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STAINLESS STEEL PROCESS AND PRODUCT

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This invention relates to stainless steel and more particularly to a method for producing stainless steel products.

An object of my invention is the provision of a simple, direct and thoroughly practical method for making corrosion-resistant magnetic sound recording wire, tape, or the like.

Another object of my invention is the provision of strong, corrosion-resistant steel products for retaining a record of sound for high fidelity sound reproduction.

A further object of my invention is that of providing magnetic recording wire, tape, or other magnetic sound recording elements which are amenable to demagnetization of recorded impulses and to reuse for further recordings of sound.

Another object of my invention is the provision of a durable and reliable magnetic sound recording element which gives sufficient magnetic field strength with respect to recorded sound impulses to enable favorable sound reproduction.

Other objects of my invention in part will be obvious and in part will be pointed out hereinafter.

The invention accordingly consists in the composition of materials, features of products, and in the several operational steps and the relation of each of the same to one or more of the others as described herein, the scope of the application of which is indicated in the following claims.

As conducive to a clearer understanding of certain features of my invention, it may be noted at this point that machines of the magnetic recording or magnetic wire recording type have heretofore been provided in which sound is recorded magnetically on a moving wire or filament, the wire being of a ferromagnetic substance and subjected to a magnetic field varying in intensity in accordance with the frequency and amplitude of the sound wave which is to be recorded. The sound wave then may be reproduced as by employing a reproducer pickup device in the magnetic field emanating from the magnetized wire while the latter is moved at recording speed past the pickup device. In most instances, a winding is provided on a core presenting a pair of pole pieces past which the record wire is moved. This same winding often is alternatively utilized for recording and reproducing, the coil being energized to produce a magnetic field between the pole pieces and through the record wire for magnetizing the latter during recording, and the flux through the pole pieces and thereby induce a potential in the winding during reproduction. The wire conveniently is wound from a holding reel onto a receiving reel for recording or for reproduction as described, this with the coil and pole pieces disposed between the several reels and at an effective distance relative to the wire.

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The use of ferromagnetic wire or other forms of magnetic carriers, such as ferromagnetic tape for recording and reproducing sound, has introduced a number of problems in the prior art. During the stages of early development, attempts were made to use low-alloy steel wire, but it soon was found that certain difficulties could be expected with the steel. In more recent years, proposals have been made to use cobalt steel, but this steel also has shortcomings, including high cost and difficulty in working.

A great number of materials which are available for making magnetic recording elements have very low magnetic retentivity and, accordingly, give a signal of the recorded sound which is too weak. Other materials have such high magnetic retentivity as to be objectionably sensitive to "cross-talk." This effect often prevails when a strand of the material is wound on a play-back reel after the sound recording operation. The adjacent portions of the strand and their magnetic fields exert a cross magnetic effect which serves to exchange or superimpose the signals and give distortion as noticed during playback from the reel.

There are numerous occasions where the magnetic recording elements heretofore employed have given difficulty from the standpoint of having an unsatisfactory coercivity factor. This factor represents the frequency response characteristics of the recording material and varies with such properties as fineness of magnetic particle dispersion. Where the magnetic particles in a given material are close, coercivity usually is high and the material will take a high frequency message. In most instances, though, recording materials which have a very high coercivity take a signal which is extremely permanent and cannot satisfactorily be demagnetized. These materials thus are not practical for further use by the elimination of one signal and the introduction of a new signal. Because of the extremely permanent magnetic properties of certain metals, therefore, utility is of necessity limited to those recording needs where demagnetization of the signal for reuse of the recording medium is not a consideration.

An outstanding object of my invention, accordingly, is the provision of practical and reliable magnetic recording wire, tape, or the like, having well balanced properties with respect to retentivity and coercivity and being well suited for any of a wide variety of recording needs.

