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# Effect of microwave irradiation on TATB explosive (II): Temperature response and other risk

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ABSTRACT

TATB (1,3,5-triamino-2,4,6-trinitrobenzene) explosives were safely irradiated with microwave and showed no visible change according to XPS and XRD spectra. Temperature of TATB sample increased quickly at the beginning and gently during sequent continuous irradiation with temperature less than 140 °C after 60 min, 480 W irradiation, and increased more quickly in 300 g at 480 W than in 150 g at 480 W, both implied that heat dissipation was in the majority of microwave energy. Two major risk factors in microwave irradiation were concerned including overheating which should be avoidable with temperature monitor and microwave discharge which should be controllable experimentally though dielectric breakdown mechanism was not elucidated theoretically yet.

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## 1. Introduction

Primary and secondary explosives were experimented not to burn, deflagrate, or detonate under low and high power microwave irradiation [1,2] and some of them were melted and recovered safely from inside obsolete huge bombs with microwave heating method [3]. However susceptible compounds of impurities and functional components would form overheating spot and make explosives mixture more hazardous under microwave irradiation [4–6].

TATB (1,3,5-triamino-2,4,6-trinitrobenzene), an extremely insensitive high explosives (IHEs) [7], was reviewed in our lab and its irradiating safety has experimented feasible for drying method [8,9]. Here was our attempt to measure real time temperature response and others for risk investigation.

## 2. Experimental

### 2.1. Reagents and instrument

Reagent: finished TATB, finished product, made from wet-amination method [10] in our laboratory.

Instrument: microwave oven (tailor-made, 2.45 GHz, 0–600 W controllable, 0–300 °C measurable, remote control); X-ray photoelectron spectroscopy (Thermoelectric VG250); XRD (Bruker D8 Advance).

### 2.2. Experiments

Microwave irradiation programmable and interruptable in case of emergency was processed inside explosion-proof chamber with remote control to avoid damage from security issues. Inside oven center was put weighed finished TATB and thermocouple shielded to avoid electromagnetic disturbance. The experiment parameters were real time indicated including irradiation period, input voltage, input current, temperature, etc.

## 3. Results and discussion

### 3.1. Temperature response

TATB sample was heated up safely by microwave irradiation expectantly and temperature response was monitored online.

TATB 300 g within 500 mL beaker increased its temperature quickly at the beginning and gently during sequent continuous irradiation as given in Fig. 1. Temperatures moved up more quickly under irradiation power of 480 W than 360 W expectantly though they were far less than between 375 and 400 °C—decomposition peak of TATB.

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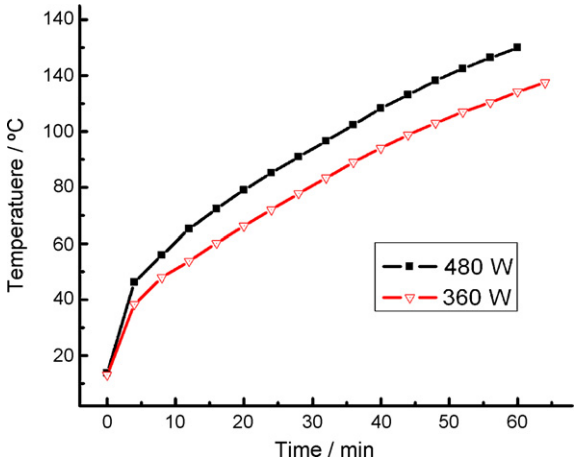


**Fig. 1.** Temperature vs. time curves of 300 g TATB in different power.

TATB increased its temperature more quickly inside 300 g sample than 150 g as given in Fig. 2, which was different from intuition that same energy could heat up smaller quantity to higher temperature. Besides, sample temperature should have exceeded decomposition peak temperature and explode in several minutes due to its specific heat between 1.0 and 2.0 kJ/kg K [10] supposing that irradiation be absorbed adiabatically.

Irradiation absorption and heat dissipation counted here. Entirely symmetrical TATB molecules practically absorbed microwave very weakly and quantity of irradiation heated other substances up to 50–100 °C including oven wall, beaker wall, atmosphere, etc. Heat dissipation decreased sample temperature seriously so that smaller pile held lower temperature at its center though both were less than 140 °C. Heat dissipation seemed determinative here.

