Journal of Thermal Analysis, Vol. 40 (1993) 357-361

THERMAL BEHAVIOUR AND FIRING CHARACTERISTICS OF $Zr/KClO_4$ PRIMER MIXTURE CONTAINING CuO

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The effect of CuO on the thermal behaviour of $Zr/KClO_4$ primer mixtures was studied by thermoanalytical techniques, and the Bruceton method and its related calculation. It was found that the CuO catalytically promoted the decomposition of $Zr/KClO_4$ primer mixtures and shifted the exothermic peak of DSC curves to lower temperatures. In addition, the $Zr/KClO_4$ primer mixture containing CuO had a significant effect on the firing characteristics of electro-explosive devices.

Keywords: effect of CuO, firing characteristics, $Zr/KClO_4$ mixtures

Introduction

The $Zr/KClO_4$ mixture is a typical primer mixture of commercial 1-amp/1-watt 5 minutes, no-fire electro-explosive devices (EEDs) [1]. The thermal properties and decomposition kinetics of the primer mixture basis of $KClO_4$ have been investigated by many researchers [2–4].

In this report, the thermal properties of various CuO-containing $Zr/KClO_4$ primer mixtures have been evaluated by TG, DSC and adiabatic calorimetry initially, after which the primer mixture, $Zr/KClO_4/CuO$ = 50/45/5, was pressed into the charge holder of the EEDs in order to evaluate performance by the Bruceton test [5].

The firing characteristics of two groups of EEDs were determined by following the Bruceton statistical calculation. In the 'up-and-down' approach of the Bruceton test only one sample is tested at a time. Before measurements can be taken, it is necessary to determine the approximate amperage at which 50% of the components will fire. Then starting at a level where about 50% responses are ex-

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pected, the test level is moved up one level after each non-response and down one level after each response.

Experimental details

The Zr metal power used was supplied by Ventron Corporation, U.S.A., and had a particle size of 1–3 microns and purity of 94% (Zr+Hf). Potassium perchlorate, obtained from Ferak Berlin Corporation, Germany, with purity of 99.5%, was first ground using a mortar and pestle and the fraction passing 325 mesh collected (particle size ≤ 44 μm). The CuO was from Fluka AG, Switzerland, with a minimum purity of 90%. A Parr adiabatic calorimeter was used to obtain the heat of explosion. A Mettler TG50 thermobalance with TA3000 system and Mettler DSC20 with Mettler TC10 processor were used in air at a 10 deg·min^{-1} heating rate. The sample size was restricted to less than 5 mg and the reference material for DSC was finely powdered α–Al_2O_3.

Results and discussion

Table 1 shows the heat of explosion the different primer mixtures containing CuO. The heats of explosion do not change significantly with different atmospheres when the CuO is added to the $Zr/KClO_4$ primer mixtures, but heat of explosions do decrease with increasing amounts of CuO.

Table 1 Heat of explosion of primer mixtures

Primer mixtures	Heat of explosion / cal·g	
	in O_2	in N_2
$Zr/KClO_4/CuO$ 50/45/5	1276.0±15.2	1224.92±2.33
$Zr/KClO_4/CuO$ 50/40/10	1267.11± 3.3	1260.58±16.67
$Zr/KClO_4/CuO$ 50/35/15	1249.34± 3.02	1227.03±20.33
$Zr/KClO_4/CuO$ 50/30/20	1253.10± 3.14	1184.76±13.33
$Zr/KClO_4/CuO$ 50/25/25	1250.38± 6.0	1126.51±2.85
$Zr/KClO_4$ 50/50	1359	1350

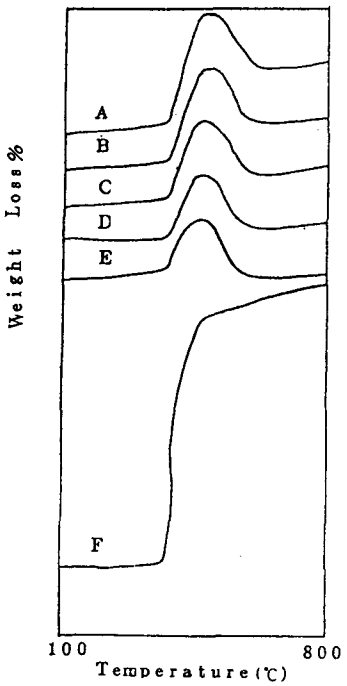

Fig. 1 TG curves of primer mixtures and $KClO_4/CuO$ mixture. A: $Zr/KClO_4/CuO$ = 50/45/5, B: $Zr/KClO_4/CuO$ = 50/40/10, C: $Zr/KClO_4/CuO$ = 50/35/15, D: $Zr/KClO_4/CuO$ = 50/30/20, E: $Zr/KClO_4/CuO$ = 50/25/25, F: $KClO_4/CuO$ = 90/10

