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Research paper

Effect of the Molecular Structure and Molecular Weight of Poly(Vinylidene Fluoride-Chlorotrifluoroethylene) Copolymers on the Characteristic Properties of TATB-based Composites

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Abstract: 1,3,5-Triamino-2,4,6-trinitrobenzene (TATB) based composites with different molecular weights and molecular structures of poly(vinylidene fluoride-chlorotrifluoroethylene) (poly(VDF-CTFE)) binder were studied to investigate their effect on the physical, thermal, mechanical and explosive properties. The poly(VDF-CTFE) with three different kinds of molecular weights (FKM₁, FKM₂ and FKM₃ samples) and three different kinds of molar ratios of VDF and CTFE (FKM₄, FKM₅ and FKM₆) was chosen as the polymeric binder. The experimental results indicated that all of these kinds of TATB-based composites do not show any measurable changes in the particle density, detonation velocity and impact sensitivity. The thermal data revealed that weight loss occurs in two steps and, that the thermal stability decreases slightly with an increase in the molecular weight. On other hand, the weight loss occurred in a single step and the thermal stability increases slightly with an increase in the molar ratio of the CTFE to VDF monomer units. The adhesion properties between the two phases of TATB crystals and polymeric matrices rely on the properties of the interface, which is expressed in terms of the mechanical properties. The storage modulus decreases with increasing molecular weight. On other hand, an increase in the CTFE to VDF molar ratio in the poly(VDF-CTFE) binder remarkably improves the mechanical strength. FKM₅-9505 shows a significant reduction in creep deformation and dramatically increases the elongation failure, compared to those of the FKM₄-9505 sample. Finally, SEM observations clearly

suggested that the coating of the polymer matrix onto the surface of the TATB crystals is clearly demonstrated.

Keywords: poly(VDF-CTFE) copolymers, TATB, sensitivity, thermal properties, mechanical properties

Supporting Information (SI) is available at:
http://www.wydawnictwa.ipowaw.pl/cejem/Vol-17-Number3-2020/CEJEM_01101_SI.pdf

1 Introduction

1,3,5-Triamino-2,4,6-trinitrobenzene (TATB) is combined with polymeric matrices to form TATB-based composites, so-called polymer bonded explosives (PBXs) [1-6]. These formulations are prepared from a solution of the polymeric material which is precipitated onto the surface of TATB crystals by the water suspension method. The formulations are mainly comprised of 90-95 wt.% of energetic crystals bonded together with 5-10 wt.% of the polymeric matrix [7]. The coated crystals are then dried and compressed into a shape by using either an isostatic or a hydrostatic pressing operation. The pellets obtained after pressing are subsequently machined into a final shape, especially for military applications.

TATB is well known as an insensitive high explosive material, which satisfies safety requirements at high temperatures and is resistant to accidental initiation and explosion [8-11]. Therefore the choice of the polymeric binder with TATB can serve to provide structural and mechanical integrity. The family of fluoropolymers like Viton cannot be used as a binder with TATB because they cannot improve the mechanical properties of the TATB formulations due to their low modulus, although they are soluble in common solvents and have good energy-transfer characteristics. They have been extensively used with sensitive high explosives to reduce the threat of detonation [12-14].

In order to achieve the maximum performance in terms of energy, improved mechanical strength and ageing properties, these binders must have a high density and thermal expansion coefficient, high modulus, reasonable elongation to failure and good energy-transfer characteristics for insensitive highly energetic compounds. Some fluoropolymers, such as Kel-F 800, which exhibit a glass transition temperature at room temperature or above, are however somewhat brittle. This restriction allows their use with insensitive explosive particles like

TATB, where the brittleness does not negatively effect the safety parameters. Here, the role of the polymeric binder has been shifted from that of a desensitizing one to one that imparts structural integrity to the TATB based formulations.

In this context, a soft rubbery polymer has been replaced by the use of hard and high modulus polymers as binders. The Kel-F 800 based formulations PBX-9502 (95% TATB and 5% Kel-F 800), LX-17 (92.5% TATB and 7.5% Kel-F 800) and PBX-9503 (80% TATB, 15% HMX and 5% Kel-F 800) have been prepared for nuclear weapons, cruise missile warheads and space applications [15, 16]. Presently, FK 800, copolymer of VDF and CTFE, is used as a binder for TATB-based formulations for nuclear weapons, specifically Lawrence Livermore's LX-17 and Los Alamos's PBX 9502 [17, 18]. It has been established that the energetic material component and the proportion of the polymeric binder have a remarkable influence on the characteristics, especially thermal decomposition behaviours, ageing resistance, sensitivity and mechanical properties [19-25].

Recently, many research studies [26-29] have been carried out to investigate the effect of the molecular structure of the polymeric binder on the non-linear viscoelastic behaviours of TATB-based formulations. Lin *et al.* [30] have investigated the non-linear viscoelastic properties of TATB-based formulations modified by a natural polymeric bonding agent. Some studies [31-34] have reported the effect of the molecular weight of the polymeric binders on the mechanical and other properties of PBXs formulations.

In our previous work [35], we have reported on the variations of the physical, chemical, thermal and thermodynamic properties of a family of fluoropolymers consisting of VDF and CTFE monomer units. Different kinds of poly(VDF-CTFE) copolymers [36, 37] have been produced from VDF and CFTE by taking different molar ratios of the respective monomers, and tailored by varying the CTFE to VDF molar ratios for the specific interests of a polymeric binder. In addition, the thermal behaviour and kinetics are also important parameters for developing a good processing methodology for explosive formulations [38-41]. In order to clarify the effects of molecular weight and structure of the poly(VDF-CTFE) copolymer on the properties of TATB-based PBXs formulations, which, to the best of our knowledge, is little addressed in the open literature, the aim of the present work was to enhance current knowledge, and understanding, and to identify a suitable polymeric binder for TATB formulations.

