

## Impact Sensitivity of RDX and Viton Compositions Prepared by Co-precipitation Method

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### ABSTRACT

Desensitisation of explosive materials using polymers is an important area in safe utilisation of explosives in various applications. The RDX/viton composition has been developed using co-precipitation method with varying content of viton, ranging from 5 to 35 wt per cent. RDX and viton were dissolved in acetone which is a common solvent for RDX and viton, and then the acetone was extracted from the solution by distillation resulting in homogeneous RDX/viton composition. Infrared spectroscopy studies indicated presence of RDX and viton in the resulting compositions. Thermogravimetric and differential thermal analysis studies made on yielded compositions confirmed that RDX is present in the composition in desired content. The shift in exotherm of RDX/viton composition as compared to RDX showed that polymer-bonded RDX compositions are more stable. The impact sensitivity studies showed that sensitivity of RDX/viton composition decreased with increasing content of viton. The similar trend was observed for friction sensitivity. The co-precipitation method has been found to be advantages to obtain homogeneous composition of RDX and viton (with viton content up to 25 wt per cent) as revealed by linear trend in sensitivity data measurements. It has been demonstrated that the sensitivity of RDX can be tailored within a wide range using viton so as to suit in desired applications.

**Keywords:** RDX, Viton, coprecipitation, polymer-bonded explosives, impact sensitivity, friction sensitivity

### 1. INTRODUCTION

For the developments in explosive field, desensitisation of sensitive explosive materials is an important aspect for their utilisation. It enables safe handling of the explosive materials. The sensitive explosive materials can be desensitised using wax<sup>1</sup> due to which the incident energy from external mechanical impact may be absorbed and distributed more homogeneously, resulting in a reduced chance of initiation. However, wax has disadvantage of low thermal-stability. The thermally stable polymers like viton have emerged as good substitutes for wax<sup>2</sup>. The explosive materials phlegmatised with thermally-stable polymers have good mechanical resistance, good thermal stability and low sensitivity to impact. The polymer content can be varied so as to achieve desired sensitivity and even rheological properties suitable for cast compositions which are useful in various applications like low vulnerable high burning rate propellants.

Various compositions of desensitised explosives using polymers, commonly known as plastic-bonded explosives (PBX), are being formulated suitable in wide range of applications like boosters with low polymer content of about 5 weight per cent to high burning rate propellants containing about 25 weight per cent polymers<sup>3,4</sup>. The compatibility of polymer with explosive materials, miscibility of polymer in

solvent, homogeneous distribution of polymer in explosive formulation, and proper coating of explosive materials by polymers, are some of the critical issues involved in developing such polymer-bonded explosives. Therefore, this is a thrust area to develop formulations of explosives and polymers and study their properties, and many researchers involved in explosive development are working in this area. The explosive mixtures being studied have a large content of secondary explosives such as cyclotri-methylene-trinitramine (RDX), pentaerythritol-tetranitrate (PETN), cyclotetra-methylene-tetramine (HMX), etc. in a composition with a polymeric matrix such as polyester, polyurethane, nylon, polystyrene, some rubbers, nitrocellulose, and fluoropolymers<sup>5-7</sup>.

RDX is a preferred explosive in ammunition due to its balance of power and sensitivity. With suitably-tailored sensitivity property, it can be used in electrical bridge wire (EBW) detonators and boosters or secondary explosives. Various binders are being studied for desensitisation of RDX materials. Viton is one of the prominent binders being studied as it offers excellent toughness. The explosive materials are commonly phlegmatised using slurry method or water dispersion method. The slurry method is used to prepare cast compositions with high polymer content. In slurry method, the viscosity of polymer is reduced significantly by increasing

temperature, and then the explosive material is blended with polymer<sup>8</sup>. The water dispersion method is used to develop formulations with low polymer content. In water dispersion method, the polymer is dissolved in a suitable solvent and then this solution is added to water in which explosive material is already dispersed. Initially, the temperature of the mixture is raised above boiling point of solvent to remove the solvent which causes precipitation of polymer. The temperature of the mixture is then lowered. During precipitation, the polymer coats the suspended particles of explosive materials<sup>9</sup>.

