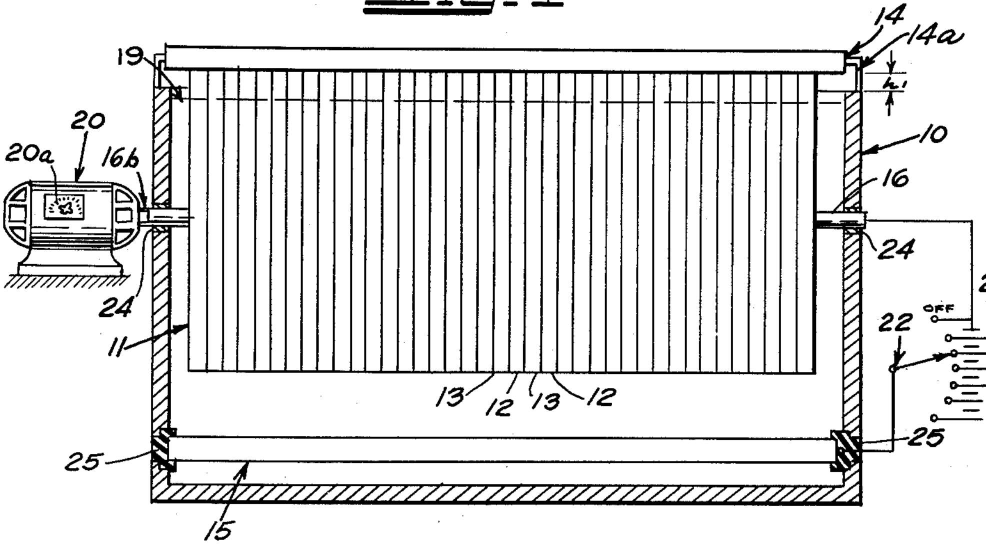


FIG. 2

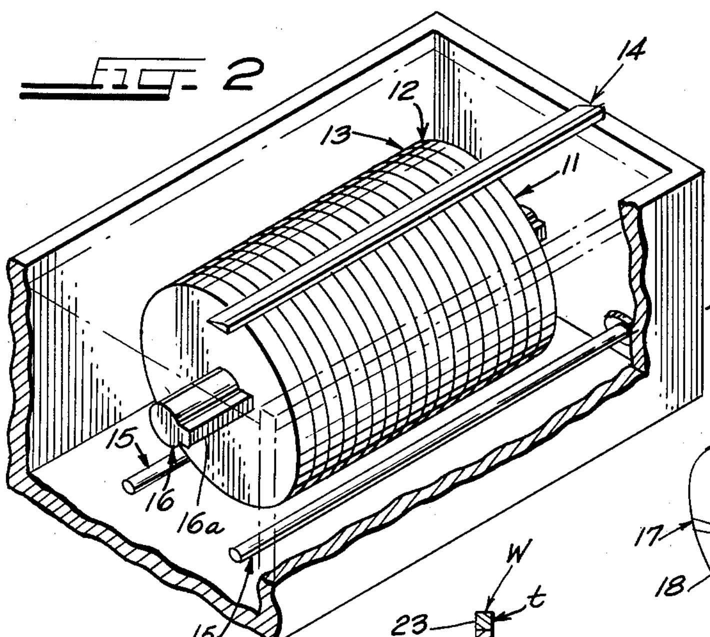


FIG. 3

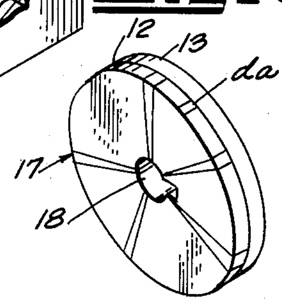
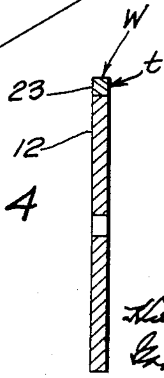


FIG. 4



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APPARATUS FOR FORMING METAL FIBERS

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1 Claim. (Cl. 204—216)

The present invention is directed to a method and apparatus for forming metal fibers and more particularly, to a method and means whereby very thin fibers of uniform dimension are readily and conveniently formed.

As employed in this specification and claim the term "fibers" denotes an elongated metallic filament having a long dimension substantially greater than its mean dimension in cross section; in other words, relatively elongated metallic bodies of fine cross section. As a general rule, a fiber should have a length of at least 10 times its mean dimension in cross section. The term "mean dimension" is related to the shape of the fiber or filament in cross section and refers to the diameter in the case of a circular filament, and in the case of a rectangular ribbon, denotes one-half the sum of the short side and the long side of the rectangle.