Glass beaker and polytetrafluoroethene (PTFE) beaker with same shape were compared and sample in glass beaker showed lower temperature during the first 20 min and a little higher temperature after 20 min than sample in PTFE beaker as in Fig. 3 though their difference looked ignorable in contextual risk analysis.

It was related that thermocouple should be shielded here to avoid electromagnetic disturbance and temperature display should have some delay due to limited touch between sensor and sample powders.

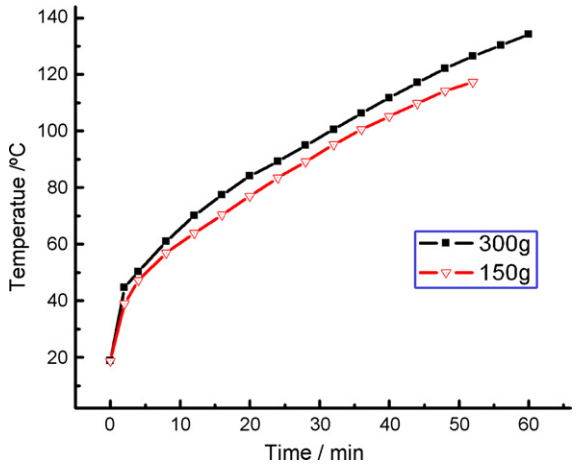


**Fig. 2.** Temperature vs. irradiation time curves of TATB in different quantity at 480 W.

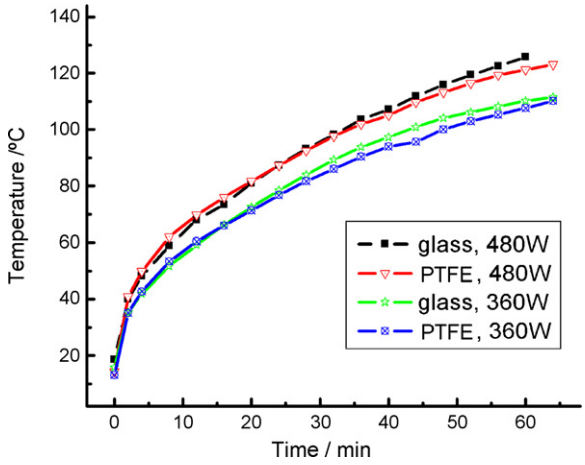


**Fig. 3.** Temperature vs. time curves of 150 g TATB in glass and plastic beakers.

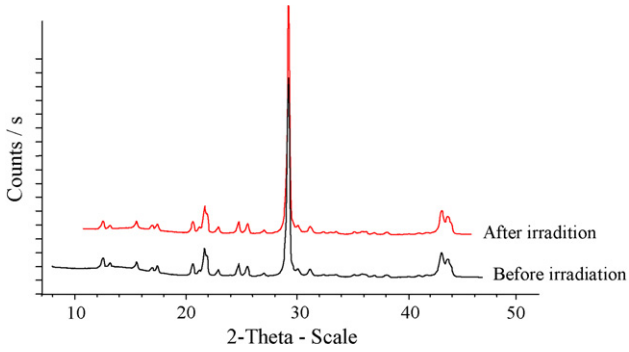


**Fig. 4.** XRD spectra of TATB origin and irradiated sample.

### 3.2. Irradiated TATB analysis

TATB samples before and after 360 W irradiation were compared to show no visible difference according to peak situation and peak intensity of X-ray diffraction chart as given in Fig. 4, which meant that sample kept its crystal lattice unchanged during irradiation.

With X-ray photoelectron spectroscopy, samples of origin, 360 W irradiation, and 450 W irradiation were measured to contain same elements including carbon, nitrogen, and oxygen as given in Fig. 5. Detailed spectra of every peak were analyzed to show no remarkable change of binding energy shift and area, which meant

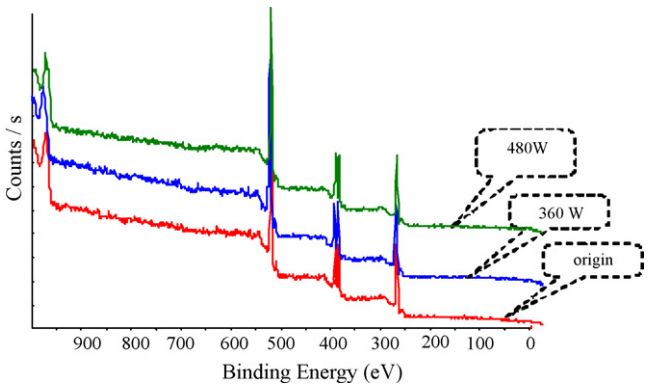


**Fig. 5.** XPS spectra of TATB origin and irradiated samples.

that chemical state and contents of three elements remained during irradiation. XPS results were different from literature which reported surface modification of TATB with microwave irradiation [11]. We suggested that microwave irradiation should not etch surface solely but accelerate surface etching of TATB in weakly acidic suspension.