In water dispersion method, there are issues of proper dispersion of polymer so as to have uniform coating. The separation of polymer-bonded explosives material is also an important aspect. Therefore, in the present work, authors have demonstrated the co-precipitation method to prepare RDX/viton compositions. This method is advantageous to overcome the limitations of water dispersion method like dispersion of polymer, and also useful to prepare compositions with large polymer content. In the present work, RDX/viton composition with varying content of viton over a comprehensive wide range from 5 wt per cent to 35 weight per cent has been studied. These compositions have been formed by co-precipitation method using acetone as common solvent. The resulting formulations have been characterised using Infrared spectroscopy, thermal analysis, and impact sensitivity measurements.

## 2. EXPERIMENTAL

RDX was received from High Energy Materials Research Laboratory, Pune, India. Analytical grade viton and acetone were obtained from Sigma-Aldrich. Co-precipitation method was used to prepare different RDX/viton mixtures by varying the viton content from 5 wt per cent to 35 wt per cent.

To prepare RDX/viton mixtures of various compositions, RDX and viton were separately dissolved in acetone as per desired weight content in the final mixture. The two solutions were then mixed and temperature of the resultant solution was raised to extract acetone from the solution. This resulted in RDX/viton mixtures which were dried at 70 °C in a vacuum oven at 1 torr vacuum for 8 h for complete drying and to remove occluded solvent from the mixture. The synthesised mixtures of RDX and viton have been designated as RDX/viton where the parenthesis denotes the weight content of RDX and viton, respectively in the mixture, like the mixture containing 95 per cent RDX and 5 per cent viton will be designated as RDX/viton (95/5).

Viton being commercially available in various grades, vacuum stability test was carried out to check the compatibility of viton used in the present work with RDX. The three samples, viz. RDX, viton, and mixture of RDX and viton in equal proportion were placed in test tubes which were evacuated and then heated at typical temperature of 120 °C. The test tubes containing samples were evacuated to vacuum of 0.2 kPa. On heating, the gases evolved from the test samples and raised the pressure in the test tubes which was measured by pressure transducers with a resolution of 2 Pa. The amount of gas evolved through decomposition of the test material during the test was measured. Simultaneous Thermo-gravimetric (TG) and differential thermal analysis (DTA) studies on RDX,

viton, and RDX/viton mixtures were carried out in an inert atmosphere in the temperature range 25 °C - 500 °C by heating the accurately weighed samples (2 mg - 5 mg) at the rate of 10 °C/min. using thermal analyser, Model No. STA 409 PC Luxx (Netzsch Gerätebau, Germany). In this work Pt vs. Pt-10 per cent Rh thermocouples were used as temperature and differential temperature sensors. Recrystallised alumina sample holders were used as sample and reference carriers. TG-DTA data analysis was done using Proteus software from Netzsch. Fourier Transform Infra Red (FTIR) spectra of pure RDX, viton, and RDX/viton mixtures were recorded at the wave numbers ranging from 500 cm<sup>-1</sup> to 4000 cm<sup>-1</sup> with ALPHA TFFIR spectrometer (Bruker, Germany) using attenuated total reflection (ATR) technique. Impact sensitivity studies were carried out using Fall Hammer Impact Test with 2 kg weight. For impact sensitivity test, powder sample of about 30 mg - 40 mg was placed on anvil and the height of impact (2 kg hammer) was varied to arrive at a height where 50 per cent probability of initiation was found using 'Bruceton up-down' method. Friction sensitivity was determined using BAM friction sensitivity test apparatus.

## 3. RESULTS AND DISCUSSION

The vacuum stability test was carried out to study the compatibility of RDX and viton and the amount of gas evolved through decomposition during test was measured. The results are expressed in normalised value of gas generated per gram of material to assess the stability of the test material and are shown in Table 1.