Metal fibers are currently manufactured primarily by four different methods, namely; scraping from wire, machining in a lathe, cutting from a stacked sheet, and wire drawing. In all of these methods the fibers produced are of relatively large cross section. That is, it is very difficult to produce extremely thin fibers. This is not to say that the likelihood of manufacturing thin fibers, by the aforementioned techniques, is entirely precluded. On the other hand, none of these methods, would continuously produce extremely thin (on the order of 0.5 thousandth of an inch in cross section) fibers.

All of these are mechanical methods with resultant drawbacks. Furthermore, as will be readily understood, only limited control of the fiber dimension is possible with these methods. For example, scraping from wire would allow the least control over fiber dimension. Contrariwise, cutting from a stacked sheet will provide the best accuracy. The latter method though accurate, is costly in that a multiplicity of operations upon the raw material are necessary.

In contradistinction to the teachings and practices of the prior art, I have developed a primarily electrochemical method enabling continuous manufacture of uniformly fine metal fibers and relatively uncomplex apparatus therefor.

It is accordingly, an object of the present invention to establish an improved method of forming thin metal fibers.

Another object of the present invention is to provide a method and apparatus for the continuous manufacture of extremely thin fibers exhibiting ease of control over fiber dimension.

Still another object of the instant invention is the provision of a method, and apparatus therefor, of electroforming metal fibers.

Yet another object of the instant invention is to provide a method, and apparatus therefor, for the continuous manufacture of extremely thin metal fibers.

The foregoing objects and others which will become apparent from a detailed reading of the description to follow, are accomplished by electrodepositing metal from an appropriate bath onto circular rotating discs immersed in the bath and controlling the dimensions of the fiber by regulating the current density in the solution and the rate of rotation of said discs.

In the drawings:

FIGURE 1 is a schematic view, partly in section, of apparatus capable of performing the method of the instant invention.

FIGURE 2 is a schematic perspective view, partly in section, particularly useful in describing the application of the principles of the claimed invention.

FIGURE 3 is a perspective view of two discs illustrating an alternative embodiment thereof.

FIGURE 4 is a view of a bisected conductive disc with a fiber **23** electrodeposited thereon in accordance with the teachings of this invention.

Before describing my method in detail, it will be helpful to outline the utility of metal fibers. Because of the increasing concern over the strength to weight ratio of metal structures and/or articles a need exists for increasing such ratio. Immediately, one recognizes that a substantial weight reduction coupled with a small decrease in strength will result in a greatly improved structure. It has been discovered that a sintered interlaced network of metal fibers can, in many instances, provide adequate structural strength coupled with a material reduction in weight, and it is along these lines that fiber metallurgy has rapidly developed. However, the ever increasing demands for metal fibers has resulted in the need for a method for economically and efficiently manufacturing thin metal fibers.

For a more detailed description of metal fibers and their field of use, the reader's attention is directed to copending applications, Serial Numbers 492,007, filed March 3, 1955, and 6,200, filed February 2, 1960, both assigned to the assignee of the present application.

Turning next to the drawings, FIGURE 1 shows a device for performing my method which includes a container **10** having mounted therein: rotatable shaft **16**, anodes **15** and cylinder **11** comprising discs **12** and **13**. Conductive metallic discs **12** are alternately interspersed between nonconductive dielectric discs **13**. Shaft **16** is insulated from container **10** by means of bushings **24** and is operatively connected to motor **20**. Shaft **16** has a key *16a* runing therealong which couples rotational motion from the shaft to discs **12** and **13**. One end of shaft **16** is connected to a pole of battery **21** while its other end is connected to the armature of motor **20**. That portion of shaft **16** connected to motor **20** is made of a non-conducting material *16b* in order that motor **20** be insulated from battery **21**. Anodes **15** are connected to the other pole of battery **21** through switch **22**. Anodes **15** are supported within, and insulated from, container **10** by rubber bushings **25**. Switch **22** through its various positions, enables control of the voltage applied across shaft **16**, conducting discs **12** and anodes **15**. By this expedient the current density in bath **19** is regulated.

Discs **12** are each provided with an opening **18** corresponding to the shaft **16** and are made of a passive metal, for example, stainless steel. By passive metal is meant that type of material to which an electrodepositable coating will not adhere.

Bath **19**, within container **10**, is a solution containing the metal to be deposited upon conducting discs **12**. The fiber composition is chosen by a proper selection of the constituents in bath **19**. For example, bath **19** may comprise solutions of: iron, nickel, copper, combinations thereof, or any other metal which is readily electrodepositable. When switch **22** is moved from the "off" position to some positive potential, a current is established between the anodes **15** and conducting discs **12** causing metal ions contained in the bath **19** to be deposited upon conducting discs **12**. It is noted that no deposit is formed on discs **13** because they are non-conductive.

It is noted that cylinder **11**, when mounted on shaft **16**, has a portion thereof (h_1, see FIGURE 1) extending out of bath **19**. The extent of protrusion of cylinder **11** out of bath 19 is not critical, however, it must extend beyond bath 19 to enable removal of the formed fibers.