This paper discusses the investigation of the physical, thermal, mechanical and explosive properties of TATB-based composites containing two sets of three kinds of poly(VDF-CTFE) matrices, containing different molecular weight and molar ratios. Moreover, the surface morphology was also studied by scanning electron microscopy.

2 Experimental and Methods

2.1 Materials

TATB used for the TATB-based composites was obtained in-house, and developed by a sister laboratory. Poly(VDF-CTFE) copolymers, which were prepared from VDF and CFTE units by suspension polymerization, were used as the polymeric matrices for coatings of TATB crystals. Three type of poly(VDF-CTFE) copolymers having CTFE:VDF molar ratio of 3:1, abbreviated as FKM₁, FKM₂ and FKM₃ with average molecular weights of 80000, 200000 and 600000 g/mol respectively were used. Similarly, FKM₄, FKM₅ and FKM₆ samples prepared with different molar ratios of the monomers VDF and CTFE, in ratios 1:2, 1:2.5 and 1:3, respectively, were also used as polymeric matrices for TATB-based composite.

2.2 Preparation of TATB-based composite

Three kinds of TATB-based composites containing FKM₁, FKM₂ and FKM₃ matrices were formulated by the water slurry coating method. In addition, three kinds of TATB-based composites containing FKM₄, FKM₅ and FKM₆ matrices were also formulated using the same experimental conditions. TATB crystals were placed in a round-bottomed reaction vessel fitted with a mechanical stirrer and a water condenser. In the first step, the TATB crystals were dispersed in distilled water with continuous stirring at 60 °C. During this stage, a lacquer of the abovementioned polymer solution was prepared by dissolution in methyl ethyl ketone, which was then added dropwise to the reaction vessel. The resulting mixture was subsequently heated to 80 °C with continuous stirring for 60 min in order to remove the organic solvent by distillation. The polymeric binder was thus precipitated onto the surface of the TATB crystals and agglomerated TATB particles were obtained. These particles, the so-called PBXs moulding powders were then filtered off and dried.

For the TATB-based composites, TATB and the copolymers of VDF and CTFE matrices were prepared in 95:5 weight percent for the each experiment, respectively. The formulations with FKM₁, FKM₂ and FKM₃ matrices were labeled as TFKM₁-9505, TFKM₂-9505 and TFKM₃-9505, respectively. Similarly, TATB-based composites containing FKM₄, FKM₅ and FKM₆ matrices were designated as TFKM₄-9505, TFKM₅-9505 and TFKM₆-9505, respectively. These formulations were transferred into a rubber bag and evacuated for compaction. Subsequently, it was compressed to obtain TATB pellets.

2.3 Characterization of the TATB-based composites

Particle density was determined by using an Ultra-pycnometer 1000 instrument (M/s Quantachrome, USA). The volume of the coated TATB particles was measured by gas pycnometry. The particle density was measured as mass per unit volume by weighing 25 g samples.

Weight loss measurements were carried out by using a Thermogravimetric Analyser (TGA)/Differential Scanning Calorimetry (DSC), model TGA/DSC 1 STAR[®] System as manufactured and supplied by Mettler Toledo, Switzerland. This instrument performed both TGA and DSC at the same time. The samples, weighing approximately 5.5 ± 1.0 mg, were placed in standard 70 μ L open alumina crucibles and subjected to heat from room temperature to 600 °C at a heating rate of 10 °C/min under a nitrogen atmosphere (flow rate 40 mL/min).

The detonation velocity was determined using a high speed streak photographic technique [42] based on an optical method. The pellets were prepared by pressing and machining processes, with dimensions of Φ 50×150 mm. These were used for the evaluation of both detonation velocity and pressure. The density of the pellets was also measured gravimetrically.

The detonation pressure was measured by high-speed photography of the detonation process in water detonations. The detonation pressure was estimated from the interaction of the detonation shock front with water.

A BAM Fall Hammer tester (OZM, Research) was used to determine the impact sensitivity. It was expressed in terms of the height from which a standard weight was dropped onto TATB-based particles, and 50% probability of explosion was observed by using the Bruceton staircase up-down method. The minimum height required for explosion was determined by repeated trials. The results are reported in terms of the drop height by conducting more than 25 trials at which 50% (H_{50}) initiation of the TATB-based formulations occurred.

A BAM friction apparatus (OZM, Research) was used to determine the friction sensitivity [43] of the TATB-based composites. The minimum weight (load) required to cause an explosion was determined by repeated trials. The 50% probability level of initiation was determined by the Bruceton up-down method by carrying out twenty-five samples measurements .

The mechanical properties were measured by employing a universal testing machine (UTM) having a capacity of 10 kN. Pellets with dimension Φ 20×30 mm, were used to measure the mechanical strength of the TATB-based composites. The pellets were compressed by a load cell at a speed of 10 mm/min until it reached its breaking point. The machine displayed the data in terms of stress against change in strain, from which the compressive strength was calculated.

3 Results and Discussion

3.1 Density

The particle densities of TFKM₁-9505, TFKM₂-9505, TFKM₃-9505, TFKM₄-9505, TFKM₅-9505 and TFKM₆-9505 were determined and found to be 1.95, 1.94, 1.95, 1.93, 1.94 and 1.94 g/cm³ (see SI, Table S1), respectively. It was observed from the results that the particle densities are very similar.

