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FUSE SUBSTANCE AND ART OF PRODUCING SAME

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In the controlling of electric circuits and in other control apparatus arranged to respond to dangerous temperatures or other controlling conditions, comparatively readily fusing material has been used and conditioned to fuse at a predetermined temperature or pressure, or other predetermined controlling factor, but difficulty has been experienced where nicety of responsiveness is desired from the fact that the eutectic point of alloys in many instances is not the temperature desired as that for effecting the fusing action. It has, accordingly, been proposed to vary the fusing point by varying the proportions of the constituents of the alloy to give the desired fusing point. This, however, has been found to result frequently in an undesirable action on the part of the fusing material from the fact that it loses its stability and its tensile and compression strength and becomes somewhat plastic before it actually reaches the fusing state. With electrical apparatus, and particularly such as is placed under tension for breaking a circuit when the fuse element is fused, the tension is likely to and under some circumstances does cause movement of the contact parts in the direction for breaking the contact when the fusing material becomes plastic and before fusing occurs. This gives rise to such defects as arcing and variation from the desired point of release temperature, and under some circumstances may, by sufficient elongation of the fuse material while plastic, cause complete failure to break the circuit as intended. It is, therefore, highly desirable to provide a fusing material possessing tensile and compression strength, which will be hereinafter referred to as stability, up to the exact temperature of complete fusing, so that the fuse is solid and strong one moment and the next moment is liquid, whereby a sharp break in the circuit or a sharp response to any mechanical apparatus controlled by a fuse is afforded without any intermediate period of elongation or other distortion of the fusing material due to plasticity.

An object of the present invention is the effective avoidance of any deleterious or substantial or prohibitive period of plasticity preceding fusing on the part of fusing material, whereby stability of the fusing material is preserved substantially to the moment of complete fusing.

A eutectic mixture or alloy is a mixture or alloy having such proportions of its constituent elements that it melts at the lowest temperature at which any alloy or mixture of the same constituents will melt, and the eutectic point is the fusing point of the eutectic mixture. A eutectic alloy possesses stability substantially to the moment of fusing, and therefore, has substantially no period of plasticity in approaching fusing. But if it is desired to vary the fusing point from that of the eutectic and a different proportion of the alloyed metals is employed for that purpose, then in most instances the stability is not preserved and a period of plasticity preceding fusing becomes substantial and pronounced.

It is an object of the present invention to provide a range of different fusing points by alloys modified from a eutectic mixture with no deleterious loss of stability, even though a partial plasticity of one or more of the lower melting-point constituents necessarily occurs at a temperature below the desired breaking or fusing point. Although absolute stability and absolute freedom from plasticity preceding fusing is not possible, it is so nearly approached by the present invention as to avoid any objectionable plastic period preceding fusing while complete fusing is assured at the desired temperature within a very limited range of variation not exceeding three degrees (3°) above or three degrees (3°) below the intended point of breaking or complete fusing.

While the addition of a modifying element to a eutectic mixture, as a third element to a binary eutectic alloy, will result in a mixture or alloy that does not have the sharp fusing point of the original eutectic in the sense that it will not change abruptly at a given temperature from a completely solid state to a completely liquid state, yet the present invention provides for such addition without a deleterious departure from such abrupt change or sharp fusing. To this end, the third or added element is, according to the present invention, kept within the limits assuring effective action of the fuse under an external separating stress. That is to say, the complete alloy, as modified by addition to the eutectiferous proportions, is such that it will, upon approaching the fusing temperature, be partly in a liquid and partly in a solid state, but the tensile strength of the solid portion will be sufficient to prevent any plasticity or "mushy" period or condition of the mass as an entirety enabling it to elongate or stretch under external stress, so that when the element or component of the alloy that melts at the lowest temperature becomes liquid within the mass the remaining solid portions of the mass prevent softening of the mass as an entirety, and afford the desired stability of the mass until the

predetermined higher temperature is reached where the whole mass becomes substantially abruptly liquid.