Referring now more particularly to the practice of my invention, I provide chromium-nickel stainless steel magnetic recording products, as for example wire or tape, which, along with the many benefits of being corrosion-resistant, have highly valuable magnetic properties for assuring good recordings. In fact, by providing the stainless steel of proper alloy content, and by introducing a controlled amount of cold-work to achieve phase transformation, I obtain excellent recording properties inclusive of well balanced magnetic retentivity and coercivity.

The stainless steel in accordance with my invention includes approximately 0.02% to 0.20% carbon, 16% to 20% chromium, from 6% to 15% nickel, manganese ranging from 0.20% to 2.5%, and the remainder substantially all iron. The carbon, chromium, nickel and manganese constituents of the steel further are substantially consistent with the empirical formula:

$$\%\ \text{chromium}\ (\%\ \text{nickel}+\frac{\%\ \text{manganese}}{2}+20\times\%\ \text{carbon})=X$$

where X=170 to 210 dictates cold-working between 40% and 80%, and where X=210 to 240 dictates a cold-reduction of more than about 80%.

The steels are borderline steels, in the sense of being austenitic and of becoming ferritic and magnetic by phase transformation as the result of the cold-work.

There are occasions where the stainless steels which I employ include columbium such as in quantities from about 8 to 15 times the carbon content to aid in grain size control. In using stainless steels containing columbium, the carbon, chromium, nickel and manganese contents of the steel preferably come within the ranges hereinbefore noted, and the numerical ranges of X for control over the amount of cold work remain substantially as hereinbefore defined. In this, though, the formula conveniently takes a simplified form as follows:

$$\%\ \text{chromium}\ (\%\ \text{nickel}+\frac{\%\ \text{manganese}}{2}+0.40)=X$$

It will be appreciated in this connection that usually only a small quantity of carbon (about 0.02%) goes into solid solution in the columbium-containing stainless steels which I provide, there contributing as an austenite former and affecting the austenite-ferrite balance of the steel. The amounts of carbon above 0.02%, as in the range of 0.02% to 0.20% carbon, however, are satisfactorily tied up by about 8 times as much columbium, or by larger quantities of the latter element. The carbon thus forms insoluble carbides with the columbium which have no appreciable affect upon the austenitic-ferritic balance of the steel. Thus, in employing my empirical formula in connection with steels of the character just noted, recognition is given only that portion of the carbon which goes into solid solution. The simplified formula, therefore, assumes about 0.02% carbon as effective, this being represented by a constant, 0.40. The steels which I employ sometimes include other elements such as molybdenum, either with or without columbium. When these elements are of such character as to tie up the carbon, as does columbium, the simplified formula still is conveniently used.

By keeping the steel composition and the amount of cold work consistent with the terms of the empirical formula, thoroughly satisfactory magnetic recording products and properties thereof are achieved. The finished products have a coercivity (Hc) in the approximate range of 100 to 300 oersteds and a retentivity (Br) of about 1000 to 3000 gausses based upon a field strength of 1000 oersteds. Where the cold-reduction is appreciably less than that called for by the empirical formula, the magnetic retentivity of the steel usually is low at the expense of field strength, and coercivity usually is too high for satisfactory demagnetization and reuse of the recording element. Where the cold-reduction exceeds the terms of the formula, magnetic retentivity usually is so high as to leave the products susceptible to "cross-talk" and coercivity usually is too low for good frequency response characteristics.

As illustrative of the practice of my invention, I refer now to the production of a stainless steel recording element, this for example being a wire made of steel containing about 0.052% carbon, 18.81% chromium, 10.59% nickel, 0.58% manganese, and the remainder substantially all iron. This composition, it will be observed, by substitution of the carbon, chromium, nickel and manganese in the empirical formula, has an X value of 224 which means that the cold-reduction should exceed about 80% for developing the best magnetic properties. I subject the steel as in the form of an annealed 0.020 inch wire to a series of cold-drawing operations or passes, and this preferably without intermediate anneals. Upon subjecting the wire to a total reduction of 84%, I find that the coercivity (Hc) is somewhere in the vicinity of 250 oersteds, and the retentivity (Br) around 1460 gausses on the basis of a field strength of 1000 oersteds. The resulting cold drawn wire is strong, durable and corrosion-resistant and has good magnetic properties for serving its intended purpose.

