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(54) **LOW-DENSITY ALLOY AND FABRICATION METHOD THEREOF**

(75) Inventors: **Tzeng-Feng Liu**, Hsinchu City (TW); **Jian-Wei Lee**, Hsinchu City (TW)

Correspondence Address:
Joe McKinney Muncy
PO Box 1364
Fairfax, VA 22038-1364 (US)

(73) Assignee: **National Chiao Tung University**

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(57) **ABSTRACT**

A low-density alloy and the fabrication method thereof are disclosed. The alloy comprises, in weight percent, equal to or greater than 15 wt. % but lower than or equal to 22.5 wt. % manganese, equal to or greater than 7.2 wt. % but lower than or equal to 9.0 wt. % aluminum, equal to or greater than 5.1 wt. % but lower than or equal to 7.8 wt. % chromium, equal to or greater than 0.6 wt. % but lower than or equal to 1.2 wt. % carbon and the balance of iron. The golf-club head made from the abovementioned alloy can obtain superior elongation, strength, damping capacity, and corrosion resistance even without any hot/cold working process, such as forging, rolling, etc.; therefore, the fabrication cost thereof can be obviously reduced.

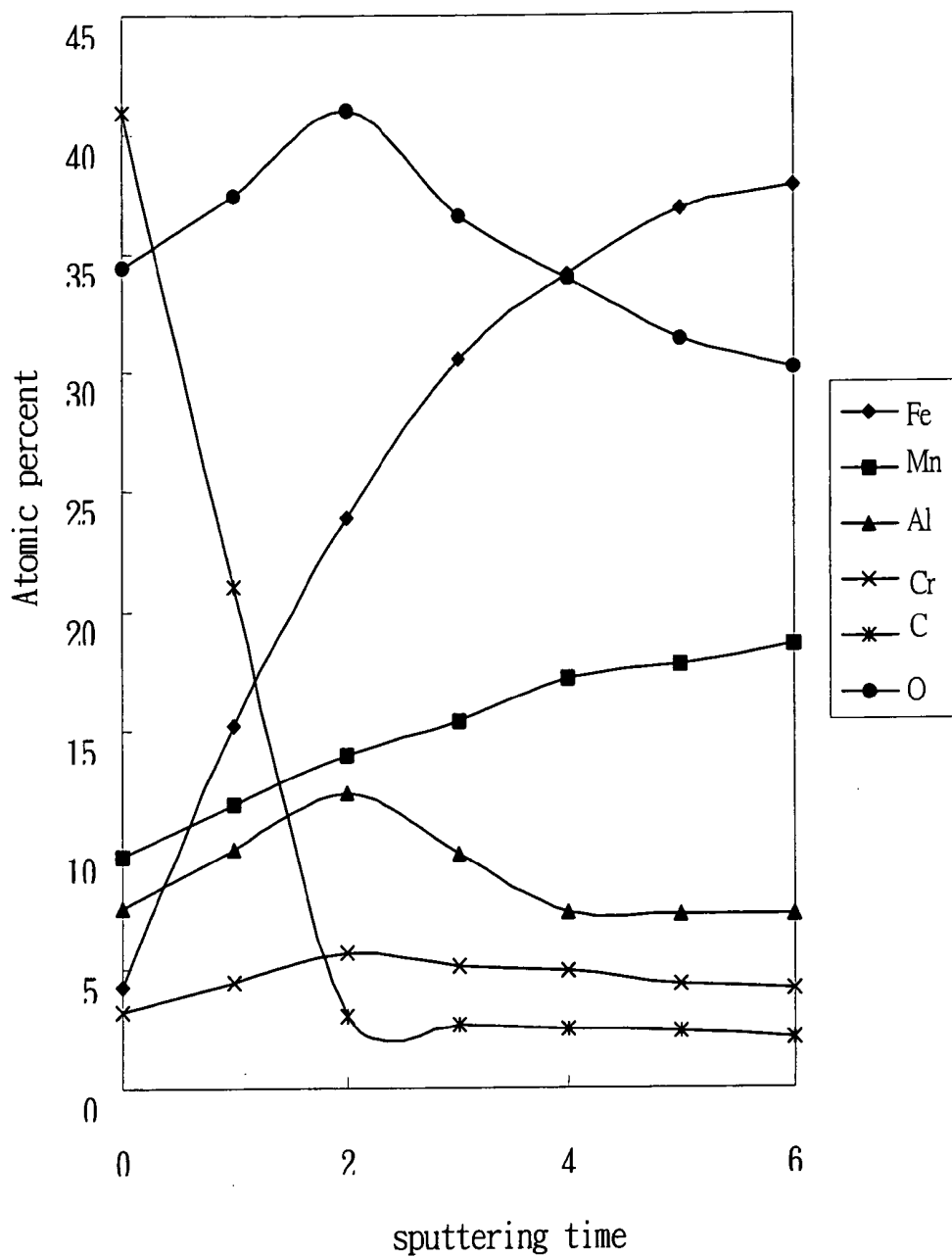


Fig.1

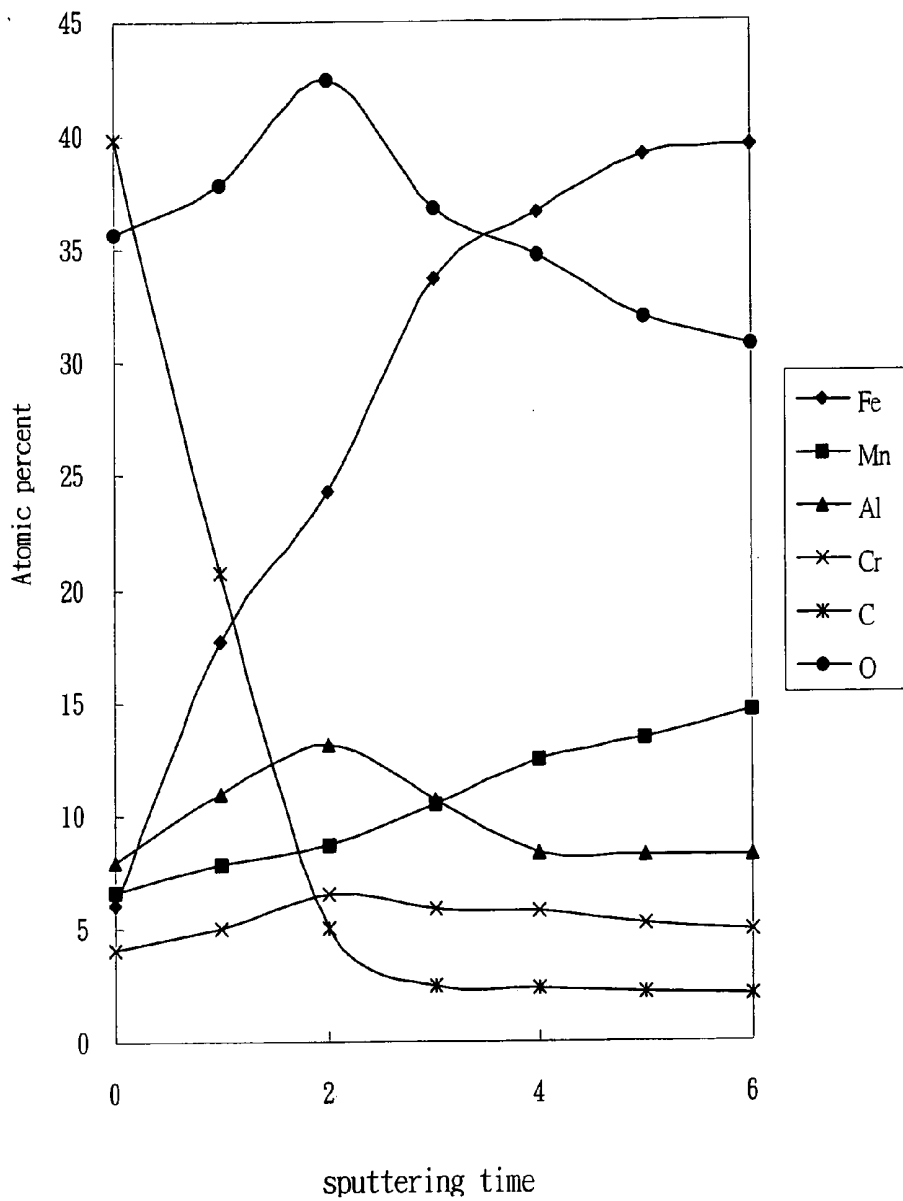


Fig.2

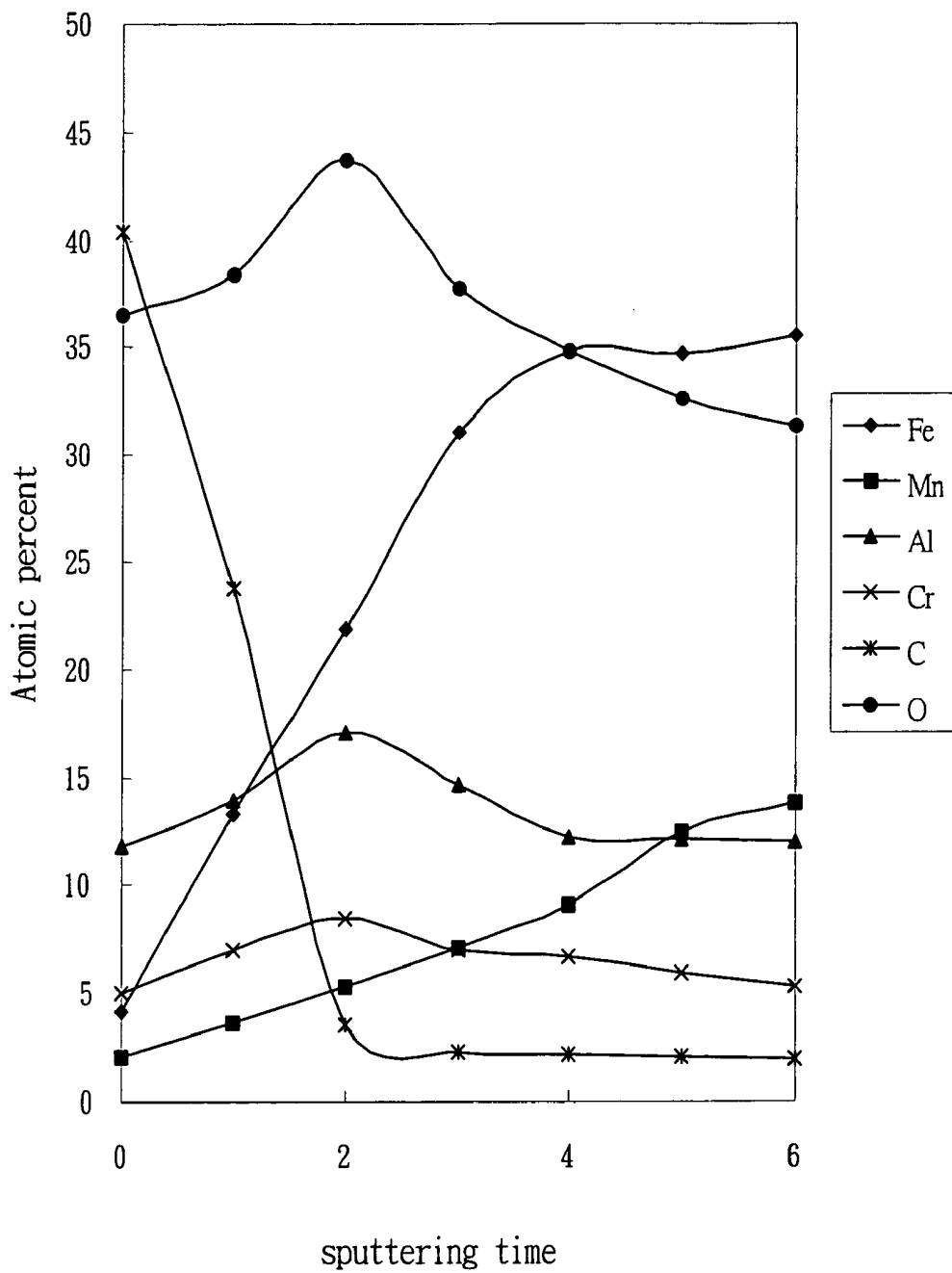


Fig.3

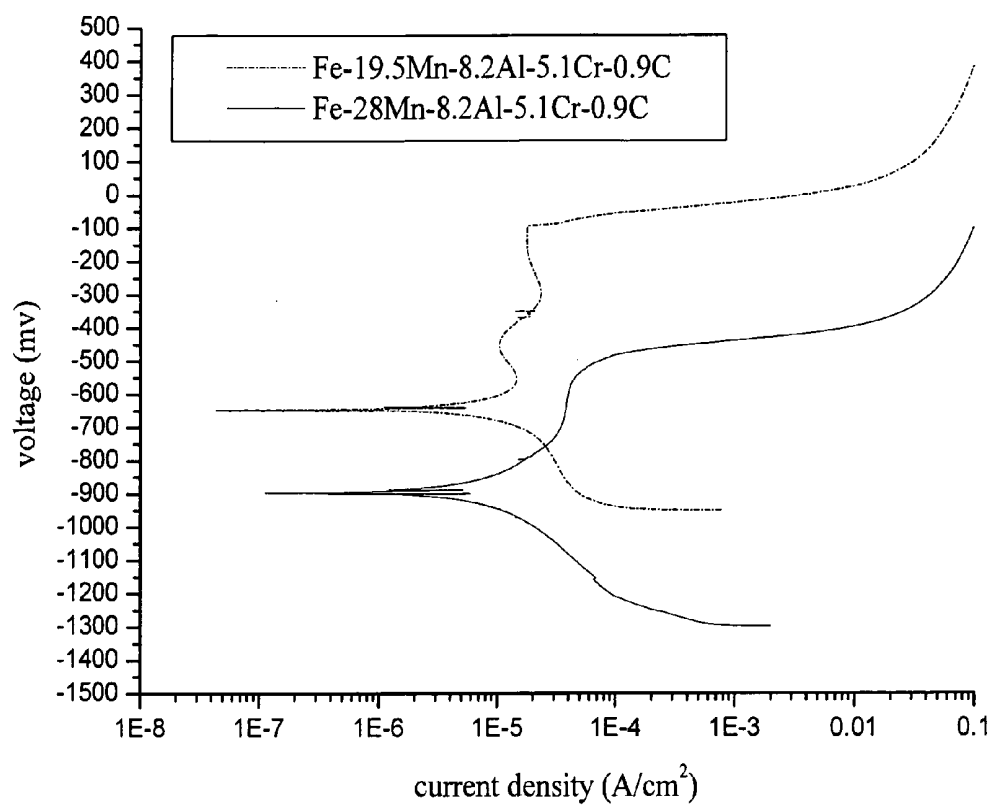


Fig.4

LOW-DENSITY ALLOY AND FABRICATION METHOD THEREOF

1. FIELD OF THE INVENTION

[0001] This invention relates to a low-density alloy, especially to a low-density alloy for making the golf-club head with superior elongation, strength, damping capacity and corrosion resistance generated without any plastic hot/cold working process, such as forging, rolling, etc., and fabrication thereof.

2. BACKGROUND OF THE RELATED ART

[0002] To provide better ball-hitting feeling for the golfer, and to enable the golfer to hit the ball farther and more stably (i.e. longer ball-contacting time, higher ball-controlling ability, and lower vibration), many commercial materials have been applied to golf-club heads, such as 8620 steel, 304 austenitic stainless steel, 17-4PH precipitation-hardening stainless steel, AISI431/AISI455 high-strength martensitic stainless steel, 18Ni(200) maraging steel, Ti-6Al-4V alloy, and SP-700 titanium alloy. Some materials have superior ductility but insufficient strength. (For example, 8620 steel and 304 austenitic stainless steel have elongations of about 30% but have tensile strengths of only about 60 ksi.) Some have very high strength but low ductility. (For example, AISI431/AISI455 high-strength martensitic stainless steel and 18Ni(200) maraging steel have tensile strengths as high as 150~200 ksi but have elongations of only 10% or below.)

