STEEL HAVING IMPROVED FREE-CUTTING PROPERTIES

Filed June 30, 1971 3 Sheets-Sheet 1

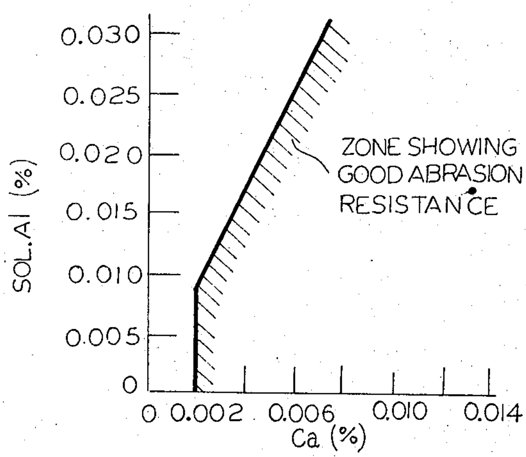

FIG. 1

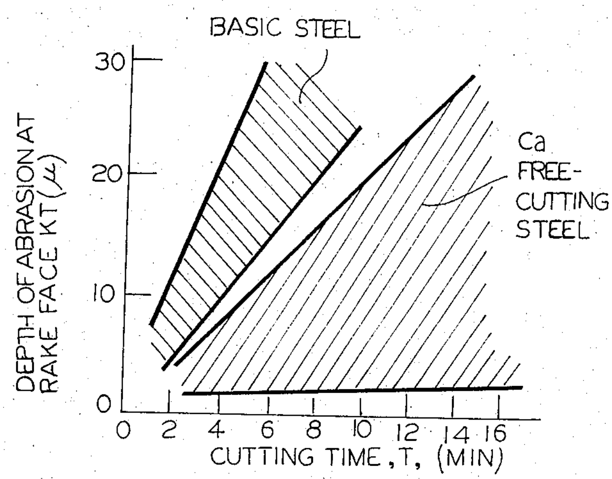

FIG. 2

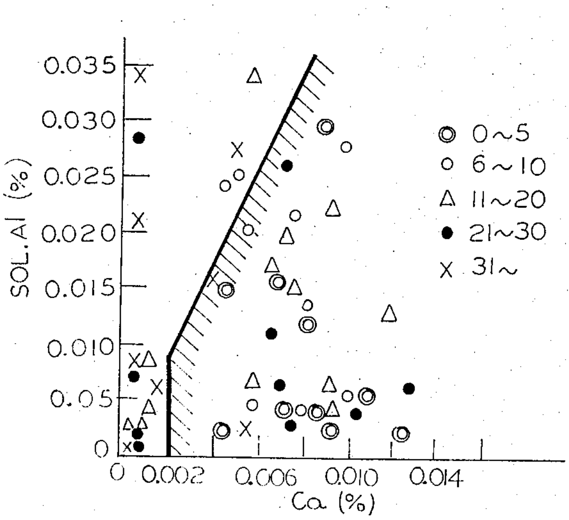

FIG. 3

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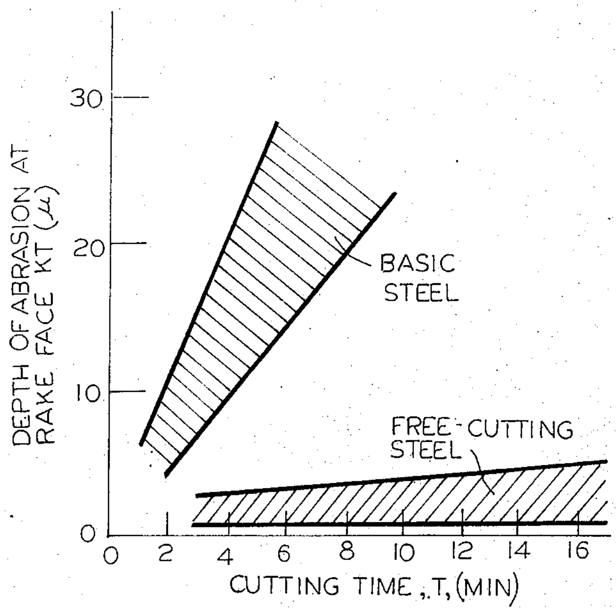