The composition and magnetic properties of several other stainless alloy steels which I have used for producing magnetic recording products in accordance with the invention, are set forth in Table I. These compositions conveniently were in the form of annealed wire, this then being cold-worked, to the extent tabulated, down to final gauge without intermediate annealing. The coercivity (Hc) and the retentivity (Br) were measured following the cold reduction, and this on the basis of a field strength of 1000 oersteds. Apart from the carbon, chromium, nickel, manganese, and columbium where used, the steels had the remainder of their composition substantially all iron.

Table I.—Magnetic recording compositions

C	Mn	Cr	Ni	Cb	X	Per Cent Cold Work	Hc Oerst.	Br Gauss
0.077	0.66	18.42	9.29	.....	199	60	175	1,375
0.045	1.54	18.38	11.12	0.84	226	90	235	1,440

To illustrate the effect of cold work on the properties of chromium-nickel stainless steels which I employ, the following group of examples are given:

Example I

A stainless steel containing about 0.052% carbon, 18.81% chromium, 10.59% nickel, 0.58% manganese and the remainder substantially all iron exhibited the following magnetic properties corresponding to different amounts of cold reduction. The formula X value was found to be 224 which calls for a cold reduction of more than about 80%.

Sample	Per Cent Cold Work	Hc Oerst.	Br Gauss	Remarks
A	75	372	710	Hc too high, Br too low.
B	84	250	1,460	Hc and Br satisfactory.
C	90	170	3,000	Do.

It will be observed that the magnetic properties corresponding to a too small cold reduction of 75% are objectionable for the reason that the coercivity (Hc) value is too high and the retentivity (Br) value is too low. The magnetic properties corresponding to the sufficiently large 84% and 90% cold reductions are satisfactory.

Example II

A steel containing about 0.77% carbon, 18.42% chromium, 9.29% nickel, 0.66% manganese and the remainder substantially all iron was found to have an X value of 119, this corresponding to the cold reduction range of 40% to 80%. Upon being cold worked by differing amounts the following comparative magnetic properties were developed.

Sample	Per Cent Cold Work	Hc Oerst.	Br Gauss	Remarks
A	36	165	115	Br too low.
B	60	240	1,730	Hc and Br satisfactory.
C	69	210	2,650	Do.
D	96	70	6,200	Hc too low, Br too high.

The method for producing stainless steel sound recording elements in accordance with my invention is simple to practice and gives very satisfactory magnetic products. Also, the particular quality of steel used in the process is amenable to the cold-working operations, and is readily rolled or drawn or otherwise subjected to cold reduction to achieve desired sound recording products, or the like. The cold-working step or steps are effective not only to work the metal to desired size, but to develop highly satisfactory magnetic properties in the products in working to size. By keeping the steel composition and the amount of cold work substantially in accordance with the terms of my empirical formula, the sound recording products achieved are magnetic and have high frequency response characteristics yet the recorded signal can be satisfactorily demagnetized for reuse of the recording material as in dictaphones or other sound recording and reproducing instruments. Also, the steel recording elements maintain the signal with adequate field strength for satisfactory reproduction of the sound and yet the magnetic retentivity is sufficient to avoid "cross-talk."

Thus, it will be seen that in this invention there are provided a stainless steel, method and products by which the various objects noted

herein together with many thoroughly practical advantages are successfully achieved. It will be seen that the invention offers many favorable features from the standpoint of the steel, the operational steps, and the resulting products obtained.

As many possible embodiments of my invention may be made and as many changes may be made in the embodiments hereinbefore set forth, it will be understood that the matter described herein is to be interpreted as illustrative and not as a limitation.