[0003] For the last decades, many specialists and scholars have developed a series of Fe—Mn—Al—C-based high-strength and high-ductility alloys, and the properties of those Fe—Mn—Al—C-based alloys are clearly described in the following papers.

[0004] 1. G. L. Kayak, "Fe—Mn—Al Precipitation-Hardening Austenitic Alloys", *Metal Science and Heat Treatment*, Vol. 2, 1969, P.95

[0005] 2. M. F. Alekseenko, et al., "Phase Composition Structure and Properties of Low-Density Steel 9G28Yu9MVB", *Metal Science and Heat Treatment*, Vol. 14, 1972, P.187

[0006] 3. G. S. Krivonogov, et al., "Phase Transformation Kinetics in Steel 9G28Yu9MVB", *Phys. Met. & Metallog.*, Vol. 4, 1975, P.86

[0007] 4. L. I. Lysak, et al., "Structural and Phase Change in Steel 9G28Yu9MVB During Aging", *Metallurgizika*, Vol. 59, 1975, P.29

[0008] 5. Charles, et al., "New Cryogenic Materials: Fe—Mn—Al Alloys", *Metal Progress*, May, 1981, P.71

[0009] 6. C. J. Altstetter, et al., "Processing and Properties of Fe—Mn—Al Alloys", *Materials Science and Engineering*, Vol. 82, 1986, P.13

[0010] 7. K. H. Ham, et al., "The Evidence of Modulated Structure in Fe—Mn—Al—C Austenitic Alloys", *Scripta Metal.*, Vol. 20, 1986, P.33

[0011] 8. P. J. James, "Precipitation of the Carbide (Fe, Mn)₃AlC in an Fe—Al Alloy", *J. Iron & Steel Inst.*, January 1969, P.54

[0012] From surveying the abovementioned papers, it is found that after the deformation processes, such as forging and rolling, a solid-solution heat treatment at the temperature of 950~1200° C. followed by a rapid quenching, and then an aging heat treatment at the temperature of 450~750° C., the Fe—(28~35) wt. % Mn—(4.9~11) wt. % Al—(0.5~2.0) wt. % C-based alloy becomes a high-strength and high-ductility alloy having an austenitic-matrix structure, a density of 6.6~6.8 g/cm³, a tensile strength of 100~180 ksi, a yield strength of 90~160 ksi, and an elongation of 25~65%.

[0013] In order to improve the corrosion resistance, 2.98~6 wt. % of Cr and 0.9~1.03 wt. % of Mo may be further added into the abovementioned Fe—Mn—Al—C-based alloy; the corrosion resistance thereof has been discussed in detail in the following papers.

[0014] 1. Jeng-Gong Duh, et al., "Diffusion-Related Kinetics in the Oxidation-Induced Phase Transformation of Fe-9Al-3Cr-31Mn Alloys", *J. Electrochem. Soc.* Vol. 136, No. 3, March 1989

[0015] 2. Jeng-Gong Duh, et al., "Microstructural development in the oxidation-induced phase transformation of Fe—Al—Cr—Mn—C alloys", *JOURNAL OF MATERIALS SCIENCE*, Vol. 23, 1989

[0016] 3. J. G. Duh, et al., "Nitriding behavior in Fe—Al—Mn—Cr—C alloys at 1000-1100° C.", *JOURNAL OF MATERIALS SCIENCE*, Vol. 28, 1993

[0017] 4. S. C. Chang, et al., "Environment-Assisted Cracking of Fe-32% Mn-9% Al Alloys in 3.5% Sodium Chloride Solution", *J. CORROSION*, Vol. 51, 1995

[0018] 5. J. G. Duh, et al., "Nitriding Kinetics of Fe—Al—Mn—Cr—C alloys at 1000° C.", *JOURNAL OF MATERIALS SCIENCE*, Vol. 25, 1990

[0019] 6. J. G. Duh, et al., "High temperature oxidation of Fe-31Mn-9Al-xCr-0.87C alloys (x=0, 3 and 6)", *JOURNAL OF MATERIALS SCIENCE*, Vol. 25, 1990

[0020] Through the developments described above, the Fe—Mn—Al—C-based alloys have been applied to golf-club heads. The compositions, heat-treatment and plastic working conditions of the disclosed Fe—Mn—Al—C-based alloys for the use of making golf-club heads in the prior arts are shown in Table 1 for comparison.

TABLE 1

Application	Composition (*: represents an optional additive)								
	Fe	Mn	Al	Cr	C	Si	Mo	Cu	Nb
TW178648	Bal.	22~36	6~8		1.5~2.0		1.0~1.5		
TW185568	Bal.	26~28	6.5~8	5~6	0.9~1.1	0.2~1.5	1.0~1.2	0.9~1.1	0.02~0.04
US20030077479	Bal.	25~31	6.3~7.8	5.5~9	0.65~0.85	*0.8~1.5	*0.5~1.0		
US20030082067	Bal.	28~31.5	7.8~10	*5~7	0.9~1.1	*0.8~1.5			
US20050006007	Bal.	25~31	7~10	5~7	0.9~1.1	*0.8~1.5	*0.5~1.0		
TW1235677	Bal.	23~30	6.3~10	5~9	0.8~1.05	*0.6~1.0			