3.2 Sensitivity study

Sensitivity parameters related to the safety of explosive formulations during processing, handling, storage, transportation and use are essential for determining the possible applications. The results of impact and friction sensitivity tests were investigated and two set of results corresponding to changes in impact and friction sensitivity as a function of molecular weight and CTFE to VDF ratio in the poly(VDF-CTFE) copolymers are discussed. It was observed that the impact sensitivity of TFKM₁-9505, TFKM₂-9505 and TFKM₃-9505 samples slightly decreased with increasing molecular weight, while the impact sensitivity of TFKM₄-9505, TFKM₅-9505 and TFKM₆-9505 samples was found to be almost similar as 121 cm (see SI, Table S2). This trend indicates that TATB-based composites with low molecular weight poly(VDF-CTFE) are slightly sensitive towards an impact force, compared to the other composites.

The impact sensitivity of TFKM₄-9505, TFKM₅-9505 and TFKM₆-9505 samples was found to be almost similar. The results did not change on varying the CTFE to VDF monomer ratio in the poly(VDF-CTFE). As far as the friction sensitivity is concerned, no reactions were observed up to a 36 kg load for all types of TATB-based composites. This indicates that these samples were insensitive to friction up to a 36 kg load (see SI, Table S2). It was reported that TATB-based composites ranked as the most insensitive formulations in defence munitions devices. The sensitivity depends on the shape, size of crystal, surface morphology, defects, purity *etc.* [44-46]. Some recent new correlations [47-50] have been reported for the evaluation of the impact sensitivity of highly energetic materials.

3.3 Thermal study

A thermal study is also important to ensure the safety of personnel and materials during processing, handling, storage and transportation. Munitions that are generally used in military and space applications must qualify for their safety parameters and performance. One way to assess their sensitivity is to investigate the thermal decomposition behaviour of energetic composite materials,

because temperature is one of the main causes of initiation. Figure 1 shows the thermogravimetric (TG) and derivative thermogravimetric (DTG) curves of the TFKM₁-9505, TFKM₂-9505 and TFKM₃-9505 samples. These showed that the weight loss occurred in two steps; the weight loss in the first step is due to the thermal decomposition of TATB at 350 °C, whereas the weight loss in the second step is ascribed as being due to the thermal decomposition of the polymeric binder, followed by a linearly progressive decrease in weight loss at high temperature. The percentage of weight losses attributed to the two steps was nearly proportional to the initial weight of the ingredients *i.e.* TATB and poly(VDF-CTFE) matrix.

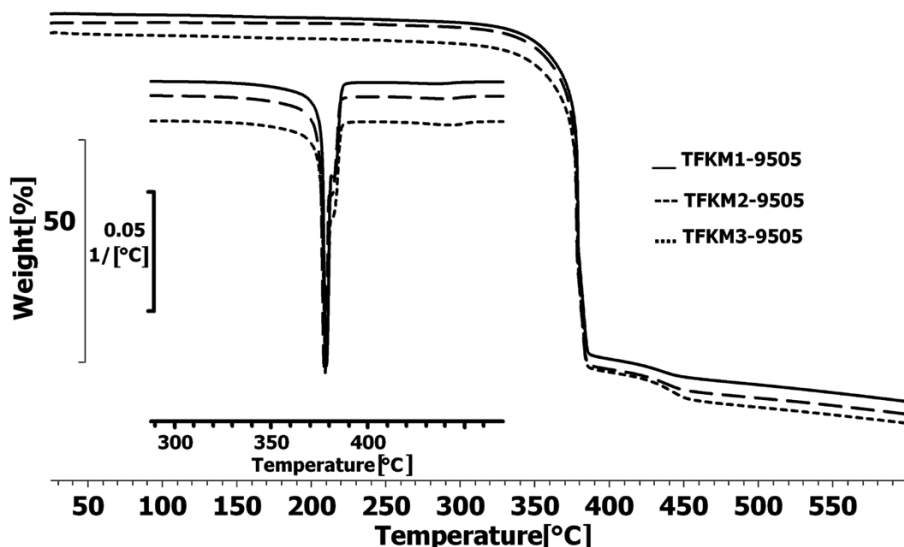


Figure 1. TG/DTG thermograms of TFKM₁-9505, TFKM₂-9505 and TFKM₃-9505 samples obtained at a heating rate of 10 °C/min using TGA under a nitrogen atmosphere

The DTG curves exhibited two thermal decomposition peaks; the first peak appeared to be the thermal decomposition of TATB, and, the second peak was attributed to the thermal decomposition of the polymer matrix. The interpolation data in terms of onset decomposition (T_{onset}), endset decomposition (T_{endset}), peak temperature for maximum mass loss (T_{max}) along with % decomposition obtained from the TG/DTG curves are summarized in Table 1.

Table 1. Thermal data of T_{onset} , T_{endset} , T_{max} and % decomposition of TATB and TATB-based composites obtained from their TG/DTG curves

Sample	Thermal data (1 st step) [°C]			Decomposition [%]	Thermal data (2 nd step) [°C]		Decomposition [%]
	T_{onset}	T_{endset}	T_{max}		T_{onset}	T_{max}	
TATB	367.8	380.3	377.6	90.2	–	–	–
TFKM ₁ -9505	375.8	381.4	379.7	76.6	432.5	433.9	9.9
TFKM ₂ -9505	375.2	381.1	379.3	77.7	434.2	438.2	10.4
TFKM ₃ -9505	374.7	381.0	378.8	74.9	433.6	441.2	12.6
TFKM ₄ -9505	371.0	376.8	374.7	77.5	–	–	7.9
TFKM ₅ -9505	373.5	378.7	376.6	77.2	–	–	9.3
TFKM ₆ -9505	374.8	380.1	378.5	78.1	–	–	8.5

The T_{onset} values of the TFKM₁-9505, TFKM₂-9505 and TFKM₃-9505 samples were found to be 375.8, 375.2 and 374.7 °C, respectively. These values gradually decreased with increasing molecular weight of the poly(VDF-CTFE) copolymer. The T_{max} values of the TFKM₁-9505, TFKM₂-9505 and TFKM₃-9505 samples were found to be 379.7, 379.3 and 378.8 °C, respectively which are almost same. These results suggest that the thermal stability is slightly reduced in the following order:



with increasing molecular weight of the poly(VDF-CTFE) copolymer.

