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ALUMINUM ALLOY

George S. Foerster, Midland, Mich., assignor to The Dow Chemical Company, Midland, Mich., a corporation of Delaware

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This application is a continuation-in-part of patent application Serial No. 182,649, filed March 26, 1962, now abandoned.

This invention relates to aluminum alloys and more particularly is concerned with a novel aluminum base magnesium-silicon alloy containing additive metals in predetermined quantities which provide a specific relationship between silicon and the additive metal and to a high strength extruded product prepared thereby.

In general, the novel aluminum base alloy of the present invention contains on a weight basis from about 0.5 to about 2 percent magnesium, from about 0.5 to about 10 percent silicon, from about 0.5 to about 20 percent of an additive metal selected from the group consisting of calcium, strontium, barium, rare earth, thorium and mixtures thereof, balance aluminum, and being further characterized in that the silicon and additive metal are maintained within a specific predetermined ratio and the silicon content is about equal to or in excess of that needed for formation of magnesium silicide (Mg_2Si).

By maintaining these specific relationships between the concentrations of alloying ingredient and silicon in the present novel alloy, I have discovered that unexpectedly high tensile strengths are realized in extruded products prepared therefrom. The alloy is particularly suited for the preparation of pellet extrusions which exhibit excellent and unusually high tensile strength in the extruded, solution heat treated, quenched and aged condition. The excellent strength characteristics of the extruded products prepared from the present novel alloy having these well-defined and requisite interrelationships of alloying component concentrations are not predictable nor anticipated from the known art.

To illustrate; Wood et al. (U.S. 1,932,836) alleges an aluminum base casting alloy having high fluidity and good general casting properties in the molten state. This alloy contains 1 to 8 percent magnesium, 0.5 to 6 percent zinc and 0.01 to 2 percent calcium, the balance being substantially aluminum. This patent suggests that other alloying elements such as manganese, nickel, copper, silicon, etc. in undetermined amounts may be added in some instances. This patented alloy which must contain zinc (excluded from the present novel alloy) and suggests the use of silicon only as an optional additive to be used, if at all, in some undetermined amount is not pertinent. (Silicon in a controlled, predetermined concentration is an essential component of the present novel alloy.)

French patent (975,591) alleges an aluminum base alloy containing magnesium to which manganese can be added and which also contains calcium. This alloy, as is set forth in the patent, contains up to 1 percent iron, up to 1 percent silicon, up to 1 percent manganese, from 1 to 13 percent magnesium and from 0.1 to 3 percent calcium. No criticality of ratio and concentration of silicon-magnesium-additive metal is indicated in this patent. In fact, the range covered by the French patent cannot meet the requisite alloy ingredient interrelationship needed for operability in the present novel alloy.

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Ordinarily, barium, calcium and cerium are employed as additive metals in the present novel alloy. The actual amount of additive to be employed in the alloy is varied within the disclosed range in accordance with the properties and characteristics, e.g. density, etc., desired in the extruded product. The actual silicon content employed in the alloy, within the range of from 0.5 to 10 percent as set forth hereinbefore, is established and maintained in accordance with the equation:

$$\text{Wt. percent Si} \geqq \frac{\text{Wt. percent Mg.}}{1.73} + K \text{ (weight percent additive member)}$$

Minimum values for K to be used with the preferred additive metals to assure the incorporation of the requisite amount of silicon into the alloy are barium (0.1), calcium (1.0) and cerium, (added as misch metal) (0.1). Preferably, for optimum alloy properties the silicon content is determined using the following K values in the equation; barium (0.2), calcium (1.4) and cerium (0.2).

The operable concentration range and preferred concentration range of barium, calcium and cerium to be employed in the alloy are shown in Table I.

TABLE I

Metal	Concentration in Alloy (weight percent)	
	Operable Range	Preferred Range
Barium	(1–10)	(3-6)
Calcium	0.75–6	2–4
Cerium [1]	1–20	5–10

[1] Added as misch metal.