TABLE 1-continued

Application Pub. No.	Composition (*: represents an optional additive)			Forging and heat treatment condition
	Ti	Co	N	
TW178648				Solid solution at 1030~1050° C. for 1~2 hours and heat treatment at 400~550° C. for 1~2 hours
TW185568 US20030077479	*2~5			Homogenization heat treatment Hot forging at 850~1050° C. and heat treatment at 980~1080° C. for 1~24 hours
US20030082067	0.35~2.5			Hot forging at 900~1100° C. and heat treatment at 950~1270° C. for 1~24 hours
US20050006007				Hot forging at 850~1050° C. and hot treatment at 980~1080° C. for 1~4 hours and at 500~650° C. for 4~8 hours
TW1235677		0.2~10	*0.2~0.4	Hot forging at 1000~1050° C., and heat treatment at 1030~1080° C. for 15~60 minutes and heat treatment at 450~850° C. for 4~24 hours

Taiwan patent of Publication No. 178648 (denoted TW178648) disclosed the compositions of an alloy without chromium, so the alloy has a poor corrosion resistance. The patent TW185568 disclosed an alloy having a better corrosion resistance than that disclosed in TW178648, but the golf-club head made from the alloy still fails the exam of salt-spraying test with 5% sodium chloride solution for 48 hours after the golf-club head has been polished to burnish.

[0021] Except for those discussed above, although the golf-club heads made from the alloys disclosed in US patents of Publication No. 20030077479, 20030082067 and 20050006007 and Taiwan patent of Publication No. 1235677 pass the exams of salt-spraying test with 5% sodium chloride solution for 48 hours, but it deserves to mention that the alloys disclosed in above patents have to be treated by a plastic working process such as forging, rolling and hot/cold working to form a superior surface condition and a microstructure of fine and homogeneous poly-crystal from a inferior dendrite structure of cast, so that the forged or worked golf-club heads are capable of passing the exams of salt-spraying test.

[0022] But, a forging process of a forged golf-club head includes several rough and precise forging procedures, which requires many expensive forging molds used in the process, so the manufacturing cost is relatively high. Moreover, it limits the shape of a golf-club head very much due to the limitation of the shape in the forging process, so that the forged or worked golf-club heads do not have varieties, functionalities and artistic shapes like the golf-club heads made by the precision casting process. However, when the alloys disclosed in aforementioned patents make the golf-club heads by a precision casting process rather than a forging process, the casting-type golf-club head fails in the exam of the salt-spraying test eventually.

SUMMARY OF THE INVENTION

[0023] For solving the above mentioned problem to enable the alloy to pass the exam of the salt-spraying test in the not only forged condition but also the casting condition, this invention provides a low-density alloy, which lowers down

the cost of fabricating a golf-club head of the Fe—Mn—Al—C-based alloy, and increases the diversity of designing the golf-club head shape, so the low-density alloy is particularly suitable for the use of making the golf-club head.

[0024] An object of this invention is to provide a low-density alloy and the fabrication method thereof, where the low-density alloy has excellent elongation, strength, damping capacity, and corrosion resistance without any plastic hot/cold working, such as forging, rolling, etc.

[0025] Another object of this invention is to provide a low-density alloy and the fabrication method thereof, where the low-density alloy can pass the exam of the salt-spraying test without any plastic hot/cold working, such as forging, rolling, etc., to reduce the cost of production. Additionally, the design flexibility for the golf-club head of the Fe—Mn—Al—C-based alloy no longer is restricted by the forging or working process.

[0026] Another object of this invention is to provide a low-density alloy and the fabrication method thereof, where the low-density alloy has a low density ranging from 6.6 to 6.9 g/cm³, an elongation ranging from 30 to 77%, a high tensile strength ranging from 100 to 140 ksi, high damping capacity and superior corrosion resistance without any plastic hot/cold working, such as forging, rolling, etc.

[0027] For achieving the abovementioned objects, a low-density alloy according to an embodiment of this invention comprises, by weight percent (wt. %), greater than or equal to 15 wt. % but lower than or equal to 22.5 wt. % manganese, larger than or equal to 7.2 wt. % but lower than or equal to 9.0 wt. % aluminum, larger than or equal to 5.1 wt. % but lower than or equal to 7.8 wt. % chromium, larger than or equal to 0.6 wt. % but lower than or equal to 1.2 wt. % carbon and is the balance of iron.

[0028] For achieving the abovementioned objects, a fabrication method of a low-density alloy, according to an embodiment of this invention, includes melting a raw material, which comprises, by weight percent (wt. %), greater than or equal to 15 wt. % but lower than or equal to 22.5 wt. % manganese, larger than or equal to 7.2 wt. % but lower than or equal to 9.0 wt. % aluminum, larger than or equal to 5.1 wt. % but lower

than or equal to 7.8 wt. % chromium, larger than or equal to 0.6 wt. % but lower than or equal to 1.2 wt. % carbon and the balance of iron, to form an alloy.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] FIG. 1 is a diagram showing the depth profile of the alloying elements on the surface layer of the Fe-32Mn-8.2Al-5.1Cr-0.9C alloy, by weight percent (wt. %), for comparison with that of this invention.

[0030] FIG. 2 is a diagram showing the depth profile of the alloying elements on the surface layer of the Fe-28Mn-8.2Al-5.1Cr-0.9C alloy, by weight percent (wt. %), for comparison with that of this invention.

[0031] FIG. 3 is a diagram showing the depth profile of the alloying elements on the surface layer of the Fe-19.5Mn-8.2Al-5.1Cr-0.9C alloy, by weight percent (wt. %), according to an embodiment of this invention.

