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The Use of Titanium in Pyrotechnics

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Titanium is a very effective generator of white (silver) sparks when used in the manufacture of fireworks. This is because of three of its properties: it ignites easily and burns readily in air, it has a high boiling point, and it is corrosion resistant. Because of this unique combination of desirable properties, the use of titanium in fireworks is generally easy, relatively safe[(a)] and very effective. Before discussing the ways in which titanium is used in fireworks and giving some sample formulations, it is useful to discuss why the properties mentioned above are so important for a pyrotechnic spark generator.

Except for smoke items, flame temperatures in fireworks range from about 1700 °C for black powder compositions, through about 2300 °C for typical color formulations, to perhaps more than 3000 °C for some metal fuel color formulations.[1] It is important that a material intended to produce sparks in fireworks ignites easily at these temperatures and that it be capable of continued burning in air after leaving the flame. Particles merely heated to high temperature but not ignited may leave the flame glowing brightly but will fade to invisibility very quickly as they rapidly cool.

In most instances, it is important that a material intended to produce sparks in fireworks have a high boiling point. This is because particles that are vaporized in a flame will not be available to produce trailing sparks, which are incandescent solid or liquid particles. Also, in colored flames, the chemistry is complex and easily interfered with.[2] Particles that vaporize in such a flame are likely to alter that chemistry, with the result of weakening or destroying the flame's color. Often it is impossible to reformulate such a composition to again produce strong colors. However, it is preferable that the addition of spark-producing particles does not require such reformulation.

It is important that a material intended to produce sparks in fireworks be corrosion resistant, or at least capable of being easily protected against corrosion. If the other materials in a formulation chemically attack the spark-generating material, it may no longer be present in sufficient quantity to produce effective sparks when the firework is used. Thus the useful shelf life of the item will be limited. More important, the corrosion process generates heat, which may be sufficient to cause spontaneous ignition of the composition.

Table 1 rates the metals most commonly used in fireworks for these three important properties. As can be seen in Table 1, titanium's set of properties is the best of any of the listed metals. It ignites easily, has a high boiling point, and is highly corrosion resistant. This makes titanium the easiest spark generating material to use, and it can be used to produce attractive sparks in more types of formulations than any of the other metals. Titanium can be added to most pyrotechnic formulations without significantly altering the performance of the composition except for the additional production of white (silver) sparks[(d)]. Tables 2a, 2b, and 2c give examples demonstrating how easily titanium can be used to produce sparks by simply adding 10 to 20% of it to standard (non-sparking) formulations.

Table 1. Some Properties of Metals Commonly Used in Fireworks.

Metal	Ease of Ignition[(b)]	Boiling Point[3]	Corrosion Resistance[(b)]
Aluminum	Hard	2467°C	Moderate
Iron	Easy	2750°C	Low
Magnalium (50:50)	Moderate	(c)	Moderate
Magnesium	Easy	1090°C	Low
Titanium	Easy	3287°C	High
Zinc	Moderate	907°C	Moderate

Table 2a. Examples Demonstrating the Conversions of Non-Sparking Formulations to Silver Sparking Ones.

	Parts by weight			
Ingredient	Flash Salute	Silver Flash	Whistle	Silver Whistle
Potassium perchlorate	70	70	70	70
Aluminum (German dark)	30	30	—	—
Sodium benzoate	—	—	30	30
Titanium[(e)(f)]	—	15	—	10
Reference	5	—	6	—

Table 2b. Examples Demonstrating the Conversions of Non-Sparking Formulations to Silver Sparking Ones.

	Parts by weight			
Ingredient	Wheel Driver	Silver Wheel	Red Fire	Silver & Red
Potassium nitrate	75	75	—	—
Charcoal (air float)	15	15	—	—
Sulfur	10	10	—	—
Potassium perchlorate	—	—	66	66
Strontium carbonate	—	—	20	20
Accaroid resin[(g)]	—	—	14	14
Titanium[(e)(f)]	—	20	—	15
Reference	—	—	5	—

Table 2c. Examples Demonstrating the Conversions of Non-Sparking Formulations to Silver Sparking Ones.