Hence, even though the alloy resulting from the present invention may not always have an actual sharp fusing point, as is true of a eutectic mixture or alloy, yet the proportions of the elements of the mass according to the present invention must always be such and of such materials relative to each other that the melting of the more readily melted component or element will not deleteriously affect the sharp fusing of the whole mass. It is accordingly an important object of the present invention that, whatever may be the alloy, the fuse substance comprising such alloy will possess the two important qualities of (first) complete fusing at an established temperature with absolute dependability and without objectionable variation therefrom, say not exceeding a variation of more than three degrees above or three degrees below the established temperature, so that the point of complete fusing is critical, and (second) the fuse substance retains sufficient tensile strength, even after its lowest-melting-point-element or component has become liquid to resist the external separating stress to which the fuse substance is subjected, and thus to insure abrupt separation of the fuse substance when it reaches the predetermined desired temperature, so that the limits indicated for the relative proportions of the substances employed are critical.

An illustrative instance of effective use of embodiments of the present invention is found in the circuit control apparatus of my co-pending application, Serial No. 630,742, filed August 27, 1932, of which this application is a continuation in part. This application is a substitute for and a continuation in part of my co-pending application Serial No. 723,997, filed May 4, 1934, which was a substitution for and continuation in part of my then co-pending application Serial No. 666,931, filed April 19, 1933. The last-named application contains a clerical error in omitting to mention that, of the initial or primary alloys A and B referred to therein, only forty (40) parts of such initial or primary alloy is taken in any one instance for the named proportions of the added material, so that through the clerical error an erroneous proportion of parts is indicated, as will readily become apparent to one preparing and testing the alloys referred to in said application Serial No. 666,931.

The substitution of the instant application for my co-pending application Serial No. 723,997, filed May 4, 1934, is made because of failure in that application to specifically set forth the common basis or genus from which the several species spring, and also because, while said last-named co-pending application recites the same proportions of the same elements for the same fusing temperatures, and those proportions and temperatures are critical, their critical character is not specifically stated but is left in the said last-named co-pending application to be spelled out from the whole disclosure or discovered from tests. However, as a result of prolonged and carefully and scientifically conducted experimentation made by me in collaboration with two eminent metallurgists, I am now able to state positively that the proportions and temperatures hereinafter set forth are in fact critical, and any appreciable or substantial departure from the hereinafter named limits of proportions of elements or components employed will result in failure. The failure may either arise from incapacity of the alloy or mixture to fuse at the desired temperature or within reasonably allowable variations therefrom (as three degrees above or three degrees below the named temperature) or from incapacity of the mixture or alloy to preserve the necessary stability on approaching fusing temperature with a resultant incapacity for sharp separation on fusing; or the failure may involve both incapacity to fuse at the predetermined temperature and incapacity to preserve stability up to the fusing point.

A further object of the present invention is to produce a fusing solder for such devices as the circuit control apparatus of my first-above-mentioned co-pending application, so that the parts may be soldered together and the solder utilized as the controlling fusing element.

In carrying out the invention, I preferably produce a trinary alloy, but, as will become apparent, the application of the invention is valuable wherever available without regard to the number of metals or metallic elements comprising the alloy.

While, of course, the alloy may be produced from a mixture in the first instance of the metallic elements hereinafter mentioned to produce the completed, finished alloy product, it has been found advantageous to first produce an initial or primary alloy and then modify its fusing point by the introduction of an additional metallic element in such relative proportion as to provide the required fusing point without deleterious departure from abrupt fusing, so that the stability is preserved and the plastic period preceding fusing largely eliminated.

As illustrative of the invention, three initial or primary eutectic alloys identified as A, B, and C are as follows:

(A) Bismuth and lead, having fifty-eight (58) parts bismuth to forty-two (42) parts lead by weight, and fusing at 257° F.; that is to say, an alloy of fifty-eight (58) per centum bismuth and forty-two (42) per centum lead by weight is eutectiferous and fuses sharply at 257° F.

(B) Tin and lead, having sixty-three (63) parts tin to thirty-seven (37) parts lead by weight, and fusing at 358° F.; that is to say, an alloy of sixty-three (63) per centum tin and thirty-seven (37) per centum lead by weight is eutectiferous and fuses sharply at 358° F.