FIG.4

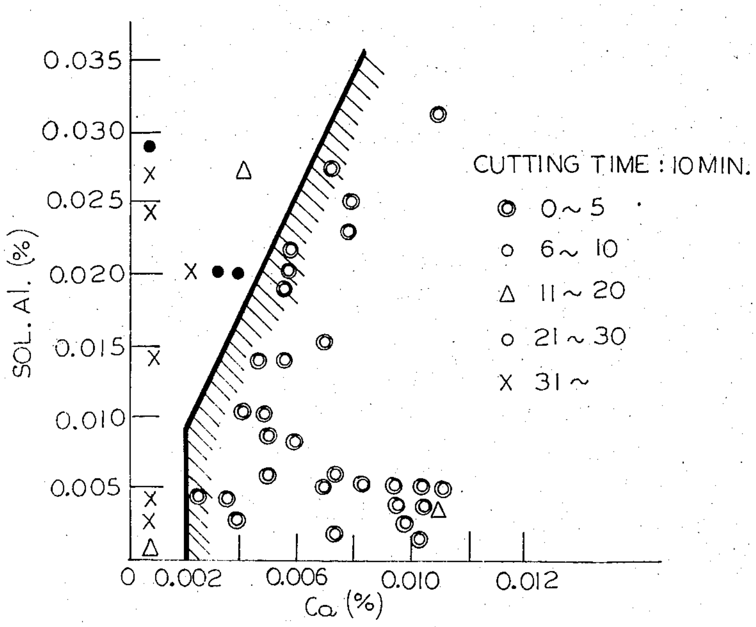

FIG. 5

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STEEL HAVING IMPROVED FREE-CUTTING PROPERTIES

Filed June 30, 1971 3 Sheets-Sheet 3

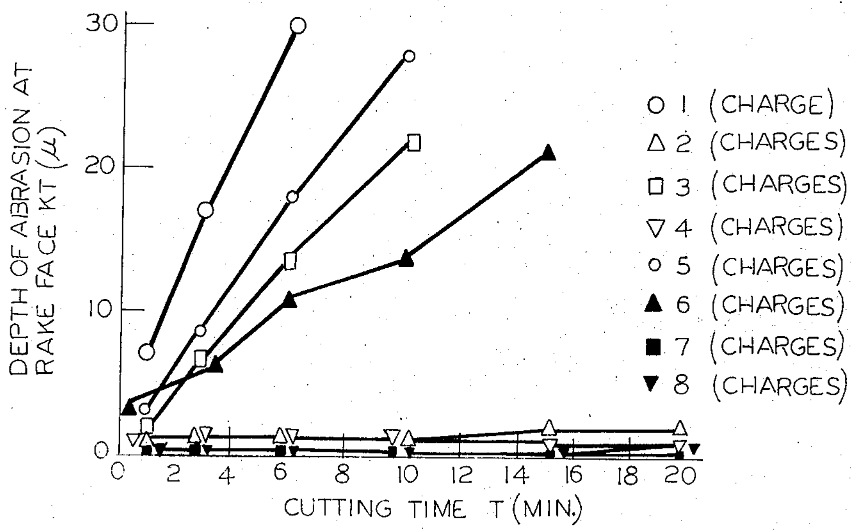

FIG. 6

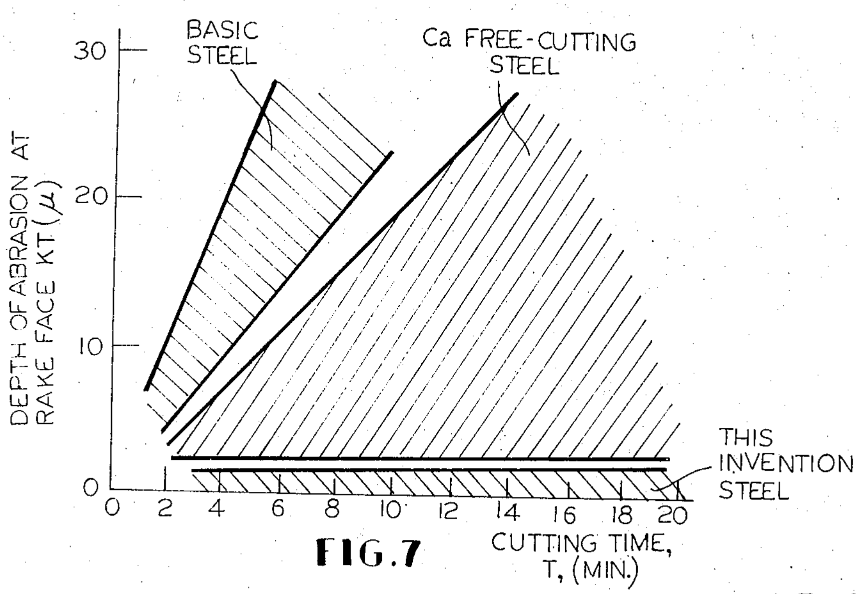

FIG. 7

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STEEL HAVING IMPROVED FREE-CUTTING PROPERTIES

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Int. Cl. C22c 37/10, 39/02
U.S. Cl. 75—124 4 Claims

ABSTRACT OF THE DISCLOSURE

A machine structure steel having superior free-cutting properties, yield strength and tensile strength and comprising the addition of 0.002% to 0.02% Ca, 0.005% to 0.04% Sol. Al. and 0.005% to 0.1% Nb and/or V, to known composition contained in ordinary steel.

BACKGROUND OF THE INVENTION

This invention relates to steel compositions and more particularly to steels having improved free-cutting properties.

Generally, the following characteristics should be considered in evaluating the free-cutting properties of a machine structural steel:

(1) useful life of a tool employing the steel,
(2) roughness of a machined surface,
(3) cutting resistance,
(4) crushing property of a chip.

It is, however, customary that among the aforementioned properties useful life is stressed most often. Accordingly, steel displaying excellent abrasion resistance may be recognized as the best suited for cutting jobs, such as when used in a tool.

Steel, which may be, for example, a sulphur (S) free-cutting steel containing about 0.3% S, a lead (Pb) free-cutting steel containing 0.15% to 0.3% Pb, or a sulphur-lead free-cutting steel containing both S and Pb have been employed for the above purpose. It is however, well-known that the utility of these steels is limited by reason of certain common defects existing in these steels, such as that such steels are confined to cutting jobs performed at low speeds.

