SEM Studies on a Strobe Star Composition

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ABSTRACT

Data obtained from an analysis of an extinguished strobe star using the technique of scanning electron microscopy (SEM) is used to provide additional evidence for a previous model for the cyclic burning process seen in a white strobe star composition. The model relies on the generation of hot liquid on the surface of the star to initiate the burning process.

Keywords: strobe star, scanning electron microscopy (SEM), hot liquid model

Introduction

The phenomenon of repeated cyclic flashing of a star is well documented.[1-4] It is thought to consist of alternate dark and light reactions, with the formation of localised "hotspots" resulting in an ignition of the gas evolved from the composition. The star then appears to self extinguish, and the cycle repeats.

This model was proposed by Shimizu[1] as a result of detailed and comprehensive experimental studies. The burning of the star is thought to start with a so-called "dark" reaction in which the combustion reaction appears to proceed without the generation of significant amounts of light. After a delay which can range from a few tens of milliseconds to several seconds depending on the composition, the semi-reacted zone undergoes a rapid reaction, producing a strong flash of light accompanied by a burst of noise. This is the "light" reaction. It is thought that a thin layer of semi-reacted material remains on the surface of the composition, and results in another "dark" reaction. The combustion process then cycles between "dark" and "light" reactions, thus producing the attractive stroboscopic effect.

The chemical nature of the "dark" and "light" reactions or the proposed thin layer of semi-reacted material have yet to be fully elucidated. This is not particularly surprising, since the examination of fleeting chemical phenomena on an extremely hot surface is not a trivial matter. In this paper, an extinguished white strobe star was examined using SEM and X-ray fluorescence techniques, these being two methods which have not been applied to the investigation of pyrotechnic strobe effects. Evidence obtained from these studies has been examined in the light of previous postulates for the strobe effect mechanism.

Composition Details

A relatively complex white strobe composition has been used for the studies presented in this paper. The base composition used is given in Table 1.

A star was used instead of powder in order to simplify the SEM work. This necessitated the use of a binder. Binders for strobe compositions need to be carefully selected so that they do not interfere with the strobing process.[1,2] Several binders were assessed for their suitability and rejected, including dextrin paste, epoxy resin, resorcinol resin, xanthan gum, accaroid resin, beeswax and polyvinylpyrrolidone. Locust bean gum was found to be the best binder of those tested, since it did not interfere too much with the strobe process. Further work is in progress on several binders in order to find a suitable one for use in simple pumped stars.

Table 1. Components of White Strobe Star Composition.

Material	Grade	Parts
Barium nitrate	140 mesh	7.0
Magnalium alloy (50:50)	60 mesh	2.0
Ammonium perchlorate	140 mesh	0.25
Antimony trisulphide		0.25
Sodium oxalate		0.25
Potassium benzoate	140 mesh	0.25
Binder (locust bean gum)		0.50

The solid components outlined in Table 1 (except the binder) were sieved separately, then mixed by repeated tumbling on paper. This was then added to a thick paste made from the binder and water, and the resulting composition was thoroughly mixed until homogeneity had been achieved. The composition was pressed into stars using a small handpress. The stars were dried in an oven for 2 hours at 60 °C.

The pellet was ignited using a silicon/red lead primer. A Black Powder based priming composition was tried, but was found to be unreliable.

Experimental

The SEM photograph taken from a star which had initiated but failed to function fully is reproduced in Figure 1. Table 2 represents an elemental analysis produced by the X-ray fluorescence method of the marked zones in Figure 1. No complex sample preparation was required. The star was fixed to a metallic probe, and placed in the instrument sample chamber. The machine used was a Jeol JSM840.

Area **a** has the appearance of a cooled liquid. Areas **c** and **d** appear to contain the flash ignition site (**c** being a charred zone, **d** being the actual flash site). Areas **b** and **f** appear to be unreacted composition. Area **e** appears to be a localised charred area.

Discussion

When combined with visual observations, this evidence immediately suggests that ignition of the star involves the liquefaction of one (or more) of the components of the star. This is based on the presence of zone **a**, which appears to be a cooled liquid.

The fact that area **a** does not cover the whole of the surface of the star suggests that the whole of the material does not liquefy during the combustion process. It is possible that liquefied areas correspond to the "hotspots" described by Shimizu.[1]

Area **a** has a relatively large amount of barium present. It is therefore possible that ignition of the star involves the melting of a barium compound. The only barium compound present in the initial composition is barium nitrate, which melts at a relatively high temperature (about 860 K), but it is possible that the barium nitrate could form a solid solution with at least one other component.

Table 2. Elemental Analysis of Zones in Strobe Star.

Zone	C	O	Na	Mg	Al	S	Cl	K	Sb	Ba
a	L	L	L	L	L	L		L	L	H
b	L	L	M	M	M	M	L	L	L	H
c	H		M	M	M		M	H	M	M
d	L						M	H	M	H
e	H									
f	L	L	M	M	M	M	L	L	L	M

Key : L = low, M = medium, H = high, blank = not present.