Figure 2 shows the TG/DTG curves of the TFKM₄-9505, TFKM₅-9505 and TFKM₆-9505 samples. The TG curves exhibited weight loss that occurred in a single step, followed by a linearly progressive decrease in weight loss over a wide range of the temperatures. This weight loss was found to exhibit a slightly different trend as compared to the TATB-based composites prepared with different molecular weights. The DTG curves showed a single peak for the thermal decomposition with a shoulder peak. This shoulder peak appeared to be due to the thermal decomposition of the polymeric matrix. For comparison, thermal analysis of pure TATB was also carried out under the same experimental conditions and these TG/DTG curves are shown in Figure 3. They showed that the weight loss that occurred in the first step is due to the thermal decomposition of TATB. The interpolation thermal data derived from the TG/DTG curves are also summarized in Table 1.

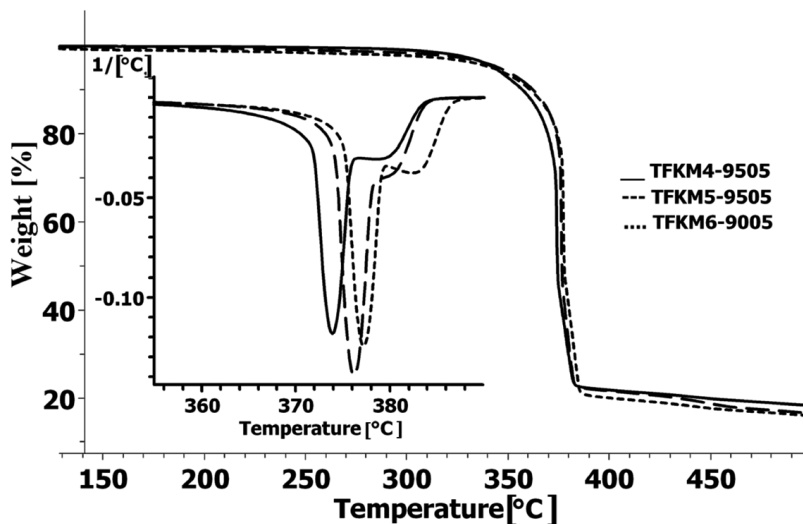


Figure 2. TG/DTG thermograms of TFKM₄-9505, TFKM₅-9505 and TFKM₆-9505 samples obtained at a heating rate of 10 °C/min using TGA under a nitrogen atmosphere

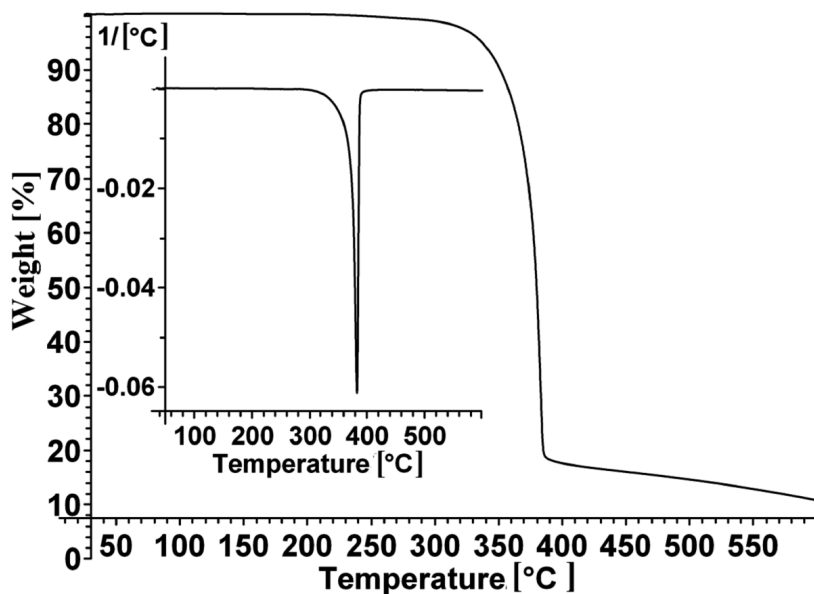


Figure 3. TG/DTG thermogram of pure TATB obtained at a heating rate of 10 °C/min using TGA under a nitrogen atmosphere

The T_{onset} values of the TFKM₄-9505, TFKM₅-9505 and TFKM₆-9505 samples were found to be 371.0, 373.5 and 374.8 °C, respectively, while the T_{max} values of TFKM₄-9505, TFKM₅-9505 and TFKM₆-9505 were found to be 374.7, 376.6 and 378.5 °C, respectively. The T_{onset} and T_{max} values of pure TATB were found to be 367.8 and 377.6 °C, respectively. It was observed that the T_{onset} and T_{max} values of the TATB-based composites increased progressively on increasing the molar ratio of CTFE to VDF in the poly(VDF-CTFE) copolymer. It is evident that the use of different molecular weights and CTFE to VDF ratios in the poly(VDF-CTFE) copolymer does not change the thermal stability of TATB based composites, but they may change the thermal decomposition mechanisms.