The calcium (Ca) free-cutting steel was thus developed. This steel contains more than 0.002% Ca and an adjusted amount of Sol. Al. It should be noted at this point that the percents recited herein refers to percentage by weight. This steel's ability to be machined is improved over that discussed above, to be suitable for cutting work at high speeds. It was found however that the Ca free-cutting steel had large dispersions of abrasion amount when employed in a tool and hence the depth of abrasion was close to that of ordinary steel. There was only slight possibility that such dispersion could be reduced. The relative amounts of Ca and Sol. Al. are difficult to adjust to the most suitable level, with concurrent stability.

Therefore, a calcium-sulphur free-cutting steel was developed, comprising the addition of S to steel, in order to remove the foregoing defect. The abrasion amount of a tool employing Ca-S free-cutting steel, is reduced to smaller dispersions and less depth. However, this steel is still deficient in certain mechanical properties.

Thus, there is a great need today for steels which have improved mechanical properties and are stable and have excellent free-cutting properties at high speeds and may be

used for example in cemented carbide tools for cutting work.

SUMMARY OF THE INVENTION

Accordingly, an object of this invention is to provide a machine structure steel stably displaying excellent free-cutting properties with the least abrasion amount when employed in a tool at high speeds.

Another object of this invention is to provide a steel which reduces the working cost when used in cemented carbide tools.

A further object of this invention is to provide a steel possessing better mechanical properties and better free-cutting properties than those of known steels.

The foregoing and other objects and features of this invention are attained by a steel comprising the addition of 0.002% to 0.02% Ca, 0.005% to 0.04% Sol. Al. and 0.005% to 0.1% niobium (Nb) and/or vanadium (V) to the known compositions of ordinary machine structure steels.