### 3.3. Other risks

The risk factors including overheating and microwave discharge were reviewed for feasibility of microwave heating process.

#### 3.3.1. Overheating

Temperature of TATB was measured safe at oven center where irradiation shall be designed intense, which meant that TATB shall not be overheated during experiments. Temperature response as described in Figs. 1–3 should be enough to forejudge heating velocity and overheating risk.

Some TNT-based melt cast mixture had been reported to melt under irradiation without other physical and chemical change [12] and microwave irradiation should be suitable for meltout and removal of TNT, Compn. B, H-6, Amatol, Cyclotol, Octol, Tetrytol, Minol II, ammonium nitrate, and tritonal [13]. Furthermore, susceptible ingredients in mixture such as carbon nanotubes could readily absorb microwave and even 1% (m/m) could induce overheating and ignition of explosives mixture instantly [14] so that explosives mixtures in use were not always safe during microwave irradiation. Violent reaction of moulding powders recently in our laboratory also agreed with that susceptible graphite additives absorbed irradiation much more readily than explosives and induced thermolysis of neighboring ingredients subsequently. It was necessary to show a home truth that some substances like graphite might own microwave susceptibility though they were employed in explosives formulation as desensitizer to decrease sensitivity of formulation to unexpected stimulus so that we could found experimentally that initiating explosives synthesis could employ microwave safely [15] while high explosives mixture with graphite could be ignited. Likewise various sensitive explosive mixtures could be safely meltouted and removed under microwave heating [13,16,17] only because they did not contain susceptible additive which shall form overheating spot and trigger surrounding explosives ingredients.

#### 3.3.2. Microwave discharge

Microwave irradiation is believed capable of initiating explosives through dielectric breakdown phenomenon such as microwave discharge (surface flashover, grain to grain arcing), or resistance heating [1]. Microwave discharge was capable of exploding secondary explosives such as PETN, RDX, HMX, and Tetryl [14].

Microwave discharge might be isolated from explosive samples in our experiments with three approaches. Firstly, microwave generator shall be isolated from explosive samples which should be restricted inside vacuum flask and escaping powders should be absorbed only by water—medium of vacuum pump. Secondary, metal scraps mixed into explosives accidentally should have been cleared out with magnet to avoid grain to grain arcing and thermocouple should have been shielded specially to avoid induced current and discharge risk. Thirdly, vacuum should be suggested at 80–95 kPa with common pump to avoid flashover possible under higher vacuum circumstance.

### 3.4. Discussions

Microwave absorption by explosives was experimented very difficultly and microwave quantum energy itself was not reported to initiate explosives according to irradiation experiments and irradiated samples analysis in the context.

TATB showed no visible change according to XPS and XRD analysis which supported conclusions in literature [9] that TATB explosives showed no remarkable change after microwave irradiation according to HPLC, particles size analysis, and differential thermal analysis.

The real risk would result from overheating and discharge. Overheating should be avoidable with temperature monitor for heating velocity of TATB could be predicted previously. Discharge would be controllable experimentally though discharge mechanism and preventive steps might be researched further theoretically.

## 4. Conclusions

TATB explosive should be safe experimentally during microwave irradiation and showed no visible change according to XPS and XRD spectra, which supported conclusions in published literature.

Temperature of TATB sample increased quickly at the beginning and gently during sequent continuous irradiation while it should be less than 140 °C during 60 min and 480 W irradiation, meanwhile temperature increased more quick in 300 g at 480 W than in 150 g at 480 W, both implied that heat dissipation was in the majority of microwave energy.

Other risks of microwave irradiation were described including overheating which was deemed avoidable with temperature monitor except inducement of susceptible ingredients and microwave discharge which could be isolated from explosive sample due to three experimental approaches while dielectric breakdown mechanism was not elucidated theoretically yet.

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