3.4 Thermal study by DSC

The DSC curves of the three samples TFKM₁-9505, TFKM₂-9505 and TFKM₃-9505 showed a single exothermic peak (see SI, Figure S1). This exothermic peak appeared to be due to the thermal decomposition of TATB. The interpolation thermal data derived from the DSC curves are summarized in Table 2. The T_{onset} values of TFKM₁-9505, TFKM₂-9505 and TFKM₃-9505 were 376.3, 375.9 and 375.7 °C, respectively, while the T_{max} values of TFKM₁-9505, TFKM₂-9505 and TFKM₃-9505 were 380.1, 379.6 and 378.8 °C, respectively. We concluded that the effect of molecular weight changes on the thermal stability was not significant because of the small differences in the T_{onset} and T_{max} values.

The DSC curves of the three TFKM₄-9505, TFKM₅-9505 and TFKM₆-9505 samples also showed a single exothermic peak (see SI, Figure S2). For comparison, the thermal analysis of pure TATB was carried out under the same experimental conditions. The DSC curve of pure TATB showed a single exothermic peak (see SI, Figure S3). The T_{onset} and T_{max} values of pure TATB were found to be 369.7 and 379.8 °C, respectively. The T_{onset} values of TFKM₄-9505, TFKM₅-9505 and TFKM₆-9505 were 372.0, 373.9 and 375.3 °C, respectively, whereas T_{max} values of TFKM₄-9505, TFKM₅-9505 and TFKM₆-9505 were 375.9, 378.2 and 378.8 °C, respectively. The T_{onset} and T_{max} values were considerably increased with an increase in the CTFE to VDF molar ratio, implying that a TATB-based composite obtained from a high molar ratio of CTFE to VDF has a slightly superior thermal stability than the others. These results also suggested that the nature of the energetic material and its subsequent interaction with polymeric matrices does not significantly change the overall thermal decomposition behaviour of TATB based composites, therefore they are compatible with each other.

Table 2. Thermal data of T_{onset} , T_{endset} , and T_{max} and ΔH of TATB and TATB-based composites obtained from their DSC curves

Sample	Thermal decomposition temperature [°C]			ΔH [J/g]
	T_{onset}	T_{endset}	T_{max}	
TATB	369.7	385.3	379.8	478.6
TFKM ₁ -9505	376.3	385.6	380.1	553.5
TFKM ₂ -9505	375.9	385.9	379.6	581.1
TFKM ₃ -9505	375.7	385.7	378.8	548.0
TFKM ₄ -9505	372.0	582.3	375.9	496.5
TFKM ₅ -9505	373.9	386.9	378.2	481.1
TFKM ₆ -9505	375.3	384.0	378.8	496.5

3.5 Detonation parameters

The detonation velocity and detonation pressure were determined using high speed streak photography and aquarium techniques. The charge (loading) density of the pellets (see SI, Figure S4) was measured gravimetrically after machining. The density of all of the TATB-based composites was around 1.83-1.84 g/cm³. An average density of the loaded charges was within 95-97% of the theoretical maximum density.

The results of the detonation velocity and detonation pressure values for all of the TATB-based composites are listed in Table 3, and were based on three measurements. The uncertainty on the results was found to be within 5-8% of reported values. The detonation velocity of TFKM₁-9505, TFKM₂-9505 and TFKM₃-9505 was 7.47, 7.45 and 7.47 km/s, respectively, while the detonation pressure of TFKM₁-9505, TFKM₂-9505 and TFKM₃-9505 was 24.8, 23.6 and 24.8 GPa, respectively. The detonation velocity and detonation pressure values did not change significantly on changing the molecular weight of the polymeric matrices. However, when varying the CTFE to VDF molar ratio in the poly(VDF-CTFE) copolymer, the detonation velocity and detonation pressure values of TFKM₄-9505 were slightly higher than those of TFKM₅-9505 and TFKM₆-9505. These results imply that the use of different molecular weights of the poly(VDF-CTFE) copolymer does not significantly change the detonation parameters.

Table 3. Performance parameters in terms of detonation velocity and detonation pressure of TATB-based composites containing different poly(VDF-CTFE) matrices

Samples	Charge density [g/cm ³]	Detonation velocity [km/s]	Detonation pressure [GPa]
TFKM ₁ -9505	1.84	7.47	24.8
TFKM ₂ -9505	1.83	7.45	23.6
TFKM ₃ -9505	1.83	7.47	24.8
TFKM ₄ -9505	1.85	7.42	24.5
TFKM ₅ -9505	1.85	7.31	23.9
TFKM ₆ -9505	1.84	7.37	24.3

3.6 Mechanical strength

When composite materials are exposed to external mechanical forces, they may cause loss of structural integrity. Therefore, it is important to study the mechanical properties of energetic composite. The stress versus strain profiles in uni-axial compression recorded for TATB-based composites are shown in Figure 4. It may be seen that the stress increased linearly with increasing strain from zero, and after a certain values, it increased dramatically with further increase in strain. It passed through a maximum which corresponds to the sample's compressive strength. The point at the maximum value is related to the failure strain. It was observed that stress-strain profiles for TFKM₁-9505, TFKM₂-9505 and TFKM₃-9505 samples were not identical. In some of the stress-strain curves, the stress either decreased continuously for a longer period or decreased sharply with increase in the strain. In a few cases the stress decreased gradually in this region of the stress-strain curves because of a softening nature of the composite.