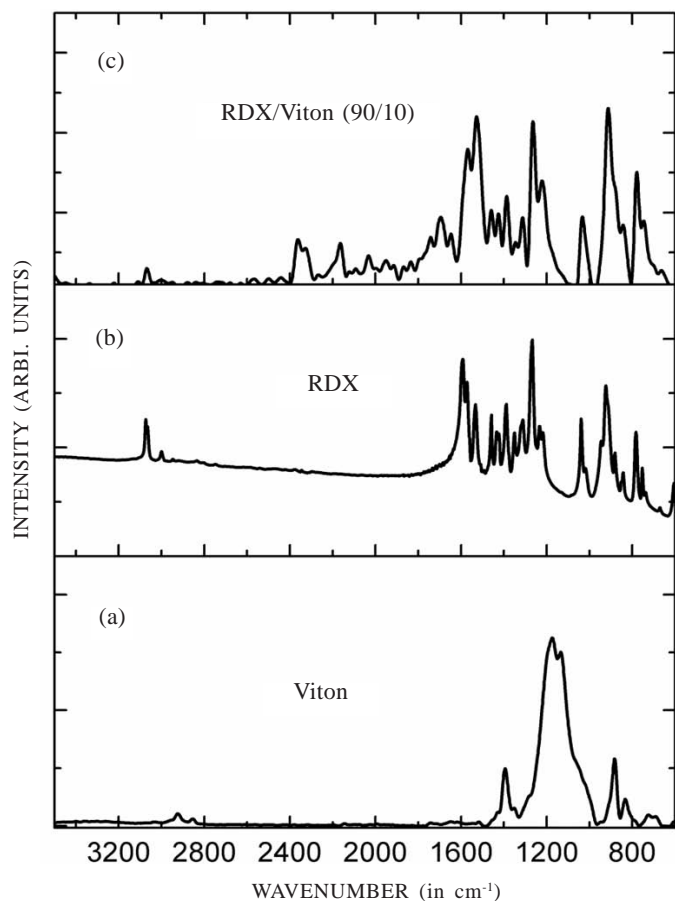
**Table 1. Vacuum stability test results for RDX, viton, and RDX/viton mixture**

| Material          | Gas released | Result |
|-------------------|--------------|--------|
| RDX               | 0.198 ml/g   | Pass   |
| Viton             | 0.269 ml/g   | Pass   |
| RDX/Viton (50/50) | 0.248 ml/g   | Pass   |

Passing criteria: gas release < 2 ml/g (STANAG 4556)

As per STANAG 4556, an advisory passing criterion of 2 ml of gas evolved per gram of explosive<sup>10</sup> is satisfied by RDX/viton mixture indicating that these materials are compatible with each other. Moreover, the gas released by RDX/viton mixture is comparable to the values of gas released by ingredient which confirms that there is no chemical reaction among the ingredients.

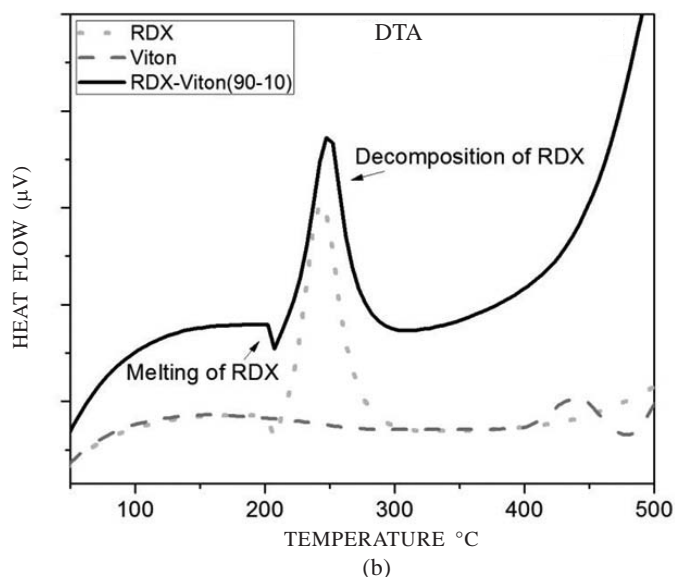
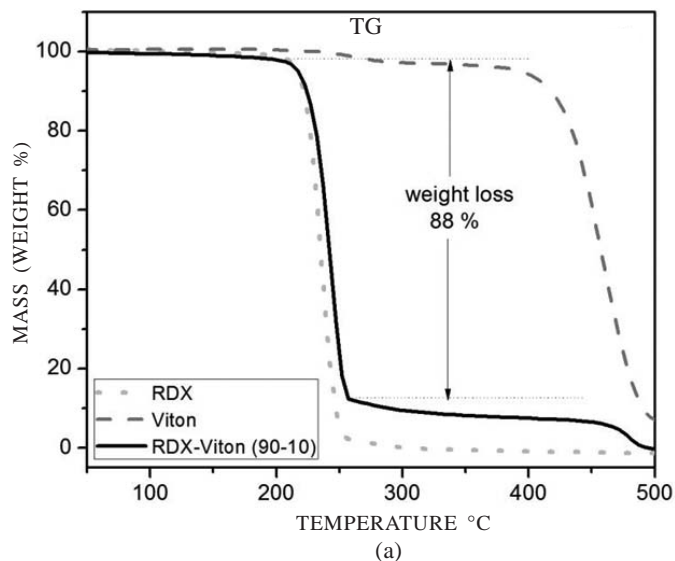
FTIR spectra of viton, RDX and RDX/viton (90/10) composition are shown in Figs. 1(a), 1(b) and 1(c), respectively. In Fig. 1 (a), the bands observed at about 890 cm<sup>-1</sup>, 1190 cm<sup>-1</sup> and 1400 cm<sup>-1</sup> are assigned to C-F linkage in viton<sup>11</sup>. Figure 1(b), shows IR spectrum of RDX in which the bands were observed at 1590 cm<sup>-1</sup>, 1570 cm<sup>-1</sup> and 1270 cm<sup>-1</sup> are assigned to stretching of NO<sub>2</sub>. The characteristic bands observed in RDX spectrum at about 1050 cm<sup>-1</sup>, 920 cm<sup>-1</sup> and 780 cm<sup>-1</sup> corresponds to ring stretching and non-planer stretching of N-NO<sub>2</sub> group in RDX<sup>12</sup>. The band observed at about 3100 cm<sup>-1</sup> is due to C-H bond vibrations. The spectrum 1 (c), confirms the presence of both RDX and viton in the RDX/viton (90/10) mixture.