The thickness t (see FIGURE 4) of fiber 23 is governed by the angular velocity of cylinder 11 and the magnitude of the current applied. In other words, the thickness is dependent upon the time a finite area (for example da in FIGURE 3) is in the bath and the magnitude of the current density causing the metal in the solution to be deposited on said area. The width w of fiber 23 is independent of the above noted factors, however, w is controlled by providing sets of discs 12 having different thicknesses.

In operation, the fiber thickness is predetermined by calculating the rate of rotation of cylinder 11 for a given voltage setting of switch 22. After controls 20*a* and 22 are set and metal is being deposited, a doctor blade 14 supported by posts 14*a* (suspended out of bath 19 but in contact with cylinder 11) scrapes the fibers from discs 12 prior to the re-entry of the disc surfaces into bath 19.

The means for transporting the fibers from doctor blade 14 are not shown in that many well known devices are suitable therefor. A conveyor belt passing immediately beneath the trailing edge of doctor blade 14 operates satisfactorily as the fiber transporting device.

FIGURE 3 depicts an alternative embodiment of the conducting discs 12 whereby the fibers 23 are of finite length. This is brought about by circumferentially spacing, about discs 12 nonconducting sections 17. Sections 17 are dielectric and may be of the same composition as discs 13. Fiber metal will only deposit upon the conducting sections and, dependent upon the number and displacement of sections 17, specific lengths of metal fibers are produced. In all cases having nonconductive discs 13 at both ends of cylinder 11 provides most efficient operaton because then no metal is deposited on the exposed planar faces of the discs.

My inventoin may best be fully envisioned by reference to the following examples:

Example I

The production of nickel fibers according to my invention is accomplished under the following bath conditions:

Bath composition:
- Nickel sulfate, $NiSO_4 \cdot 7H_2O$ ----grams/liter-- 300
- Nickel chloride, $NiCl_2 \cdot 6H_2O$ ---------do---- 60
- Boric acid, H_3BO_3 ----------------do---- 38

Temperature ---------------------------° C-- 54
pH -- 2.0

Fiber width is determined by the width w of discs 12 in the figures. Fiber length may be continuous as in FIGURES 1 and 2, or of such dimension as determined by the segment size of discs 12 as shown in FIGURE 3.

Fiber thickness is determined by the area and speed of rotation of cylinder 11 and by the current density employed. Specific fiber thicknesses for various cylinder speeds and plating current densities are as follows:

Cylinder Speed (square feet per hour passing through bath)	Current Density (amperes per square foot)	Fiber Thickness (thousandths of an inch)
1	10	0.52
10	10	0.052
10	100	0.52
10	1,000	5.2
100	1,000	0.52

Example II

The same equipment produces iron fibers when an iron plating bath is used under the following conditions:

Bath composition: Ferrous ammonium sulfate, $Fe(NH_4)_2(SO_4)_2$ --------------grams/liter-- 350
Temperature ---------------------------° C-- 60
pH -- 3.0

Fiber thickness for iron deposition was found to be very similar to that for nickel, being about 8% greater than the nickel thickness under like conditions of cylinder speed and current.

Example III

An example of alloy fiber production is brass, plated from the following bath and with the conditions noted:

Bath composition:
- Copper cyanide, CuCN --------grams/liter-- 30
- Zinc cyanide, $Zn(CN)_2$ ------------do---- 9.4
- Sodium cyanide, NaCN -grams/liter (total)-- 56.3
- Sodium carbonate, Na_2CO_3 ----grams/liter-- 30

Temperature ---------------------------° C-- 25
pH -- 12.7

The plating efficiency of brass baths is quite variable, therefore, only an approximate fiber thickness is given; thicknesses generally of the same order as for nickel are produced under similar conditions of cylinder speed and current.

From the foregoing it will be appreciated that I have provided a novel method and apparatus for the production of uniformly fine fibers. However, it is noted that the invention is not limited thereto. The method affords considerable versatility coupled with the unique capability of enabling the continuous manufacture of metal fibers of smaller cross section than those heretofore presented.

Accordingly, it is to be understood that within the scope of the appended claim the invention may be practiced otherwise than has been specifically set out in the detailed description of my invention.

I claim as my invention:

In combination, apparatus for the manufacture of thin metal fibers comprising: container means; a solution containing an electrodepositable material in said container, conductive means suspended within said container but insulated therefrom; a series of discs having conductive and non-conductive sections uniformly spaced from each other about the periphery of said discs; a series of non-conductive discs interspersed alternately between said last mentioned discs whereby all the discs are in axial alignment and substantially completely immersed in said solution; means for rotating said discs in unison; means for applying a voltage across said discs and the conductive means; means for removing the electrodepositable material from said conductive sections; means for regulating the rate of rotation of said rotating means; and means for regulating the magnitude of voltage applied across said discs and the conductive means.

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