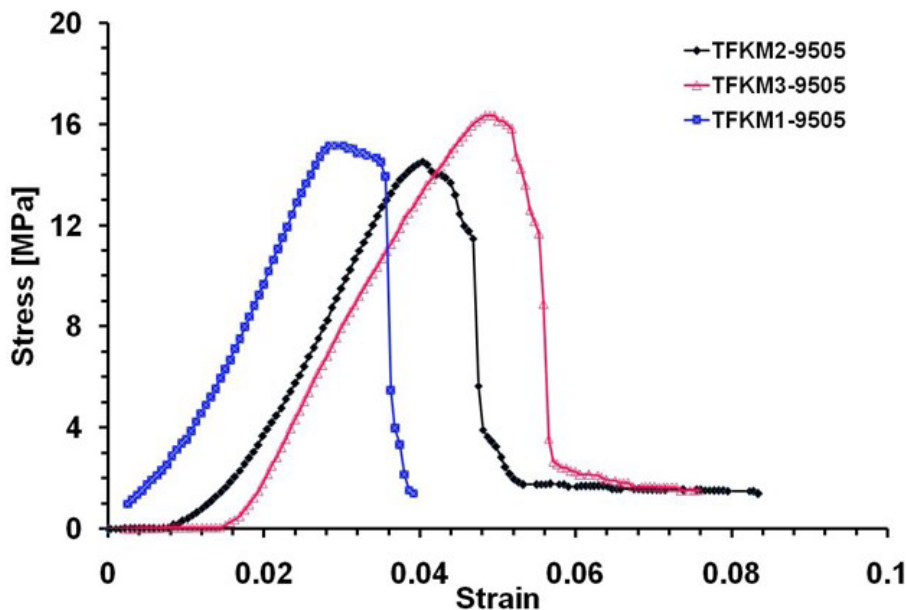


Figure 4. Stress versus strain graphs of TFKM₁-9505, TFKM₂-9505 and TFKM₃-9505 samples measured using a UTM instrument

The data for compressive strength are listed in Table 4. It was observed that the compressive strength of TFKM₁-9505, TFKM₂-9505 and TFKM₃-9505 was 15.6, 14.5 and 17.3 MPa, respectively, whereas the compressive strength of TKM₄-9505, TFKM₅-9505 and TFKM₆-9505 was 20.8, 24.1 and 19.7 MPa. The TFKM₅-9505 sample exhibited a higher compressive strength than that of the TFKM₄-9505 and TFKM₆-9505 samples. The mechanical strength of explosive formulations depends on many variables, such as particle size and its distribution, compaction density, relative humidity of the storage environment, processing method, deformation strain rate, thermal history, polymer characteristics, pressing conditions, storage and test temperature *etc.* [51-53]. The interfacial binding forces between the polymer matrix and the energetic crystals plays an important role in obtaining the desired mechanical properties.

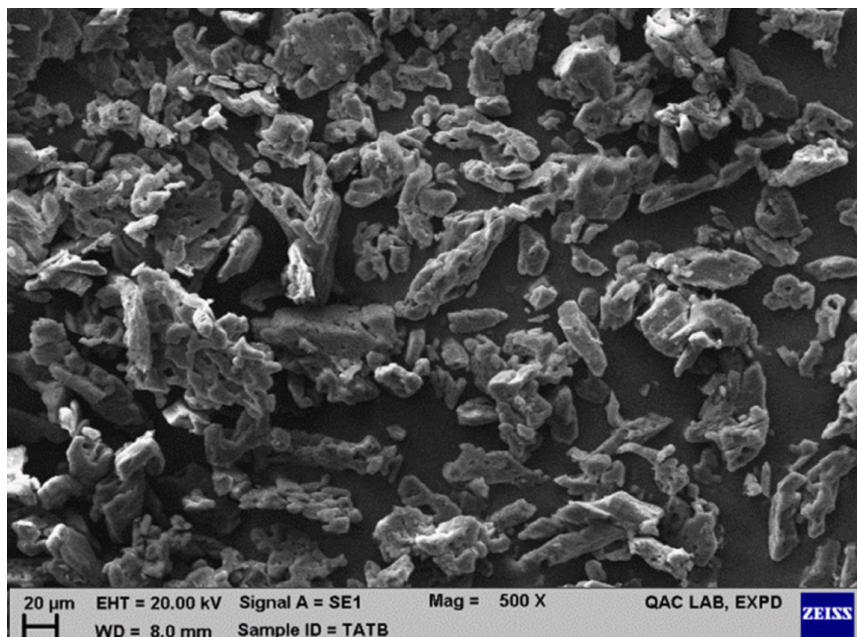
Table 4. Mechanical properties of TATB-based composites obtained by the UTM method

Samples	Compressive strength [MPa]	Young's Modulus [MPa]	Strain
TFKM ₁ -9505	15.6	675.0	2.4
TFKM ₂ -9505	14.5	604.1	7.2
TFKM ₃ -9505	17.3	533.2	8.4
TFKM ₄ -9505	20.8	1250.3	15.2
TFKM ₅ -9505	24.1	1339.0	21.2
TFKM ₆ -9505	19.7	997.5	23.3