I claim:

1. In a method for producing magnetic sound recording steel products, the art which includes providing stainless steel wire, tape or the like of about 0.02 inch thickness and in which there are correlated about 0.02% to 0.20% carbon, 16% to 20% chromium, 6% to 15% nickel, 0.20% to 2.5% manganese and the remainder substantially all iron in relationship substantially consistent with the formula:

$$\%\text{ chromium }(\%\text{ nickel}+\frac{\%\text{ manganese}}{2}+20\times\%\text{ C})=X$$

where X=170 to 210 dictates a 40% to 80% cold reduction of said steel and where X=210 to 240 dictates more than about 80% cold reduction,

and cold-working said steel wire, tape or the like, substantially consistent with the formula.

2. In a method of producing magnetic sound recording steel products, the art which includes, providing stainless steel wire, tape or the like of about 0.02 inch thickness and in which there are correlated about 16% to 20% chromium, 6% to 15% nickel, 0.20% to 2.5% manganese, 0.02% to 0.20% carbon, columbium in amounts of about 8 to 15 times the carbon content, and the remainder substantially all iron in relationship substantially consistent with the formula:

$$\%\text{ chromium }(\%\text{ nickel}+\frac{\%\text{ manganese}}{2}+0.40)=X$$

where X=170 to 210 dictates a 40% to 80% cold reduction of said steel and where X=210 to 240 dictates more than about 80% cold reduction,

and cold-working said steel wire, tape or the like, substantially consistent with the formula.

3. A cold-worked stainless steel magnetic sound recording product not exceeding about 0.01 inch thickness and having magnetic coercivity in the approximate range of 100 to 300 oersteds and magnetic retentivity of about 1000 to 3000 gausses based upon a field strength of 1000 oersteds, containing about 16% to 20% chromium, 6% to 15% nickel, 0.20% to 2.5% manganese, 0.02% to 0.20% carbon, columbium amounting to about 8 to 15 times the carbon content, and the remainder substantially all iron in relationship substantially consistent with the formula:

$$\%\text{ chromium }(\%\text{ nickel}+\frac{\%\text{ manganese}}{2}+0.40)=X$$

where X is a numerical value of about 170 to 210 with a cold reduction of 40% to 80% and where X is a value of 210 to 240 with a cold reduction of more than about 80%.

4. A cold-drawn stainless steel magnetic sound recording wire not exceeding about 0.008

inch thickness and having magnetic coercivity in the approximate range of 100 to 300 oersteds and magnetic retentivity of about 1000 to 3000 gausses based upon a field strength of 1000 oersteds, containing about 0.02% to 0.20% carbon, 16% to 20% chromium, 6% to 15% nickel, 0.20% to 2.5% manganese and the remainder substantially all iron in relationship substantially consistent with the formula:

$$\%\text{ chromium }(\%\text{ nickel}+\frac{\%\text{ manganese}}{2}+20\times\%\text{ C})=X$$

where X is a numerical value of about 170 to 210 with a cold reduction of 40% to 80% and where X is a value of 210 to 240 with a cold reduction of more than about 80%.

5. A cold-rolled stainless steel magnetic sound recording tape not exceeding about 0.008 inch thickness and having magnetic coercivity in the approximate range of 100 to 300 oersteds and magnetic retentivity of about 1000 to 3000 gausses based upon a field strength of 1000 oersteds, containing about 0.02% to 0.20% carbon, 16% to 20% chromium, 6% to 15% nickel, 0.20% to 2.5% manganese and the remainder

substantially all iron in relationship substantially consistent with the formula:

$$\%\text{ chromium }(\%\text{ nickel}+\frac{\%\text{ manganese}}{2}+20\times\%\text{ C})=X$$

where X is a numerical value of about 170 to 210 with a cold reduction of 40% to 80% and where X is a value of 210 to 240 with a cold reduction of more than about 80%.

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