	Parts by weight			
Ingredient	Blue Star	Silver & Blue	Bright Green	Bright Silver & Red Fire
Potassium perchlorate	61	61	16	16
Copper carbonate	12	12	—	—
Parlon	13	13	—	—
Accroides resin	9	9	—	—
Rice starch[(h)]	5	5	[(i)]	[(i)]
Barium nitrate	—	—	42	42
Magnesium[(j)]	—	—	25	25
Polyvinyl chloride	—	—	15	15
Lamp black	—	—	2	2
Titanium[(e)(f)]	—	10	—	20
Reference	(6)	—	(6)	—

In addition to the many ways titanium can be used by simply adding it to standard non-sparking formulations, there are two other applications that should be addressed. The first is a very attractive sparkler that generates an abundance of white sparks that seem to flow in long-lived cascades from the end of the sparkler. The second is sparking primes that some

Table 3. Examples of Other Uses for Titanium in Fireworks.

Ingredient	Parts by weight		
	Titanium Sparkler	Sparking Prime	Sparking Hot Prime
Potassium perchlorate	100	—	70
Titanium	100[k]	15[l]	15[l]
Dextrin	45	[m]	[m]
Hydroxypropylguar[n]	5	—	—
Potassium nitrate	—	75	—
Charcoal (air float)	—	15	20
Sulfur	—	10	—
Accroides resin	—	—	10
Potassium dichromate	—	—	2
Reference	8	—	—

have used successfully in place of cross-matching inside aerial shells. Table 3 gives formulations for these applications.

In addition to a few unique uses, titanium has the ability to produce white (silver) sparks in most standard (non-sparking) formulations without the necessity of altering the basic formulation. Thus it may not be an exaggeration to proclaim titanium as the most versatile and easiest to use pyrotechnic material in fireworks today.

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Notes

(a) The use of titanium metal in pyrotechnic formulations is relatively safe, particularly in regard to adverse chemical reactions. However, titanium metal powders finer than about 240 mesh are quite susceptible to accidental ignition by static electricity, and the presence of an oxidizer only aggravates this situation. Thus caution is appropriate when using titanium finer than 100 mesh, particularly when it is possible that the material contains titanium finer than about 240 mesh. Titanium metal powders finer than about 325 mesh can be almost pyrophoric (spontaneously burn in air). Material this fine must be handled with extreme caution.

(b) Ease of ignition and degree of corrosion resistance are given in subjective terms. This is because the author is not aware of a reference that appropriately quantifies them. The information presented is based on the general observations of the author and reviewers.

(c) The exact boiling point of 50:50 magnalium could not be found in the literature. However, based on information supplied by Reade Metal, Inc., its boiling point is probably in the range from 1200–1500 °C.

(d) Strobe formulations and many glitter formulations[9] are the most notable exceptions to this rule. Also, regarding spark color, it must be noted that titanium sparks can appear yellowish in some formulations.

(e) The titanium used can be either granular sponge or flakes, both work satisfactorily. However, granular sponge does work somewhat better in salutes while flake material works better in most other applications.[4]

(f) The particle size of the titanium used in these formulations generally falls into one of three ranges; –10 to +20 mesh, –20 to +40 mesh, and –40 mesh. The choice of particle size is dependent on the desired duration of the sparks to be produced by the firework. Coarse material produces longer-lived sparks. However, for a given weight of titanium, there are many more particles in the finer material, and the number of sparks produced is roughly proportional to the number of particles. Thus, the choice of titanium particle size involves a tradeoff between producing a modest number of long-lived sparks and producing many more short-lived sparks. In general, the size of the titanium is scaled approximately to the size of the fireworks item. For example, a large gerb (1 to 2") probably would use –10 to +20 mesh titanium, while a medium gerb (½ to 1") probably would use –20 to +40 mesh titanium, and a small gerb (<½) probably would use –40 mesh titanium.

(g) Acaroid resin is also known as red gum and accroides resin.

(h) It is satisfactory to use dextrin in place of soluble glutinous rice starch.

(i) Binding of the star should be accomplished using a non-aqueous binding system such as nitrocellulose-acetone. As an alternative, Parlon can be substituted for PVC, and the Parlon solvated using acetone and methylethylketone.[7]

(j) The magnesium called for is 60 mesh material coated with linseed oil.

(k) The titanium called for in the sparkler formulation is only identified as "mixed fines". This probably equates to –100 mesh material although slightly coarser material might also be used effectively. Remembering the caution in note (a) above, it might be prudent to sieve the –100 mesh titanium with a 240 mesh screen and dispose of any material finer than 240 mesh.

(l) The titanium used in the sparking primes should be no coarser than –40 mesh; –100 mesh works well.

(m) A dextrin—water binding system could be used but this can result in long-lasting moisture accumulation in the powder train of the time fuse. Thus, it is generally preferred to use the nitrocellulose-acetone binding system with primes.

(n) Most likely CMC (sodium carboxymethylcellulose) can be used in place of hydroxylpropylguar in this formulation.

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