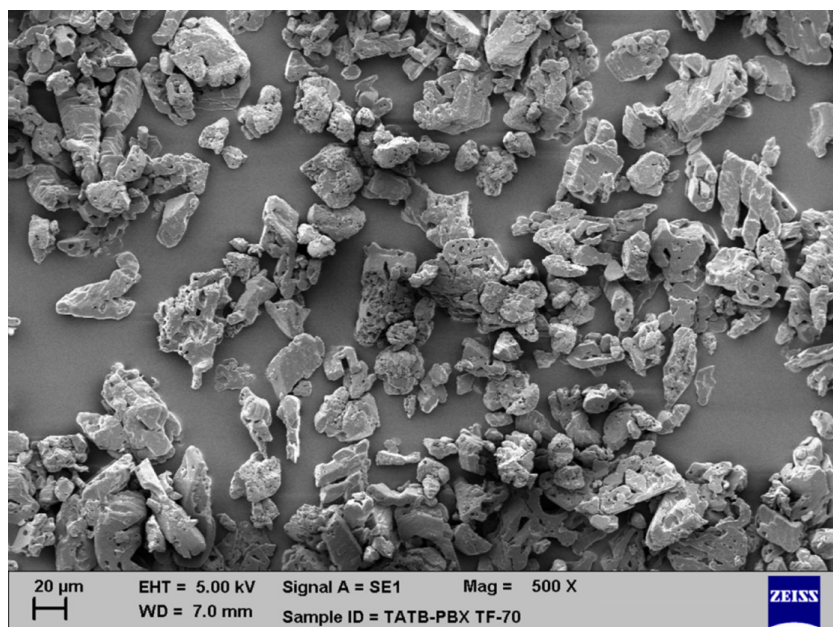
In the literature, the mechanical properties have been investigated by many researchers under various experimental conditions [54-57]. Moreover, TATB is a more insensitive energetic filler, therefore the role of a polymeric matrix is shifted from that of a desensitizing one to one that imparts structural integrity. In this perspective, a soft rubbery polymer matrix is replaced by the use of hard and high modulus polymers as binders. It was reported [10, 17] that a TATB-based composite containing KeL-F 800 matrix exhibited better binding strength.

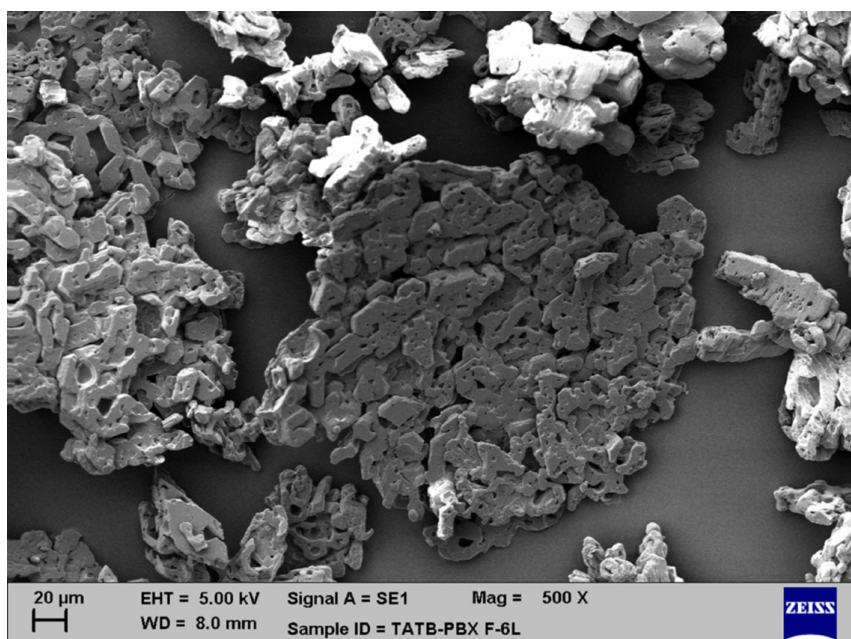
3.7 Scanning electron microscopic (SEM) study

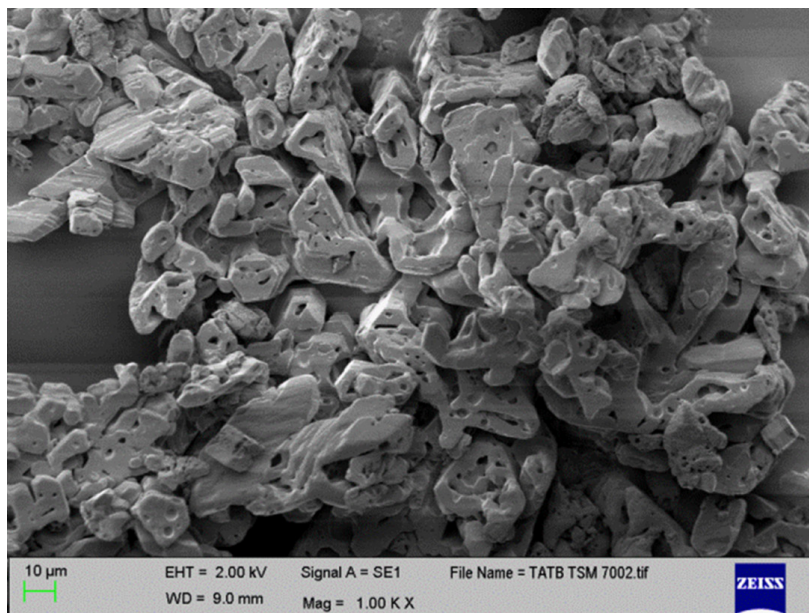
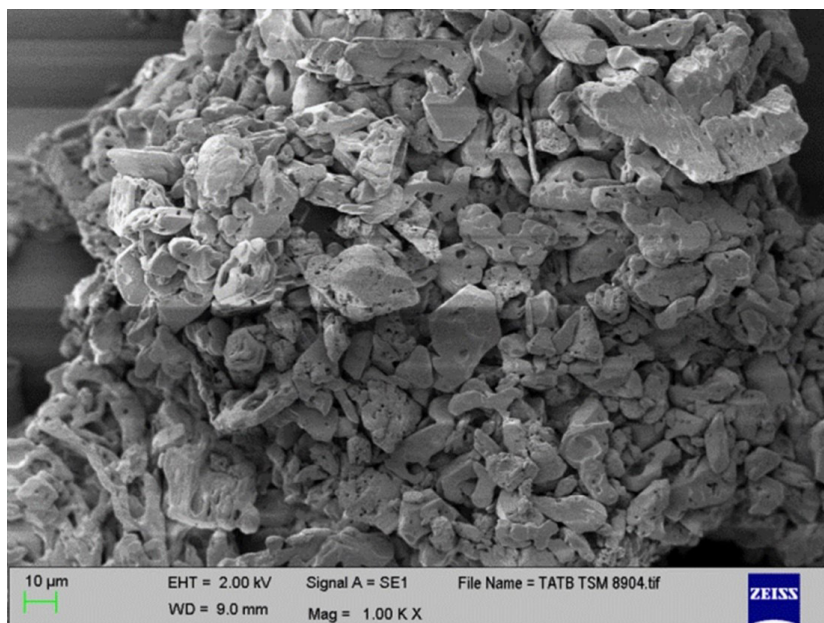
Figure 5 shows SEM micrographs of pure TATB, and TFKM₁-9505, TFKM₂-9505, TFKM₃-9505, TFKM₄-9505, TFKM₅-9505 and TFKM₆-9505 samples. The SEM micrograph of pure TATB showed that the particles were irregular in shape and distinctly separated from each other. In the cases of the TAT-based composites, the TATB crystals were well-embedded in the polymer matrices. They indicated further that the particles were agglomerated with each other. The mechanism of agglomeration in moulding powders has been studied by many researchers [58, 59]. Capes and Sutherland [60] reported the growth of agglomerates. They described that agglomeration took place due to preferential wetting of the crystals by lacquer droplets.