TG and DSC plots of $Zr/KClO_4$ primer mixtures are given in Figs 1 and 2. The TG curves show that the temperature of the initial weight loss of the primer mixtures decreases with increasing amount of CuO. This result shows that the CuO accelerated decomposition of the $Zr/KClO_4$ primer mixtures.

Table 2 The firing characteristics for EED's

Firing characteristics	Primer mixtures	
	$Zr/KClO_4$ = 50/50	$Zr/KClO_4/CuO$ = 50/45/5
Maximum no-fire current (A)	1.63	1.10
50% firing current (A)	1.82	1.65
Minimum all-fire current (A)	2.30	1.90

The DSC curves show an endothermic peak near 305°C, followed by an exotherm, and a second exotherm at higher temperature. The first exothermic peak represents the reaction of the $Zr/KClO_4$ primer mixture. DSC experiments also show that the first exotherm shifts to lower temperatures with increasing amount of CuO.

Using the Bruceton method and associated statistical calculation, the firing characteristics of the $Zr/KClO_4/CuO$ = 50/45/5 primer mixture were calculated. The data indicated that the EEDs prepared from a pilot-scale process possess 1-amp/1-watt, 5 minutes, no-fire character.

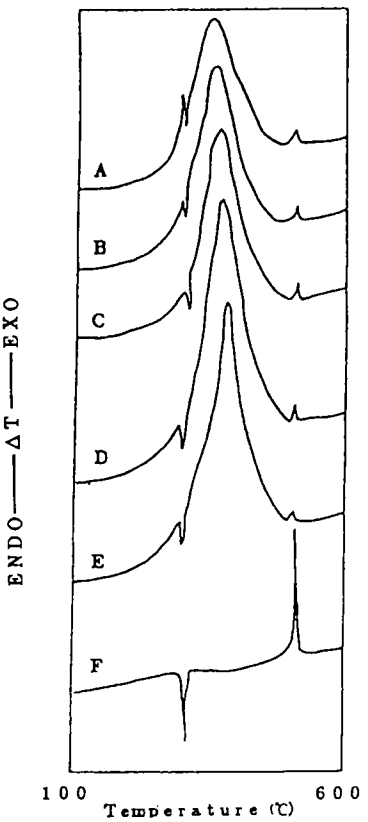

Fig. 2 DSC curves of primer mixtures and $KClO_4/CuO$ mixture. A: $Zr/KClO_4/CuO$ = 50/45/5, B: $Zr/KClO_4/CuO$ = 50/40/10, C: $Zr/KClO_4/CuO$ = 50/35/15, D: $Zr/KClO_4/CuO$ = 50/30/20, E: $Zr/KClO_4/CuO$ = 50/25/25, F: $KClO_4/CuO$ = 90/10

Table 2 shows the firing characteristics of two kinds of EEDs, which have different primer mixture compositions. The DC sensitivity of $Zr/KClO_4$ = 50/50 primer mixture tended to decrease with additions of CuO.

Conclusion

A series of $Zr/KClO_4$ primer mixtures containing CuO can be screened using TG, DSC, DTA and adiabatic calorimetry. It was found that CuO additive catalytically promoted decomposition of the $Zr/KClO_4$ primer mixtures, and $Zr/KClO_4$ primer mixtures containing 5% CuO by weight are suitable for the production of 1A/1W, 5 minutes, no-fire EEDs.

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Zusammenfassung — Mittels thermoanalytischen Verfahren, der Bruceton-Methode und der damit verbundenen Berechnungen wurde der Einfluß von CuO auf das thermische Verhalten von $Zr/KClO_4$ Primärgemischen untersucht. Es wurde gezeigt, daß ein Zusatz von CuO die Zersetzung von $Zr/KClO_4$ Primärgemischen katalytisch begünstigt und den exothermen Peak der DTA-Kurve in Richtung niedriger Temperaturen verschiebt. Außerdem haben $Zr/KClO_4$ Primärgemische mit einem Gehalt an CuO einen eindeutigen Einfluß auf die Brenncharakteristik von Elektroexplosivapparaturen.