

Static Charge Development on Explosives

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ABSTRACT

Static charge development character of some of the important explosive crystals have been predicted on the basis of their crystal class and symmetry. Among the important mechanism of charge development, the piezoelectric and pyroelectric characters have been considered. Ammonium trinitrate, ammonium nitrate, m-dinitro-benzene, trinitro-toluene, styphnic acid, β -lead styphnate, 4, 4' dinitro-diphenyl, α -hexamethylenetetranitramine, nitroguanidine, picric acid, dimethylnitramine, α -lead azide and β -lead azide are pyroelectric in nature, whereas pentaerythritol tetranitrate, picryl iodide, s -hexamethylenetetranitramine, tetranitromethane and trinitroethane are piezoelectric in nature.

1. INTRODUCTION

One of the main causes of accidental explosion is static electrification¹⁻⁴ which may be generated externally or internally within the explosives. When the most widely used explosive nitrocellulose is handled, its particles are found to cluster together due to static charge development. Much work has been reported from safety consideration, to evaluate static charge on initiators like lead azide⁵, lead styphnate⁶ and high explosives⁷⁻¹⁰. Boyle¹¹, Moris¹² and recently Berger¹³ have shown that primary explosives are most sensitive to static charge and require only a spark of 10^{-6} to 10^{-2} J to cause ignition but secondary explosives require a minimum spark energy much above 0.02 J to cause ignition.

The development of charge on insulators like organic explosives having very high electrical resistance may be the most basic property¹⁴ when it is deformed by external force or impact. Even a single crystal of sodium chloride which belongs to symmetric

class generates¹⁵ a static field of 1.1 V/cm under one kg/cm² pressure. Many explosives crystallise in structure of low symmetry and some of them with a direction of permanent polarisation possess¹⁶ piezoelectric or pyroelectric character. When these crystals are subjected to slight temperature fluctuations they develop static charge due to pyroelectric property.

To follow proper safety precautions in the manufacture of explosives, crystallisation process, storage, handling, etc., it is essential to know the cause of static charge development of each explosive. In the literature, no such detailed report is available about the group of explosives which are pyroelectric or piezoelectric in nature. A knowledge of the crystal structure permits to predict the possibility and nature of static charge development character. This paper presents a list of a good number of explosives which are piezoelectric or pyroelectric in nature on the basis of their crystal class and point group symmetry available in the published literature¹⁷.

2. DISCUSSION

The structure of a crystal, viz. its class and symmetry, is the most important factor for determining its physical properties along different crystallographic directions. According to Neumann's principle¹⁶, there is a correspondence between the geometrical form and physical properties of a crystal. If a crystal is symmetrical with respect to a point, the body is centro symmetric, thereby devoid of polar properties and hence no piezoelectric property can be observed in any of the eleven centro symmetric classes. Thus with one exception of cubic hemihedral, 432, all classes devoid of centre of symmetry are piezoelectric and those with a permanent direction of polarization are pyroelectric in nature. A substance with pyroelectric character necessarily possesses piezoelectric property.

On the basis of Neumann's principle, if the class and symmetry of a explosive crystal is known, the basic cause of charge development can be easily predicted. The crystal class and symmetry of a good number of explosive compounds are shown in Table 1. It is observed that a considerable number of explosive crystals possess structural asymmetry and amongst them some crystals possess permanent direction of polarisation.

A cursory glance at the table indicates that many of the explosive compounds belong to the orthorhombic system. In this class, crystals with point group mm2 symmetry are pyroelectric and those with 222 symmetry are piezoelectric. Ammonium nitrate, *m*-dinitrobenzene, trinitrotoluene (TNT), nitroguanidine, *a*-hexamethylenetetranitramine (*a*-HMX), picric acid and *a*-lead azide belong to this class with mm2 symmetry. All of them are both piezoelectric and pyroelectric in nature.