[0032] FIG. 4 is a diagram showing the potentiodynamic polarization curves performed in 5% NaCl solution for both alloys of Fe-28Mn-8.2Al-5.1Cr-0.9C and Fe-19.5Mn-8.2Al-5.1Cr-0.9C, by weight percent, containing different Mn contents respectively.

DETAILED DESCRIPTION OF TIRE INVENTION

[0033] The alloy of this invention is based on iron (Fe), manganese (Mn), aluminum (Al), chromium (Cr) and carbon (C) where Mn is one of stabilized elements for austenite phase, and the greater Mn content of an alloy makes more austenite phase. The austenite has more slip systems due to the FCC structure to enhance the elongation, so to add a moderate amount of Mn to the alloy is beneficial to enhance the elongation of the alloy. However, according to the research of the inventors, Mn element in the alloy enhances the elongation but deteriorates the corrosion resistance, since Mn is oxidized with ease in atmospheric environment, and the manganese oxide has poor adherence to the substrate and tends to spall off, so that it cannot provide the protection to prevent oxidation from proceeding to the interior of the substrate. Further, analyzing oxides of the passivated layer on the Fe—Mn—Al—Cr—C alloy surface by X-Ray Photoelectron Spectroscopy/Electron Spectroscopy of Chemical Analysis (XPS/ESCA) finds that the oxides of the passivated layer consists primarily of anti-corrosion Cr_2O_3 and Al_2O_3 oxides, and non-corrosion-resistant oxides of manganese oxide MnO (Mn_3O_4), Mn_2O_3 and ferric oxide $\text{FeO}(\text{Fe}_3\text{O}_4)$, Fe_2O_3 . Based on the analysis of the passivated layer, a greater Mn content in the alloy results in a higher proportion of manganese oxides on the passivated layer. As a result, the non-continuous passivated protection layer with anti-corrosion Cr_2O_3 and Al_2O_3 oxides is formed on the surface of the alloy containing a higher Mn content. In corrosive environment, the corrosion attack is observed to be took place in the region devoid of the passivated protection layer or the region of the manganese oxides, and then extends to the interior of the substrate to form the localized pits of the pitting corrosion rather than the general corrosion. This is in agreement with the corroded surface result of the Fe—Mn—Al—Cr—C alloy after the salt-spraying test.

[0034] Therefore, in order to improve the pitting corrosion resistance of the Fe—Mn—Al—Cr—C alloy in the condition without any hot/cold working process, such as forging, rolling, etc., and aim at passing the exam of salt-spraying test with 5% sodium chloride solution for 48 hours for a golf-club

head made from the Fe—Mn—Al—Cr—C alloy, the inventors carried out an experiment first to investigate the influence of the decrease in the Mn content of the alloy on the oxide constitution of the passivated layer on the surface of the alloy. FIGS. 1 through 3 represent the depth profiles of the oxides on the surface of the Fe—(32,28,19.5)Mn-8.2Al-5.1Cr-0.9C alloys (in weight percent, wt. %) having 32, 28 and 19.5 wt. % Mn, respectively. From those drawings, it is found that the ratio of the manganese oxides in the passivated layer decreases with decreasing the Mn content of the alloy. As decreasing the Mn content to 19.5 wt. %, the ratio of the manganese oxides has a great decrease. On the contrary, aluminum oxide and chromium oxide have an obvious increase in ratio. FIG. 4 shows potentiodynamic polarization curves of both the Fe-28Mn-8.2Al-5.1Cr-0.9C and Fe-19.5Mn-8.2Al-5.1Cr-0.9C alloys (in weight percent) performed in 5% NaCl solution to illustrate the corrosion resistance. From FIG. 4, it is found that when the Mn content was lowered to 19.5 wt. %, there is a great decrease in the passivated current intensity (I_p), and an obvious increase in the passivated potential (ΔE) and the pitting potential (E_{pp}). Accordingly, the alloy has a much better corrosion resistance than another alloy of Fe-28Mn-8.2Al-5.1Cr-0.9C with 28 wt. % Mn, so that the Fe-19.5Mn-8.2Al-5.1Cr-0.9C alloy can pass the exam of salt-spraying test with 5% NaCl for 48 hours without any hot/cold working, such as forging, rolling, etc. However, as abovementioned, the Mn content is raised to stabilize the austenite phase, so as to increase the elongation. Thus when the Mn content is less than 15 wt. %, the elongation of the alloy is not satisfied. On the contrary, as adding more than 22.5 wt. % Mn, there is an obvious deterioration in the corrosion resistance of the alloy. Therefore, in order to obtain both a high corrosion resistance and an excellent toughness, the Mn content of the alloy should be controlled to be equal to or greater than 15 wt. % but lower than or equal to 22.5 wt. %.

[0035] Aluminum (Al) is one of the stabilized elements for the ferrite phase, so a higher Al content of an alloy makes more ferrite phase and less austenite phase to decrease the elongation of the alloy. Further, an excess of Al in the alloy tends to form the very brittle D0_3 ordered phase to severely destroy the elongation of the alloy; meanwhile, Al is also one of the constituent elements of the $(\text{Fe},\text{Mn})_3\text{AlC}_x$ carbide acting as precipitation-hardening to strengthen the Fe—Mn—Al—C-based alloys. Once Al content is not high enough, the strength of the alloy is insufficient due to the lack of the $(\text{Fe},\text{Mn})_3\text{AlC}$ carbides. Besides, according to the research of the inventors, insufficient Al proportion suppresses anti-corrosion oxide of Al_2O_3 to be formed on the surface to reduce the corrosion resistance of the alloy. Therefore, in order to obtain a high corrosion resistance, a high strength and an excellent elongation for the alloy with Mn content between 15 to 22.5 wt. %, the Al content of the alloy should be controlled to be equal to or greater than 7.2 wt. % but lower than or equal to 9.0 wt. %. Chromium (Cr), a rather active element, has a strong tendency to form a protective layer of chromium oxide Cr_2O_3 on the surface of the alloy to enhance the corrosion resistance of the alloy. However, Cr is an element not only of the ferrite-former but also of the carbide-former. Insufficient Cr content cannot provide an enough corrosion resistance for an alloy. But, excess Cr may not only reduce the elongation but also deteriorate the corrosion resistance of the alloy attributed to the formation of chromium carbide Cr_7C_3 along the grain boundaries. Since the formation of the Cr_7C_3 carbide

