Supporting Information

Versatile Boron Carbide-Based Visual Obscurant Compositions for Smoke Munitions

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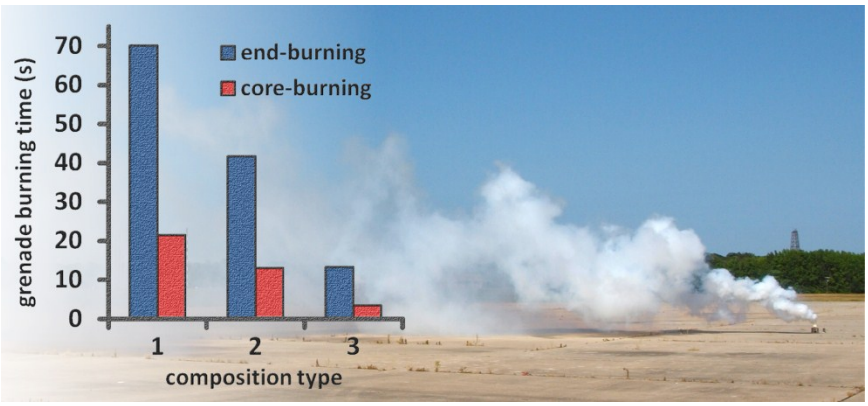

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Table S1. Mass-Based Smoke Chamber Data.

Composition	Y [a)]	α_m (m^2/g) [b)] 380-780 nm	α_m (m^2/g) [b)] 555 nm	α_m (m^2/g) [b)] Photopic	FM_m (m^2/g) [c)] 380-780 nm	FM_m (m^2/g) [c)] 555 nm	FM_m (m^2/g) [c)] Photopic
BC (Average) [d)]	0.75 (0.03)	3.81 (0.40)	4.05 (0.43)	4.01 (0.43)	2.87 (0.39)	3.06 (0.43)	3.03 (0.42)
TA [e)]	0.30	4.74	4.85	4.80	1.42	1.46	1.44
HC [f)]	1.26	2.42	2.36	2.36	3.04	2.97	2.97

a) Yield factor. b) Mass-based extinction coefficient. c) Mass-based composition figure of merit.
d) Averages for all BC grenades tested with standard deviations in parentheses.
e) Data for a typical M83 TA grenade. f) Data for an AN-M8 grenade at 25 °C and 32% relative humidity.