**Figure 1.** FTIR spectra of: (a) Viton, (b) RDX, and (c) RDX/Viton (90/10) composition.

Figure 2 (a) represents typical TG curves for RDX, viton, and RDX/viton (90/10) mixture whereas Fig. 2 (b) represents DTA curves for the same materials. The comparison between the TG curves of RDX and RDX/viton (90/10) mixture [Fig. 2 (a)] shows prominent mass loss around 220 °C - 250 °C, associated with the decomposition of RDX. The observed mass loss is in consistency with the expected mass loss from the RDX content, present in the mixture. In TG curves, the weight loss in viton was found at temperature of about 450 °C. It reveals that viton has good thermal stability up to 450 °C. Qi-Long Yan and coworkers have reported the decomposition temperature for viton A as 462 °C<sup>13</sup>. DTA curves of RDX and RDX/viton mixture Fig. 2 (b) show endothermic peak at 205 °C attributed to melting of RDX succeeded by an exothermic peak associated with the decomposition of RDX. The reported melting temperature for RDX was 204 °C<sup>14</sup>. Comparison between DTA curves of RDX and RDX/viton mixture confirms the presence of RDX in RDX/viton mixture. The shift in the peak temperature of exothermic peak towards higher temperature in RDX/viton mixture as compared to that of RDX indicates the reduced sensitivity and higher stability of the mixture over RDX. The decomposition temperature of RDX and viton has been found to be consistent in all samples. It confirms phlegmatisation of RDX by viton.

Figure 3 represents the impact sensitivity data obtained by fall hammer impact test for RDX and RDX/viton mixture. With



**Figure 2.** (a) Thermogravimetric, and (b) Differential thermal analysis curves for RDX, viton, and RDX-Viton (90/10) composition.

increase in weight content of Viton in the RDX/viton mixture, the sensitivity to impact is found to be decrease. It confirms that RDX gets coated with viton and the desensitisation has been achieved successfully. The polymer viton serves as shock absorber and distributes the impact force minimizing the chances of initiation on impact. The sensitivity data is almost linear up to 20 wt per cent of viton in the mixtures and above 20 wt per cent viton content in the mixtures, the deviation from linearity towards reduced sensitivity can be seen from Fig. 3. The results showed that the sensitivity of RDX can be significantly lowered and can be tailored by varying the viton content in RDX/viton compositions, prepared by co-precipitation method. Friction sensitivity studies were also carried out on the RDX/viton compositions. The results are presented in Table 2.

The similar trend as of impact sensitivity has been observed for friction sensitivity of the test samples. The sensitivity of the RDX/viton compositions is found to decrease with increase in viton content in the mixture. The RDX/viton

Table 2. Friction sensitivity test results for RDX and RDX/viton mixtures (various composition)

| Sample           | RDX | RDX/viton (95/5) | RDX/viton (90/10) | RDX/viton (80/20) | RDX/viton (75/25) |
|------------------|-----|------------------|-------------------|-------------------|-------------------|
| BAM friction (N) | 112 | 128              | 168               | 216               | Not ignited       |