In the monoclinic system, crystals with symmetry 2 or *m* belong to both pyroelectric and piezoelectric class. Ammonium trinitrate, dimethylnitramine and β -lead azide have symmetry 2. β -lead styphnate, 4,4' dinitrodiphenyl and one variety of β -lead azide have symmetry *m*. All of them generate both piezoelectric and pyroelectric charge.

In the tetragonal system, crystals with point group 4 and 4 mm are pyroelectric. No explosive compound could be found in this point group. In this class, crystals with

point group 4, $\bar{4}2m$ and 422 are piezoelectric. Pentaerythritol tetranitrate (PETN) and picryl iodide belong to this class with point group $\bar{4}2m$ and 422 respectively.

In the trigonal system, crystals with point group 3 and 3 *m* are pyroelectric and those with point group 32 are piezoelectric in nature. Styphnic acid belongs to this class with point group 3 *m*, and so is pyroelectric.

In the cubic system, crystals with point group 23 and $\bar{4}3m$ are piezoelectric. Tetranitro methane and trinitro ethane fall under this category with point group $\bar{4}3m$ and hence are piezoelectric in nature.

Table 1. Explosive crystals, their symmetry, piezoelectric and pyroelectric nature

S. No.	Explosive	Morphology	Point group	Remarks
	<i>o</i> -nitrobenzoic acid			-
	Ammonium trinitrate			Pyroelectric
	<i>p</i> -dinitrobenzene			-
	Trinitrotoluene ¹⁸			-
	β -lead styphnate			Pyroelectric
	4, 4'-dinitrodiphenyl			Pyroelectric
	1, 5-dinitronaphthlene			-
	Ethylene nitroguanidine			-
	BSX			-
	BSX acetone			-
	BSX acetonitrile			-
	Cyclonite oxide			-
	β -HMX			-
	<i>g</i> -HMX			-
	Dimethylnitramine			Pyroelectric
	β -lead azide			Pyroelectric
17.	Tetryl ¹⁹			-
18.	Ammonium nitrate			Pyroelectric
19.	<i>m</i> -dinitrobenzene			Pyroelectric
20.	Trinitrotoluene ¹⁸			Pyroelectric
21.	Ethylenedinitroamine			-
22.	Nitroguanidine			Pyroelectric
23.	RDX			-
24.	1, 3, 5-trinitronbenzene			-
25.	Picric acid			Pyroelectric
26.	Mercury fulminate			-
27.	Strontium azide			-
28.	<i>a</i> -lead azide			Pyroelectric
29.	Cadmium azide			-
30.	Ammonium azide			-
31.	Ammonium perchlorate			-
32.	<i>a</i> -HMX			Pyroelectric
33.	<i>s</i> -HMX			Piezoelectric
34.	PETN			Piezoelectric
35.	Picryl iodide			Piezoelectric
36.	Copper azide			-
37.	Styphnic acid			Pyroelectric
38.	Tetranitromethane			Piezoelectric
39.	Trinitroethane			Piezoelectric
40.	Cyanouric triazide			-

In hexagonal system, *s*-HMX possesses 622 point group symmetry which belongs to piezoelectric category.

Thus the prediction of the charge development characteristic of explosive compounds based on crystal structure supports the observations of Greenwood¹⁰ for pyroelectric behaviour of picric acid. Maycock's observation⁹ on piezoelectric behaviour of *s*-HMX and his prediction for TNT and PETN have also been experimentally confirmed²⁰. The crystal structure of RDX, tetryl and β -HMX suggests it to be non-piezoelectric in behaviour which has been confirmed by the experimental observations^{20,21}. Ammonium perchlorate²² belongs to the orthorhombic class with space group $D_{2h}16$ or *mmm* which is also non-piezoelectric in behaviour whereas, Maycock⁹ predicted it to possess this property. This prediction for charge development character of explosives offers a guideline for carrying out further research in this line.

ACKNOWLEDGEMENTS

The authors are thankful to Padmashri N.S. Venkatesan, Director, ERDL for granting permission to publish this paper.

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