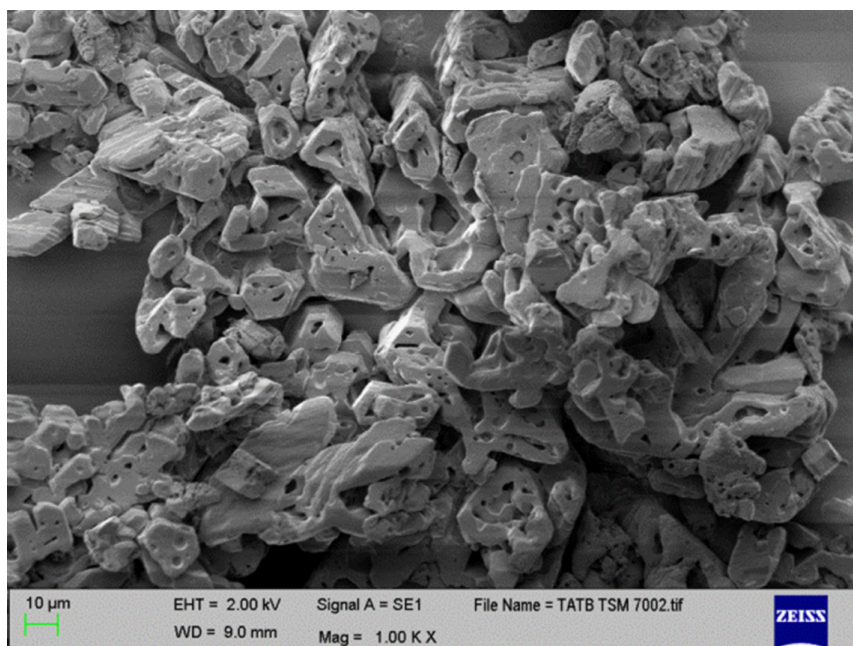


TATB

TFKM₁-9505

TFKM₂-9505TFKM₃-9505

TFKM₄-9505TFKM₅-9505



TFKM₆-9505

Figure 5. SEM micrographs of TATB, and TFKM₁-9505, TFKM₂-9505, TFKM₃-9505, TFKM₄-9505, TFKM₅-9505 and TFKM₆-9505 samples

4 Conclusions

To investigate the effects of molecular weight and CTFE to VDF molar ratio of the poly(VDF-CTFE) matrices in TATB-based composites, different kinds of TATB-based composites were formulated and characterized for their physical, surface morphology, thermal, mechanical and explosive properties. The impact and friction sensitivity were not changed significantly with changing molecular weight and molecular structure. The results of our tests indicated that thermal stability was affected only slightly by molecular weight, but was found to decrease with an increase in the CTFE to VDF ratio in the poly(VDF-CTFE) copolymer. SEM studies revealed that the TATB crystals were well coated within the poly(VDF-CTFE) matrices and agglomerated in form. The detonation velocity and detonation pressure were not changed significantly on changing the molecular weight or the CTFE to VDF molar ratio. The compressive

strength of TFKM₁-9505, TFKM₂-9505 and TFKM₃-9505 was 15.6, 14.5 and 17.3 MPa, respectively, while the compressive strength of TFKM₄-9505, TFKM₅-9505 and TFKM₆-9505 was 20.8, 24.1 and 19.7 MPa, respectively. These results indicated that TATB-based composites obtained from the different CTFE to VDF molar ratios exhibited higher compressive strength and modulus than those derived from different molecular weights. The storage modulus of TATB-based composites was reduced with increasing molecular weight. These findings indicate that molecular structure and molecular weight play an important role on the final characteristic properties of TATB-based composites.

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