BRIEF DESCRIPTION OF DRAWING

FIG. 1 is a graph depicting the relation between Ca percent and Sol. Al. percent in a known Ca free-cutting steel and the resulting influence on abrasion of a tool employing such steel;

FIG. 2 is a graph depicting how the abrasion amount of a tool using a known Ca free-cutting steel is changed with passage of cutting time, in comparison with that of basic steel;

FIG. 3, is a diagram depicting the relation between Ca percent and Sol. Al. percent as shown in FIG. 1 plotting with actual samples;

FIG. 4 is a graph depicting how the abrasion amount of a tool using a known Ca-S free-cutting steel is changed with passage of cutting time, in comparison with basic steel;

FIG. 5 is a diagram depicting the relation between Ca percent and Sol. Al. percent in a Ca-S steel as plotted with actual samples;

FIG. 6 is a graph depicting the abrasion amount of a tool using the steel of this invention as changed with passage of cutting time, and plotted using a comparison with each of several steels.

FIG. 7 depicts a graph showing how the abrasion amount of a tool using the steel of this invention is changed with the passage of cutting time, in comparison with other steels.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

Turning now to FIG. 1 there is depicted a graph showing the relation between Sol. Al percent and Ca percent in a Ca free-cutting steel. This steel was produced by adding Ca to the basic steel discussed above and to be discussed in greater detail hereinbelow. There is depicted a zone showing good abrasion resistance. Experiments have shown that Ca free-cutting steel has large dispersions of amount of dispersive abrasion. FIG. 3 depicts the relation as plotted with actual data from actual samples.

FIGS. 2 and 3 depict the amount of abrasion depth as measured against cutting time. It can be readily understood that the increase of depth of abrasion with time is not desirable.

Turning then to FIG. 5, there is depicted a plot of data obtained with actual examples of Ca-S free-cutting steel, measuring Sol. Al percent against Ca percent. The cutting time was 10 minutes. In FIG. 4, there is depicted the depth of abrasion as measured against time for a Ca-S free-cutting steel. The depth does not increase in any substantial manner with passage of cutting time. This is probably due to the addition of more than 0.04% S to the Ca steel discussed above with reference to FIG. 1.

It was found that despite the advantageous small dispersions and no substantial increase in depth of abrasion with passage of time, certain mechanical properties are deficient. The following Table I shows mechanical properties of the above Ca-S free-cutting steel in comparison with that of Ca free-cutting steel.

TABLE I

Kind of steel	Direction of test piece	Yield point, kg./mm.²	Tensile strength, kg./mm.²	Elongation percent	Heat treatment
Ca free-cutting steel	Longitudinal (L)	42.5	62.5	33	Normalizing 850° C x 30 min. Air cooling.
	Transverse (C)	43.0	61.8	33	
Ca-S free-cutting steel	Longitudinal (L)	41.8	59.4	33	
	Transverse (C)	41.6	59.0	28	

It can be readily understood from Table I that the mechanical properties of Ca-S free-cutting steel are lower than those of Ca free-cutting steel, especially in that of the transverse direction (C). It was confirmed through many experiments that the reason for this degradation was use of a higher S content in the Ca-S cutting steel.

The values which are depicted in the previously discussed and following figures were obtained with the same type cutting tools, depth of cut and cutting speed.

All of the machine structure steel, as shown in American Standards, i.e. AISI and the like, may be utilized as a basic starting point to which the other components of this inventive steel are added. The basic steel may be selected from common carbon steels, heat resisting steels, chromium molybdenum steels, nickel chromium molybdenum steels or the like. When each of the elements Ca., Sol. Al., and Nb and/or V is added to each of the above steels, a new steel, which is the present inventive steel was produced. The inventive steel displays outstanding free-cutting properties and excellent mechanical properties as a machine structure steel. It is readily attained to perfection with ease and stability.

C, silicon (Si) and manganese (Mn) which are common elements in the above steels should be within certain ranges. For example, C should preferably range from 0.08% to 0.6%; Si should preferably range from 0.15% to 0.60%; and Mn should preferably range from 0.30% to 2.00%. More than 0.6% C reduces the workability of steel and less than 0.08% C will substantially reduce the advantageous effects of C as required in a machine structure steel, such as hardness. Si and Mn are useful for deoxidation, and increasing yield strength and tensile strength of steel with low cost. However, when the Si content is more than 0.6% or Mn is more than 2.00%, the toughness of the steel is adversely affected. Conversely, when the Si content is less than 0.15% or Mn is less than 0.30%, the same above effects will be reduced substantially.