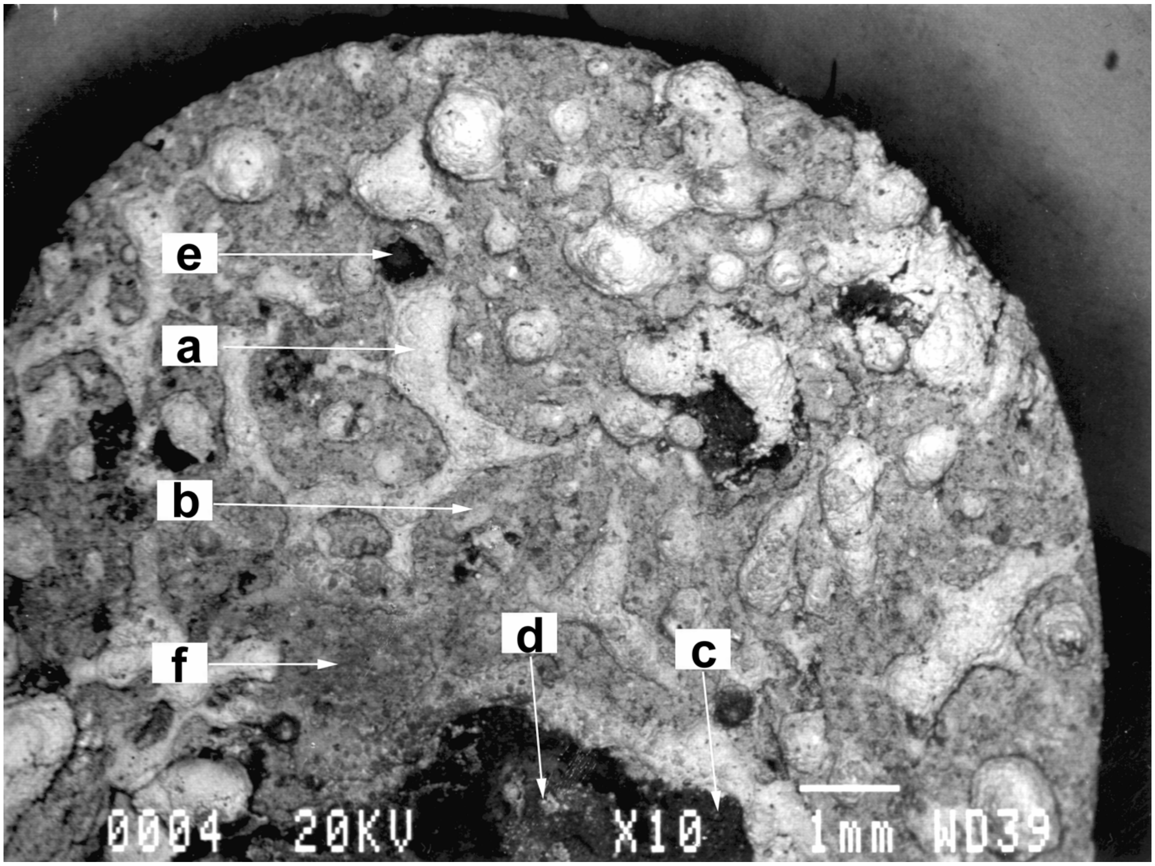

Figure 1. SEM photograph of surface of strobe star.

This would result in a eutectic mixture with a significantly lower melting point than barium nitrate. Thermal analysis studies are currently in progress to examine possible eutectic mixtures involving barium nitrate.

The star is difficult to ignite. This ties in with the above proposal that ignition requires the melting of an inorganic solid or solid solution. The high temperature required for this process may be responsible for the charring zones (**c** and **e**) in the vicinity of the unreacted cooled liquid (area **a**) and the flash site (area **d**). The charred zones contain a relatively large amount of carbon, which indicates the rapid burning of organic material such as the potassium benzoate or the organic binder.

The production of gaseous products from the light-producing reaction will probably blow some of the unreacted hot liquid off the surface of the star. It is possible that subsequent ignitions will take place at other points on the surface of the star, where enough hot liquid remains. If, however, too much of the liquid is blown off the surface of the star, then the reaction will cease and the star will go out.

The presence of ammonium perchlorate appears to facilitate the strobing process. Chlorine is present in areas **b**, **c** and **d**. Area **b** is unreacted and unmelted composition, so the presence of chlorine is not entirely unexpected. It is possible that the presence of ammonium perchlorate speeds the production of the hot liquid phase, but its presence is not critical since strobing will occur without ammonium perchlorate being present.[5]

Conclusion

The work presented in this paper suggests that the mechanism of operation of the strobe star relies on the generation of a hot liquid on the surface of the star. The liquid may contain barium nitrate, and its melting is possibly accelerated by the presence of ammonium perchlorate. The presence of the hot liquid results in a light generating reaction at points on the surface of the star (i.e., the strobing process). This was first put forward by Shimizu in the early 1980's.[1]

After the light-generating reaction has occurred, the gases produced during this reaction blow any localised hot liquid off the surface of the star. The process will then repeat the above cycle. If, however, too much of the hot liquid is removed from the surface of the star, then the reaction will stop and the strobing will cease.

Ternary strobe systems are currently being examined using the techniques used in this work, and it is intended to use gas analysis methods to provide additional data on which a more descriptive model can be constructed. Work on finding a suitable binder is also in progress. We hope to be able to report on this work in the not too distant future.

Acknowledgments

The author wishes to thank Mr. Rob Kimber (RMCS) for the SEM analyses.

References

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