(C) Tin and copper, having ninety-nine (99) parts tin to one (1) part copper by weight, and fusing at 440.6° F.; that is to say, an alloy of ninety-nine (99) per centum tin to one (1) per centum copper by weight is eutectiferous and fuses sharply at 440.6° F.

To vary the fusing point of these alloys, while preserving substantially their stability and freedom from a deleterious plastic period preceding fusing, to the Alloy A should be added certain proportions of tin hereinafter recited to give the respective fusing points hereinafter recited; and to the Alloys B and C should be added certain proportions of bismuth hereinafter recited to give the respective fusing points hereinafter recited.

As a matter of convenience in preparation, I have employed the proportions of added metallic elements with respect to forty (40) parts only of the amount named of the initial or primary alloy (A, B, and C respectively), and the following lists so indicate.

Eleven (11) alloys having eleven (11) different fusing points, as hereinafter indicated, may be produced from the initial or primary Alloys A, B, and C by adding thereto the tin, or the bismuth, as the case may be, respectively in the proportions recited in the following lists:

To forty (40) parts of Alloy A add five and two-tenths (5.2) parts tin to fuse at 212° F. Thus the proportions of the elements in the final alloy are $51\frac{37}{113}$% or approximately 51⅓% bismuth to $37\frac{19}{113}$% or approximately 37⅙% lead, and $11\frac{57}{113}$% or approximately 11½% tin to fuse at 212° F.

To forty (40) parts of Alloy A add three and twenty-five hundredths (3.25) parts tin to fuse at 222° F. Thus the proportions of the elements in the final alloy are $53\frac{111}{173}$% or approximately 53⅝% bismuth to $38\frac{146}{173}$% or approximately 38⅞% lead, and $7\frac{88}{173}$% or approximately 7½% tin to fuse at 222° F.

To forty (40) parts of Alloy A add one and two-tenths (1.2) parts tin to fuse at 240° F. Thus the proportions of the elements in the final alloy are $56\frac{32}{103}$% or approximately 56⅓% bismuth to $40\frac{80}{103}$% or approximately 40⅘% lead, and $2\frac{91}{103}$% or approximately 2⅑% tin to fuse at 240° F.

To forty (40) parts of Alloy A add eight-tenths (.8) parts tin to fuse at 245° F. Thus the proportions of the elements in the final alloy are $56\frac{44}{61}$% or approximately 56⅞% bismuth to $41\frac{9}{61}$% or approximately 41⅛% lead, and $1\frac{8}{51}$% or approximately 1⅝% tin to fuse at 245° F.

To forty (40) parts of Alloy B add nine and two-tenths (9.2) parts bismuth to fuse at 265° F. Thus the proportions of the elements in the final alloy are $51\frac{9}{41}$% or approximately 51¼% tin to $30\frac{10}{123}$% or approximately 30½% lead, and $18\frac{86}{123}$% or approximately 18¾% bismuth to fuse at 265° F.

To forty (40) parts of Alloy B add five (5.0) parts bismuth to fuse at 298° F. Thus the proportions of the elements in the final alloy are 56% tin to 32⅝% lead, and 11⅛% bismuth to fuse at 298° F.

To forty (40) parts of Alloy B add three and two-tenths (3.2) parts bismuth to fuse at 332° F. Thus the proportions of the elements in the final alloy are 58⅓% tin to $34\frac{7}{27}$% or approximately 34¼% lead, and $7\frac{1}{27}$% or approximately 7⅜% bismuth to fuse at 332° F.

To forty (40) parts of Alloy B add two (2.0) parts bismuth to fuse at 338° F. Thus the proportions of the elements in the final alloy are 60% tin to $35\frac{5}{21}$% or approximately 35¼% lead, and $4\frac{1}{21}$% or approximately 4⅘% bismuth to fuse at 338° F.

To forty (40) parts of Alloy B add one and two-tenths (1.2) parts bismuth to fuse at 350° F. Thus the proportions of the elements in the final alloy are $61\frac{7}{103}$% or approximately 61⅛% tin to $35\frac{95}{103}$% or approximately 35⅑% lead, and $2\frac{91}{103}$% or approximately 2⅑% bismuth to fuse at 350° F.