If it is desired to employ thorium, strontium, or other rare earths as additives in the alloy the absolute quantities of these elements and the ratio to be used for determining silicon level is the atomic percent equivalent of the concentration levels shown hereinabove for barium, calcium or cerium.

The additive members can be used alone in the alloy or a mixture of additives can be employed. With mixtures of additive metals the concentration of each of the individual members used therein is proportionally reduced so that the total concentration of the additive in the alloy falls within the range and in accordance with the relationships set forth hereinbefore.

The alloy is prepared using foundry alloying and melt techniques as practiced in the aluminum art.

This alloy is suited for use both with ingot and pellet extrusion processes and as set forth hereinbefore is particularly suitable for fabricating high strength pellet extrusions. For the two types of extrusion operations, a melt of the alloy is solidified into ingots, or preferably more rapidly quenched as by atomizing into pellets. Conveniently pellets can be produced by jet atomizing or wheel atomizing either in an inert atmosphere such as natural gas, nitrogen, argon, etc. for example, or in air. The billet or atomized pellets are fabricated into extrusions using normal billet or pellet extrusion techniques and apparatus.

For use in the pellet extrusion process, ordinarily the pellets are preheated to a temperature at least that of the extruder container and the heated pellets then are loaded into the container and extruded. However, if desired, the pellets can be used in the extrusion process without preheating. Also, the pellets can be precompacted prior to extrusion. By precompacting the pellets under reduced pressure, blistering and formation of internal voids substantially are avoided during any post extrusion heat treatment that may be employed.

The so-extruded product ordinarily is solution heat treated, quenched and aged thereby providing a final product exhibiting unexpectedly high tensile strength. In this treatment, preferably the length of time for solution heat treatment is minimized to avoid (1) agglomeration of any dispersed phase that might be present in the alloy, (2) recovery, (3) recrystallization and (4) loss of strength.

For those alloys which contain silicon in excess of the solid solubility of this element in the alloy, high strength extrusions and particularly pellet extrusions unexpectedly can be produced at relatively low extrusion temperatures, i.e. from about 750 to about 850° F. Further increase in the strength of the extrusion results by directly quenching the extruded product as it emerges from the die and aging.

The following example will serve to illustrate further the utility of the present invention but is not meant to limit it thereto.

Example.—An aluminum base-magnesium-silicon alloy containing either barium, calcium or cerium (added as misch metal) as an additive member was prepared. One portion of the alloy was atomized into pellets, about 85% of which ranged from −20 +200 mesh, U.S. Standard Sieve, balance passing through the 200 mesh sieve. A second portion of the alloy was cast into a 3 inch diameter ingot.

The two forms of the alloy were extruded as follows.

For the pellet extrusion, a batch of the pellets was preheated to about 700° F. and placed in the pellet container of a ram extruder which container also was about this same temperature.

For ingot extrusion, billets about 4 inches long were cut from the cast ingot.

The pellets and billets both were extruded at an extrusion temperature of about 800° F. and an extrusion rate of about 5 feet per minute into a strip 0.2 inch thick by 1 inch wide. The resulting strip then was solution heat treated at about 970° F. for ½ hour, quenched and aged 16 hours at 320° F.

Standard test bars were prepared and the percent elongation, tensile yield strength and tensile strength of the alloys determined at room temperature. The results of these tests are presented in Table II which follows.