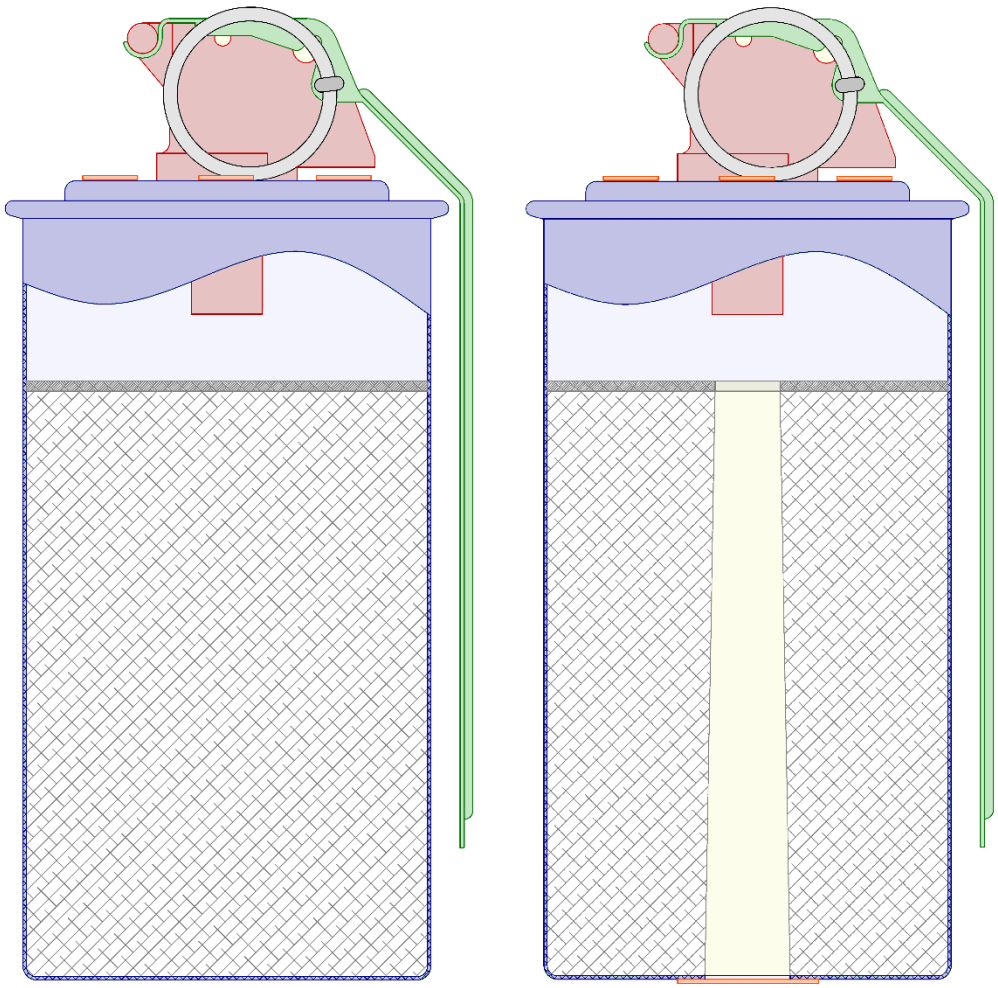

Figure S1. Large format version of Figure 1. Diagrams of the end-burning (left) and core-burning (right) experimental grenade configurations. Partial cross sections show the solid end-burning pellet and the core-burning pellet with an axial core hole. The grenade lids and/or can (blue) contain vent holes covered by tape (orange). Other parts, common to both configurations, include the fuze (red), pull ring and pin (gray), and lever (green).

XRD/XRF Experiments. Small cylindrical pellets (2 g, 0.95 cm diameter) of a type 1 BC composition were ignited with an electrically heated nichrome wire. An inverted steel cup was positioned above the burning pellets so that a portion of the volatilized combustion products condensed within it. The light gray residue was scraped out and used for X-ray analysis.

X-ray diffraction (XRD) of the sample was carried out in a Rigaku Ultima III diffractometer with CuKα radiation (1.54 Å). A step size of 0.02 degrees and a scan rate of 0.25 deg/min were used. The pattern was analyzed with JADE 7 software (Materials Data Inc., Livermore CA). Semi-quantitative chemical composition analysis was carried out in a Rigaku ZSX Primus II wavelength dispersive X-ray fluorescence (XRF) spectrometer. The spectrometer contained a 4 kW Rh anode and the detector system used a scintillation counter for detecting heavy elements and a flow proportional counter for detecting light elements. The samples were tested in a vacuum and the data were analyzed using SQX software that can correct for matrix effects, overlapping lines, and secondary excitation effects by photoelectrons. Increased accuracy was achieved using built-in matching library and perfect scan analysis programs.

The major crystalline phase identified by XRD was KCl (sylvite), Figure S2. XRF indicated the presence of 36.7 wt% O, 31.4 wt% K, 25.0 wt% B, 6.7 wt% Cl, 0.1 wt% Ca, and trace elements including Si and Fe as the balance. Potassium borates and boron oxides are rarely crystalline [1].

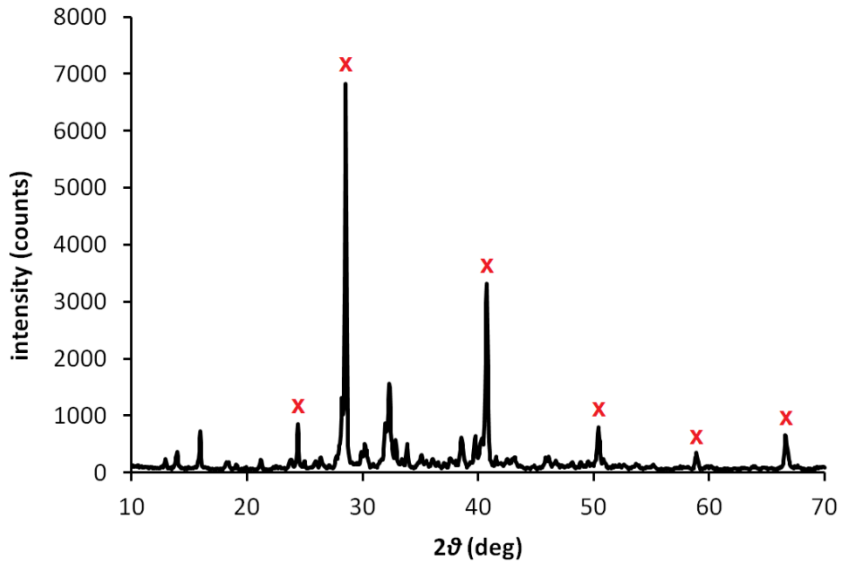

Figure S2. XRD pattern of collected residue with KCl (sylvite) peaks marked.

[1] Akagi, R.; Ohtori, N.; Umesaki, N. Raman spectra of K_2O–B_2O_3 glasses and melts. *Journal of Non-Crystalline Solids.* **2001**, *293-295*, 471-476.