In the steel obtained with this invention, each of the elements, Ca, Sol. Al., and Nb and/or V, should be further added together with the above-mentioned basic elements or other elements specified in the variously used standards. The added ranges of Ca., Sol. Al., Nb. and V. are as follows: Ca is from 0.002% to 0.02%; Sol. Al. is from 0.005% to 0.04%; and Nb. and/or V. is from 0.005% to 0.1%. When the Ca content is more than 0.02%, workabiilty of the resulting steel is reduced substantially and its cost increased. Conversely, less than 0.002% of Ca will substantially reduce the abrasive qualities of a tool using the resulting steel. When the Sol. Al. content is more than 0.04% the abrasion resistance of the tool is lowered to a considerable degree and when the Sol. Al. content is less than 0.005% deoxidation and grain size of the resulting steel will be difficult to control. More than 0.1% Nb or V or Nb and V brings little change of the abrasion resistance of a tool using the resulting steel and brings only added costs. Less than 0.005% of the same substantially reduces the abrasion amount to an undesirable degree.

Many experiments have been performed on the above steels. Typical steels actually tested are shown in the below Table II. In this Table II, Charge No. 1 steel is based on known steel AISI–1045 and is regarded as a basic steel to which the other elements may be added in accordance with this invention. Charge No. 2 steel is a Ca free-cutting steel produced by adding Ca to the basic steel such as of Charge No. 1. Charge No. 3 steel is another Ca free-cutting steel. Charge No. 4 steel is a Ca-S free-cutting steel produced by adding S to the Ca free-cutting steel such as of Charge No. 2. Charge No. 5 steel is a Ca-Nb free-cutting steel produced by adding Nb to the Ca free-cutting steel such as of Charge No. 2, but, the Sol. Al. content is more than that of the present inventive steel.

TABLE II

Charge number	Components	Chemical composition (percent)							
		C	Si	Mn	S	Sol. Al	Ca	Nb	V
1	Basic steel	0.41	0.28	0.68	0.022	0.008	Trace		
2	Basic steel + Ca	0.42	0.27	0.65	0.015	0.004	0.0072		
3	do	0.45	0.25	0.63	0.027	0.010	0.0065		
4	Basic steel + Ca + S	0.46	0.18.	0.74	0.060	0.010	0.0042		
5	Basic steel + Ca + Nb	0.43	0.28	0.78	0.029	0.044	0.0048	0.031	
6	Basic steel + Ca + V	0.43	0.32	0.82	0.021	0.049	0.0074		0.043
7	Basic steel + Ca + Nb	0.43	0.30	0.74	0.028	0.009	0.0070	0.021	
8	Basic steel + Ca + V	0.45	0.27	0.73	0.028	0.008	0.0105		0.021

Charge No. 6 steel is a Ca-V free-cutting steel produced by adding V to a Ca free-cutting steel such as of Charge No. 2, but with the Sol. Al. content more than that of this invention. Charge No. 7 steel is a Ca-Nb free-cutting steel produced in accordance with this invention. Charge No. 8 steel is a Ca-V free-cutting steel produced in accordance with this invention.

The cutting requirements of the above samples were as follows:

cutting tool: A cemented carbide tool bit.
cutting speed: 150 m./min.
depth of cut: 2 mm.
feed: 0.25 mm./revolution.

Turning now to FIG. 6, there is depicted in graphic format, the abrasion properties of a tool using the steel samples of Charges Nos. 1–8 discussed above and shown in Table II. From FIG. 6, it can be readily understood that the abrasion amount of a tool using the basic steel of Charge No. 1 is large and for Ca free-cutting steel of Charges Nos. 2 and 3, which were developed to improve the free-cutting properties of basic steel, abrasion amount is unstable. Charge No. 3 steel shows a considerable amount of abrasion as cutting time passes. The amount of abrasion of Charge No. 2 steel is very small and is comparatively stable.

Ca-S free-cutting steel of Charge No. 4 was developed to stabilize the free-cutting properties of Ca steel and is produced by the addition of sulphur. Referring again to FIG. 6, it can be readily understood that the object of the Ca-S free-cutting steel has been accomplished. The abrasion resistance of the tool using the Ca-S free-cutting steel is superior to Charge No. 2 steel and is stable, which was confirmed by other experiments, not shown herein. However, as mentioned above, there are deficiencies in the mechanical properties of the Ca-S free-cutting steel.