To forty (40) parts of Alloy C add two (2.0) parts bismuth to fuse at 410° F. Thus the proportions of the elements in the final alloy are $95\frac{105}{1041}$% or approximately 95⅒% tin to $\frac{100}{1041}$% or approximately ⅒% copper, and $4\frac{836}{1041}$% or approximately 4⅘% bismuth to fuse at 410° F.

To forty (40) parts of Alloy C add one (1.0) part bismuth to fuse at 425° F. Thus the proportions of the elements in the final alloy are $97\frac{56}{127}$% or approximately 97⅛% tin to $\frac{25}{254}$% or approximately ⅒% copper, and $2\frac{117}{254}$% or approximately 2½% bismuth to fuse at 425° F.

Thus, a binary alloy is changed to a trinary alloy to vary the effective fusing point of the binary alloy without appreciably varying the stability or capacity of the fusing material to resist becoming deleteriously plastic prior to complete fusing, and, in each instance, the trinary alloy is well adapted for such apparatus as set forth in my above-mentioned patent application Serial No. 630,742.

While, for convenience, the procedure above outlined is preferred wherein a binary alloy is first prepared with which is alloyed a third metallic element to modify the fusing point of the completed alloy without occasioning any deleterious variation from the stability of the completed or final alloy immediately preceding fusing, so that a plastic state is largely avoided while affording a dependable fusing point, namely a point in the temperature range at which the fuse changes abruptly from a rigid and strong state to its liquid easily-parting state, it will be obvious that the exact sequence in which the several elements or components making up the completed alloy are brought together is not controlling so long as the proportions are maintained. Also, the making up of a bulk of binary or initial alloy and the use of forty (40) parts thereof relative to the stated number of parts of the modifying metallic element or component to be added is more or less arbitrary for convenience, and so long as the resulting proportions are maintained any actual quantities may be dealt with. For example, instead of employing forty (40) parts of Alloy A with five and two-tenths (5.2) parts tin, the Alloy A may be made up in the first instance of twenty-three and two-tenths (23.2) parts bismuth and sixteen and eight-tenths (16.8) parts lead to which will be added five and two-tenths (5.2) parts tin to produce the final alloy. All of the parts are by weight. Or the Alloy A may be made up of fifty-eight (58) parts bismuth, forty-two (42) parts lead, and the whole bulk employed with thirteen (13.0) parts tin. This can be carried out throughout all the alloys above indicated, and, of course, the ingredients for any one alloy may be alloyed in a single operation instead of two successive steps so long as the proportions are preserved.

While the several specific, completed or trinary alloys described above are of particular value for temperature fuses and other fuses and other uses, they are given as illustrative examples with respect to the broader concepts of the invention which include other unnamed alloys determined by the temperature responsiveness required and the physical fact of stability. Various other metallic elements, as is clear from the foregoing, may be alloyed in the manner above set forth to give different temperature ranges and fusing points, but in each instance the principle should be followed of modifying the fusing point of a primary alloy by supplemental substance without deleterious departure from the eutectic fusing action. In this way, highly efficient fuses are provided having any fusing point desired.

It will be apparent from the foregoing that the invention in addition to comprehending an alloy product also comprises an art, mode or method under which certain steps are taken or executed to produce a new substance having highly valuable and distinctive characteristics.

What is claimed is:—

1. A metallic fuse element consisting of an

alloy of lead and the elements bismuth and tin, one of said elements being in eutectic proportion with the lead, and the other of said elements comprising 11½% or less by weight of the alloy so that the alloy will have rigidity under stress up to a predetermined temperature.

2. A metallic fuse element consisting of an alloy of the elements lead, bismuth and tin, the elements lead and bismuth being in eutectic proportion and the element tin comprising 11½% or less by weight of the alloy so that the alloy will have rigidity under stress up to a predetermined temperature.

3. A metallic fuse element consisting of an alloy of the elements lead, bismuth and tin, the elements lead and tin being in eutectic proportion and the element bismuth comprising 11½% or less by weight of the alloy so that the alloy will have rigidity under stress up to a predetermined temperature.

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