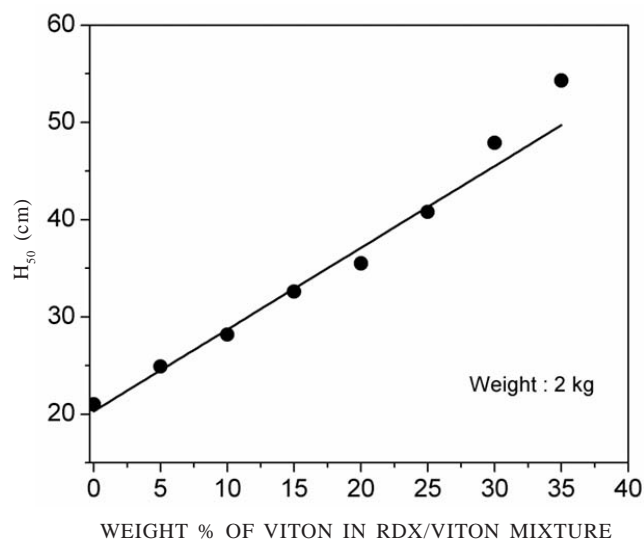


Figure 3. Impact sensitivity data RDX/Viton mixtures.

compositions with viton content 25 per cent and more failed to ignite within the limits of the apparatus used to measure the friction sensitivity.

#### 4. CONCLUSIONS

RDX-viton compositions have been prepared by co-precipitation method. The co-precipitation method prevents non-uniform dispersion of viton in water, as observed in water slurry method or non-uniform distribution of explosive content in polymer, as found in polymer slurry method to a great extent. The sensitivity studies suggested that the RDX/viton mixture is uniform over a wide range of viton content. FTIR studies confirm the presence of RDX whereas the TG-DTA reveals that the RDX is in desired proportion in RDX/viton mixture. It has been demonstrated that using polymer method, the sensitivity of RDX in RDX/viton mixtures can be significantly lowered and can also be tailored suitably as per intended applications like booster or cast compositions in rocket propellants.

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**Dr P.B. Wagh** has received his PhD (Physics) in 1999 from Shivaji University, Kolhapur. Presently he is working as Scientific Officer in Applied Physics Division, Bhabha Atomic Research Centre (BARC), Mumbai. He has to his credit about 45 research publications in cited international and national journals. Presently, he is involved with synthesis and characterization of nano-size explosive materials by sol-gel method. He is life member of High Energy Materials Society of India.

In the current study P.B. Wagh proposed idea of phlegmatisation of RDX using viton polymer by coprecipitation method. Conducted processing work of phlegmatisation and also participated in characterisation of yielded phlegmatised RDX materials.

**Mr S.V. Ingale** has obtained his MSc (Physics) from Shivaji University, Kolhapur. Presently he is working in the Applied Physics Division, BARC, Mumbai. He is involved in the development and processing of nano structured materials and energetic materials.

In the current study S.V. Ingale participated in characterisation of phlegmatised RDX materials by various techniques like FTIR, Vacuum stability and impact sensitivity.

**Mr Ratanesh Kumar** carried out processing work of phlegmatisation of RDX materials subject to dependant process parameters like solubility of precursor materials in solvent. Performed experimental work subject to filtration for removal of solvent after process and drying of yielded phlegmatised RDX in vacuum oven.

**Mr Naina R.H.** carried out thermogravimetric and differential thermal analysis of phlegmatised RDX materials.

**Dr T.C. Kaushik** has received his PhD from University of Bombay, Mumbai in 1995. Currently, he is the Head, High Energy Density Application Section, Applied Physics Division, BARC, Mumbai. He is recipient of DAE Special Contribution Award and has around 80 publications in journal, national and international conferences. Presently he is working on experiments and numerical simulation related to Megagauss magnetic fields, flux compression generators, opening switch, pinches and accelerators (electric gun/rail gun) using pulsed power sources.

In the current study T.C. Kaushik was instrumental in the process of experimental work and interpretation of obtained data in terms of results and discussions.

**Dr Satish C. Gupta** working in the Applied Physics Division, BARC, Mumbai. He has to his credit a large number of publications in internationally reputed journals. He is recipient of DAE Special Contribution Award. His research interests include: behavior of high energy density matter and response of material to dynamic compression at high strain rate using shock wave.

In the current study Satish C. Gupta as a team leader got availed the process facility and characterisation facilities like fall hammer test apparatus, friction sensitivity test apparatus and vacuum stability test apparatus. Guided and boosted to conduct the process work and characterisation work of yielded phlegmatised RDX materials.