depletes its surrounding Cr, along with the precipitation of the carbide, the surrounding region is lacked in Cr and then the alloy becomes much sensitive to the intergranular corrosion. Therefore, in order to obtain a high corrosion resistance and inhibit the formation of the Cr_7C_3 carbide for the alloy with Mn content between 15 to 22.5 wt. %, the Cr content of the alloy should be controlled to be equal to or greater than 5.1 wt. % but lower than or equal to 7.8 wt. %, and the C content should be controlled to be equal to or greater than 0.6 wt. % but lower than or equal to 1.2 wt. %. Additionally, to add a little amount of silicon (Si) and molybdenum (Mo) properly increases the corrosion resistance also.

[0036] A low-density alloy, according to this invention, comprises, in weight percent, 15~22.5 wt. % Mn, 7.2~9.0 wt. % Al, 5.1~7.8 wt. % Cr, 0.6~1.2 wt. % C and the balance of Fe, and the addition of 0~1.5 wt. % Mo can increase the pitting corrosion resistance. Further, in another embodiment, to add 0.7 wt. % Si at most improves the fluidity of the present alloy in molten state. An alloy, according to this invention, has a low density ranging from 6.6 to 6.9 g/cm³, an excellent elongation ranging from 30 to 77%, a tensile strength ranging from 100 to 140 ksi, a high damping capacity and a high corrosion resistance, and succeeds in the exam of the salt-spraying test without any plastic hot/cold working process to reduce the fabrication cost.

[0037] A fabrication method, according to this invention, is to melt raw materials, which include larger than or equal to 15 wt. % but lower than or equal to 22.5 wt. % Mn, larger than or equal to 7.2 wt. % but lower than or equal to 9.0 wt. % Al, larger than or equal to 5.1 wt. % but lower than or equal to 7.8 wt. % Cr, larger than or equal to 0.6 wt. % but lower than or equal to 1.2 wt. % C, 1.5 wt. % Mo at most, 0.7 wt. % Si at most and the balance of Fe, where the melting process can be an atmospheric melting process, a vacuum melting process, or a reducing atmospheric melting process. The molten alloy is then poured into the molds to form the casts. Without any plastic hot/cold working process, the casts are followed by the processes of sand-blasting, grinding, welding, drilling, polishing, surface treating, artistic working, etc. to produce the casting-type golf-club heads. The producing processes further optionally include a solid-solution heat treatment at 950~1200° C. for 0.5~10 hours and then an aging heat treatment at 500~700° C. for 0~10 hours to further increase the ductility and strength of the alloy. Since the alloy, according to this invention, has an excellent toughness even in the cast state, the alloy is also suitable to be subject to a series of plastic hot/cold working processes to produce the forging-type golf-club heads or the complex ones of the combination of casting and forging-types.

[0038] For example, an alloy, according to a better embodiment of this invention, comprises 22.1 wt. % Mn, 8.01 wt. % Al, 6.21 wt. % Cr, 0.99 wt. % C and the balance of Fe. The alloy may be melted with a high-frequency induction furnace, and then, the molten alloy is poured into pre-heated dewaxed shell molds of golf-club heads. After the casts with shell molds cool down, the casts are processed by shell removing, sprue-gate cutting, sand-blasting, grinding, welding, drilling, polishing, surface treating, artistic working, etc. to produce the casting-type golf-club heads. Even without any plastic hot/cold working process, the golf-club head not only is capable of passing the exam of the salt-spraying test With 5% NaCl solution for 48 hours but also possesses a density as low as 6.74 g/cm³, an elongation as high as 38.6%, and a tensile

strength as great as 112.1 ksi. Therefore, the fabrication cost of golf-club heads can be greatly reduced.

[0039] An alloy, according to a better embodiment of this invention, comprises 16.3 wt. % Mn, 8.56 wt. % Al, 5.16 wt. % Cr, 1.10 wt. % C and the balance of Fe. In addition to the manufacturing process described in the first embodiment, the golf-club head castings are further subject to solid-solution heat treatment at 1050° C. under vacuum for 1 hour to enhance their mechanical properties. Accordingly, the golf-club head not only is capable of passing the exam of the salt-spraying test with 5% NaCl solution for 48 hours but also possesses a density as low as 6.69 g/cm³, an elongation as high as 76.9%, and a tensile strength as great as 118.7ksi even though it is free of any plastic hot/cold working process. Therefore, the fabrication cost of golf-club heads can be greatly reduced.