In a manner similar to that shown by the foregoing examples, alloys can be prepared containing:

Al—1Mg—0.7Si—1Ba	(K=0.1)
Al—0.5Mg—1.3Si—10Ba	(K=0.1)
Al—1.4Mg—1.4Si—3Ba	(K=0.2)
Al—1.0Mg—1.8Si—6Ba	(K=0.2)
Al—1.3Mg—1.25Si—0.5Ba	(K=1.0)
Al—1.5Mg—6.9Si—6Ca	(K=1.0)
Al—1.4Mg—9.2Si—6Ca	(K=1.4)
Al—1.0Mg—1.6Si—0.75Ca	(K=1.4)
Al—1.4Mg—.9Si—1Ce	(K=0.1)
Al—1.4Mg—2.8Si—20Ce	(K=0.1)
Al—1.4Mg—1.8Si—5Ce	(K=0.2)
Al—1.4Mg—2.8Si—10Ce	(K=0.2)

These alloys readily can be fabricated into ingots or pellets and subsequently extruded into fabricated form.

Various modifications can be made in the present invention without departing from the spirit or scope thereof for it is understood that I limit myself only as defined in the appended claims.

I claim:

1. A high strength aluminum alloy pellet extrusion consisting essentially of from about 0.5 to about 2 weight percent magnesium, from about 0.5 to about 10 weight percent silicon, an additive metal, and remainder aluminum, said additive metal being a member selected from the group consisting of barium, calcium and cerium, said alloy being further characterized in that the concentration of said additive metal and the actual weight percent of silicon in said alloy are predetermined in accordance with the following relationship:

(a) wt. percent Si $\gtreqless \frac{\text{wt. percent Mg.}}{1.73}+0.1$ (1—10 wt. percent barium)

(b) wt. percent Si $\gtreqless \frac{\text{wt. percent Mg.}}{1.73}+1.0$ (0.75—6 wt. percent calcium)

(c) wt. percent Si $\gtreqless \frac{\text{wt. percent Mg.}}{1.73}+0.1$ (1-20 wt. percent cerium)

said extrusion being in the extruded, solution heat treated, quenched and aged condition and characterized by an unexpectedly high tensile strength.

2. A high strength aluminum alloy pellet extrusion consisting essentially of from about 0.5 to about 2 weight percent magnesium, from about 0.5 to about 10 weight percent silicon, an additive metal, and remainder aluminum, said additive metal being a member selected from the group consisting of barium, calcium and cerium, said alloy being further characterized in that the concentration of said additive metal and the actual weight per-

TABLE II

Run No.	Alloy Composition (Values are wt. percent)	K	Test Results		
			Percent E	1,000 p.s.i.	
				TYS	TS
Ingot Extrusion:					
1	Al—1.2 Mg—1.55 Si—4 Ba	0.2	6	41	45
2	Al—1.2 Mg—2.3 Si—4 Ba	0.4	7	42	47
3	Al—1.2 Mg—3.5 Si—2 Ca	1.4	4	42	46
4	Al—1.2 Mg—1.7 Si—5 Ce [1]	0.2	8	39	45
5	Al—1.2 Mg—2.7 Si—5 Ce [1]	0.4	6	47	51
Pellet extrusion:					
6	Al—1.5 Mg—4 Si—2 Ca	1.6	4	50	56

[1] Added as misch metal.

cent of silicon in said alloy are predetermined in accordance with the following relationship:

(a) wt. percent $Si \gtreqless \frac{\text{wt. percent Mg.}}{1.73} + 0.2$ (3–6 wt. percent barium)

(b) wt. percent $Si \gtreqless \frac{\text{wt. percent Mg.}}{1.73} + 1.4$ (2–4 wt. percent calcium)

(c) wt. percent $Si \gtreqless \frac{\text{wt. percent Mg.}}{1.73} + 0.2$ (5–10 wt. percent cerium)

said extrusion being in the extruded, solution heat treated, quenched and aged condition and characterized by an unexpectedly high tensile strength.

3. A high strength aluminum alloy pellet extrusion consisting essentially of about 1.5 weight percent magnesium, about 2 weight percent calcium, about 4 weight percent silicon, balance aluminum, said extrusion being in the extruded, solution heat treated, and aged condition and characterized as having a minimum tensile yield strength of about 50,000 p.s.i.

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DAVID L. RECK, *Primary Examiner.*

C. N. LOVELL, *Assistant Examiner.*