The steels produced in accordance with the principles of this invention and shown as Charges Nos. 7 and 8 steels, have been developed to improve or eliminate the aforementioned deficiencies. Returning again to FIG. 6, the abrasion amount of a tool using the steel produced in accordance with this invention is superior to that of the Ca-S free-cutting steels and is also outstanding in stability, that is to say that the abrasion depth does not change significantly with passage of time. At the same time, as hereinafter mentioned the mechanical properties of each of the steels produced using the principles of this invention are excellent and substantially better than those of the other above steels. In this invention the Sol. Al. content is within a certain range; as well as the amount of each of the other elements Ca and Nb and/or V are within the above discussed ranges.

The steel charges having Sol. Al. contents outside of the ranges of this invention are shown as comparative examples. These comparative samples are Charges Nos. 5 and 6 Steel in FIG. 6. Referring to FIG. 6, it can be readily understood that the abrasion resistance of a tool using steels having Sol. Al. contents more than 0.04% become substantially worse.

The mechanical properties of the steel shown in Table II are shown in Table III, given below. According to this Table III, it can be readily understood that the mechanical properties of new steels produced in accordance with this invention, namely Charges Nos. 7 and 8 steels, are far superior to those of any of the other steels. At the same time it should be noted that the mechanical properties of the Ca-S free-cutting steel Charges No. 4 steel, is clearly inferior to those of any of the other steels and especially inferior to a greater degree in elongation. Even though abrasion resistance of a tool using the Ca-S free-cutting steel is acceptable, as shown in FIG. 6, because of its inferior mechanical properties, its utility is substantially restricted. The new steels of this invention are not so restricted.

TABLE III

Charge number	Cut direction of test piece	Yield point, kg./mm.²	Tensile strength, kg./mm.²	Percent Elongation	Percent Reduction	Heat-treatment and test condition
1	Longitudinal (L)	42.7	68.5	28.0	49.0	850° C. x 30 min. air cooling (normalizing). Test piece; Longitudinal, JIS No. 5, Transverse, JIS No. 5.
	Transverse (C)	43.0	69.0	27.5	48.0	
2	Longitudinal (L)	42.4	69.3	28.5	50.5	
	Transverse (C)	41.5	69.0	28.0	51.5	
4	Longitudinal (L)	40.2	66.6	29.4	52.1	
	Transverse (C)	40.7	67.5	24.5	42.5	
7	Longitudinal (L)	43.0	69.5	29.5	51.8	
	Transverse (C)	42.5	70.1	29.0	50.5	
8	Longitudinal (L)	42.8	70.5	28.5	50.5	
	Transverse (C)	41.9	68.9	29.3	49.8	

Turning now to FIG. 7, there is depicted a graph showing the change of amount of abrasion of a tool using the new steel produced according to the invention, with the passage of cutting time, as compared with that of other typical steels. The graph data are the results of plotting data obtained through many experiments and samples. From the FIG. 7, it can be readily understood that the free-cutting properties of this invention has little dispersion and outstanding stability. The depth of abrasion does not increase in any significant amount with passage of cutting time.

Another example of this invention namely steel comprising Nb and V together with the other above specified elements, is not shown in the above tables. However, the results obtained with actual samples showed that they are comparable with the results obtained with the separate addition of Nb or V, provided that the added amounts of Nb and V together is within the range as specified above.

Thus, it may be noted that the combination of the desired properties discussed above, which are required in the cutting work, has been obtained by this invention for the first time.

While this invention was explained in terms of a preferred embodiment, various modifications and variations thereof would be evident to one skilled in the art, and such modifications and variations are to be considered within the spirit and scope of this invention.

What is claimed is:

1. Steel composition consisting essentially of 0.002% to 0.02% Ca; 0.005% to 0.04% sol. Al.; 0.005% to 0.1% Nb and/or V; 0.08% to 0.60% C; 0.15% to 0.60% Si; 0.30% to 2.00% Mn and balance Fe and unavoidable traces.

2. Composition of claim 1, wherein said element is Nb.

3. Composition of claim 1, wherein said element is V.

4. Composition of claim 1, wherein said element is Nb and V in combination.

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