[0040] An alloy, according to yet another better embodiment of this invention, comprises 19.2 wt. % Mn, 7.78 wt. % Al, 6.73 wt. % Cr, 1.03 wt. % C, 0.21 wt. % Si and the balance of Fe. In addition to the manufacturing process described in the first embodiment, the golf-club head castings are further subject to solid-solution heat treatment at 1050° C. under vacuum for 1 hour to enhance their mechanical properties. Accordingly, the golf-club head not only is capable of passing the exam of the salt-spraying test with 5% NaCl solution for 48 hours but also possesses a density as low as 6.78 g/cm³, an elongation as high as 66.9%, and a tensile strength as great as 115.3 ksi even though it is free of any plastic hot/cold working process. Therefore, the fabrication cost of golf-club heads can be greatly reduced.

[0041] According to the abovementioned illustration, utilizing the fabrication method, according to embodiments of this invention, forms an alloy with low density ranging from 6.6 to 6.9 g/cm³ for use of making the golf-club heads without any plastic hot/cold working, such as forging, rolling, etc., and then the alloy has the excellent ductility ranging from 30 to 77%, high tensile strength between 100 to 140 ksi, high damping capacity and high corrosion resistance (which can pass the exam of salt-spraying test with 5% NaCl for 48 hours for the golf-club head). The proper design for the alloy improves the fluidity in its molten state, casting ability and plastic working ability to reduce the cost and time of making the golf-club head, and increases also the design capacity of a golf-club head shape, as compared to that made from the conventional Fe—Mn—Al—C-based alloys requiring plastic working process to enhance their corrosion resistance. So, the alloys are suitable for the golf-club heads.

[0042] In conclusion, an golf-club bead made from an alloy, whose compositions and the fabrication method are disclosed in this invention, has low density, high strength, high toughness, high damping capacity and high corrosion resistance, and it can pass the exam of salt-spraying test with 5% NaCl for 48 hours without any plastic deformation process; moreover, due to increasing the fluidity, it is easy to cast the shape with small words, trenches of the striking face and thin part of the head without mechanical carving, so that the fabrication cost and defect rate of the products are lowered down very much.

[0043] Those embodiments described above are to clarify the present invention to enable the persons skilled in the art to understand and use the present invention; however, the embodiments are not intended to limit the scope of the present invention; therefore, any equivalent modification and varia-

tion according to the spirit of the present invention is still to be included within the scope of the claims of the present invention stated below.

What is claimed is:

1. A low-density alloy comprising greater than or equal to 15 wt. % but lower than or equal to 22.5 wt. % manganese, greater than or equal to 7.2 wt. % but lower than or equal to 9.0 wt. % aluminum, greater than or equal to 5.1 wt. % but lower than or equal to 7.8 wt. % chromium, greater than or equal to 0.6 wt. % but lower than or equal to 1.2 wt. % carbon and the balance of iron.

2. A low-density alloy according to claim 1, further comprising 1.5 wt. % molybdenum at most.

3. A low-density alloy according to claim 1, further comprising 0.7 wt. % silicon at most.

4. A low-density alloy according to claim 2, further comprising 0.7 wt. % silicon at most.

5. A low-density alloy according to claim 1, having a density in a range from 6.6 to 6.9 g/cm³, an elongation in a range from 30 to 77% and a tensile strength in a range from 100 to 140 ksi.

6. A fabrication method of a low-density alloy, including melting a raw material, which comprises greater than or equal to 15 wt. % but lower than or equal to 22.5 wt. % manganese, greater than or equal to 7.2 wt. % but lower than or equal to 9.0 wt. % aluminum, greater than or equal to 5.1 wt. % but lower than or equal to 7.8 wt. % chromium, greater than or equal to 0.6 wt. % but lower than or equal to 1.2 wt. % carbon and the balance of iron, to form an alloy.

7. A fabrication method of a low-density alloy according to claim 6, wherein said raw material further comprises 1.5 wt. % molybdenum at most.

8. A fabrication method of a low-density alloy according to claim 7, wherein said raw material further comprises 0.7 wt. % silicon at most.

9. A fabrication method of a low-density alloy according to claim 8, further including a step of heat-treating said alloy at a temperature in a range from 950 to 1200° C. for a duration in an interval from 0.5 to 10 hours, and then at a temperature in a range from 500 to 700° C. for a duration up to a limit of 10 hours.

10. A fabrication method of a low-density alloy according to claim 7, further including a step of heat-treating said alloy at a temperature in a range from 950 to 1200° C. for a duration in an interval from 0.5 to 10 hours, and then at a temperature in a range from 500 to 700° C. for a duration up to a limit of 10 hours.

11. A fabrication method of a low-density alloy according to claim 6, wherein said raw material further comprises 0.7 wt. % silicon at most.

12. A fabrication method of a low-density alloy according to claim 11, further including a step of heat treating said alloy at a temperature in a range from 950 to 1200° C. for a duration in an interval from 0.5 to 10 hours, and then at a temperature in a range from 500 to 700° C. for a duration up to a limit of 10 hours.

13. A fabrication method of a low-density alloy according to claim 6, further including a step of heat-treating said alloy at a temperature in a range from 950 to 1200° C. for a duration in an interval from 0.5 to 10 hours, and then at a temperature in a range from 500 to 700° C. for a duration up to a limit of 10 hours.

14. A fabrication method of a low-density alloy according to claim 6, wherein said step of melting said raw material is an atmosphere melting, a vacuum melting, or a reducing atmosphere melting.

15. A fabrication method of a low-density alloy according to claim 6, wherein said alloy has a density in a range from 6.6 to 6.9 g/cm³, an elongation in a range from 30% to 77% and a tensile strength in a range from 100 ksi to 140 ksi.

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