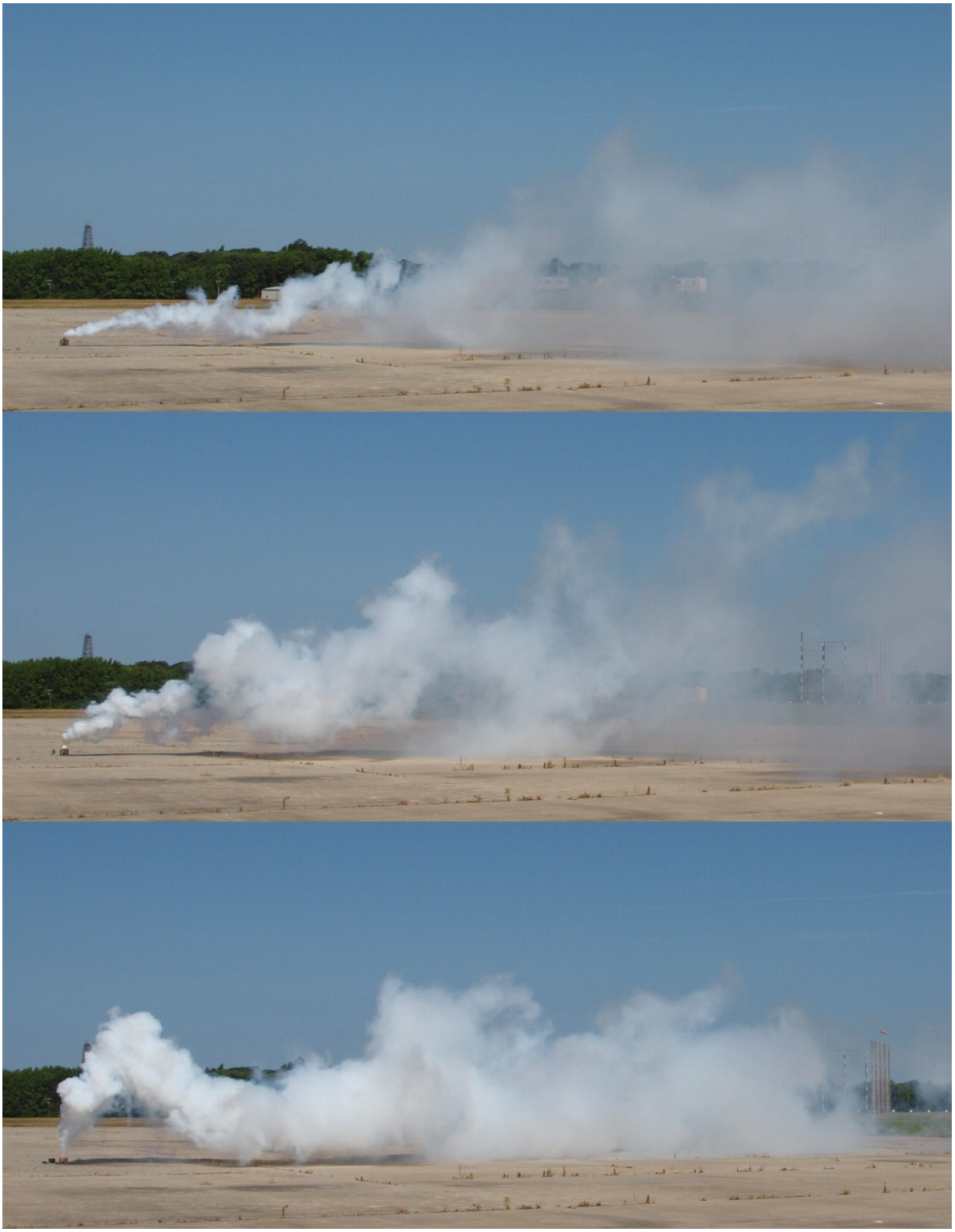

Figure S3. Large format version of Figure 3. Smoke screens produced by end-burning BC smoke grenades, mid-burn. Type 1 (top), type 2 (middle), type 3 (bottom).

Figure S4. Large format version of Figure 4. Time sequence for a core-burning BC smoke grenade containing the type 3 composition. Images show smoke screen formation at 0.4 s (top), 2.8 s (middle), and 8.0 s (bottom). The total grenade burning time was 3.5 s.

Figure S5. Smoke screen produced by an end-burning BC smoke canister, mid-burn. The canister contained 2 kg of the type 1 composition and burned for about 100 s.

Figure S6. Smoke screen produced by an end-burning BC smoke canister, mid-burn. The canister contained 2 kg of the type 2 composition and burned for about 59 s.

Figure S7. Smoke screen produced by an end-burning BC smoke canister, mid-burn. The canister contained 2 kg of the type 3 composition and burned for about 19 s.

Figure S8. Smoke screen produced by a core-burning BC smoke canister at 1.7 s. The canister contained 2 kg of the type 3 composition and burned for 8.0 s.

Figure S9. Smoke screen produced by a core-burning BC smoke canister at 3.9 s. The canister contained 2 kg of the type 3 composition and burned for 8.0 s.

Figure S10. Smoke screen produced by a core-burning BC smoke canister at 6.5 s. The canister contained 2 kg of the type 3 composition and burned for 8.0 s.