

COATING OF EXPLOSIVES*

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Summary

The coating of high explosives is a very important technique for lowering the sensitivity of explosives. Different methods for coating explosives with waxes and polymers are discussed. The adhesion between the binder and the explosive crystals is dependent upon the wax type or the specific polymer used. Examples of good and poor adhesion are demonstrated.

Introduction

The coating of explosives is a process used to obtain a phlegmatizing effect on the explosive. It is about 100 years since the expression phlegmatization was used by Alfred Nobel and his coworkers for the first time. By phlegmatizing high explosives he succeeded in transforming very sensitive explosives into considerably safer forms and thus the first explosives used for civil and military purposes were prepared on a large scale.

Considering the length of time that this topic has been studied, about 100 years, one would expect that most of the problems in this area should have been solved by now. Unfortunately this is not the case, more problems seem to arise as the knowledge deepens. In addition, for modern explosives (Fig. 1), the phlegmatization processes must be used not only to guarantee the highest possible safety during handling, but also to impart other valuable properties to the product such as good pressability, high mechanical strength of the charges, etc.

Looking at Table 1, it is only TNT and possibly TNB which can be melted without risk of detonation. Since both TNT and TNB are quite insensitive explosives, this means that they can be used as phlegmatizers for the other more sensitive explosives, which may not be safely melted. The more sensitive explosive crystals then lie in a matrix of solidified TNT. A recent development will make it possible in the future to incorporate explosives

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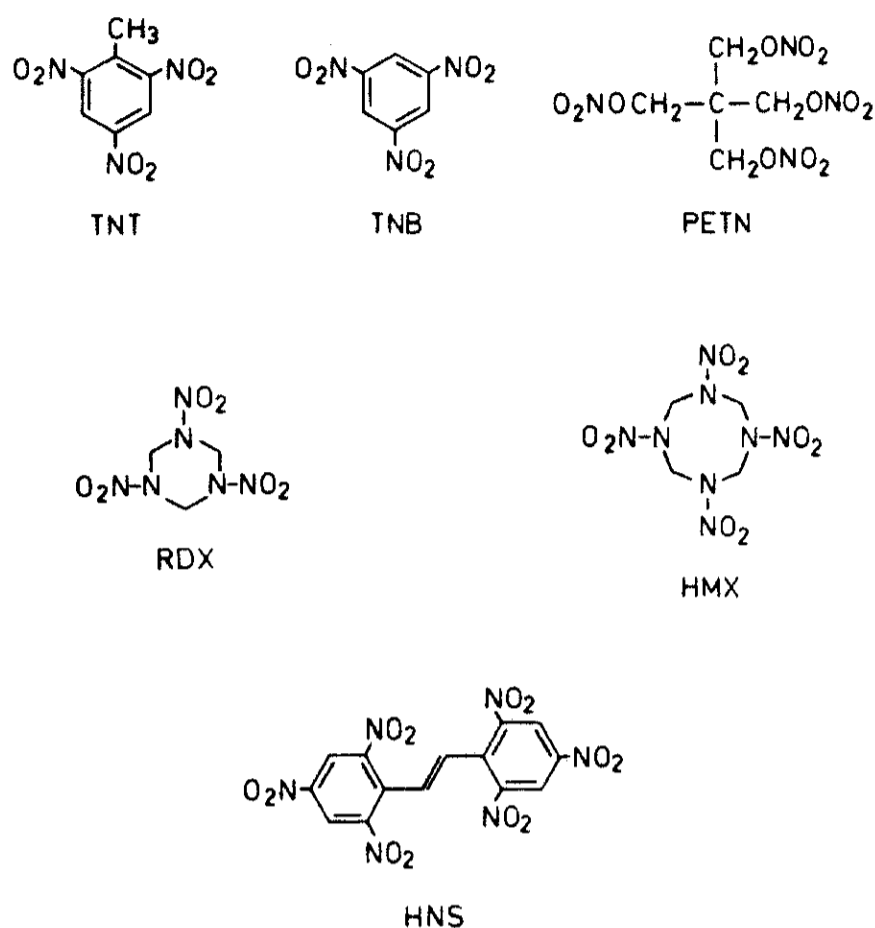


Fig. 1. Some commonly used explosives.

TABLE 1

Melting point and explosion temperatures for some explosives

Explosive	Melting point (°C)	Explosion temperature (°C)
TNT	80.8	300
TNB	123.2	> 315
PETN	141.3	205
RDX	202	230
HMX	282	280
HNS	320	320

coated with a mixture of wax and polymer into the molten TNT, with the coating-film remaining on the explosive crystals. This gives considerable improvement in the safety of the final product. A further improvement in such compositions can be obtained by addition of 0.5–10% polymer, which forms a network throughout the explosive mass. This gives a very good binding of the explosive crystals and furthermore, the polymer encourages the formation of small-sized TNT crystals. This in turn diminishes the risk of the formation of cavities.

In this connection the addition of HNS into melted TNT may also be mentioned briefly. A complex formed between HNS and TNT acts as seeds

for the TNT crystallization, inducing the TNT to crystallize into small crystals and thus avoiding the formation of cavities. This is certainly not a phlegmatization process but nevertheless a higher degree of safety is obtained. Starting from these results we are actively working on the development of phlegmatization processes which also include TNT.

Binders

A large number of chemical substances can be used as phlegmatizers:

- A. Waxes
- B. Thermoplastic polymers
- C. Mixtures of waxes and polymers
- D. Two- or more-component polymeric systems.

An absolute prerequisite for substances to be used as phlegmatizers for explosives is their compatibility with the explosives. These characteristics can be studied by differential scanning calorimetry (DSC) and micro calorimetry. The most studied binders and those which have been used for the longest time, are waxes. A large number of waxes are available based on oil- or brown coal (Montan) fractions. In addition there are many chemically modified waxes. In spite of the great variety of existing waxes, only a restricted number of waxes are practically suitable as phlegmatizers for explosives. This is due to the fact that most of the waxes are either not suitable for the coating processes or they are not completely compatible with the explosives. Furthermore, it can be difficult to achieve good binding between the explosive crystals and the binder, especially when the wax content is very low. Finally the military specifications of the products must be fulfilled. To satisfy all of these requirements, special compositions of different wax types are used. These exhibit fairly characteristic DSC-curves. Figures 2—4 show three typical DSC-curves for some commonly used waxes.

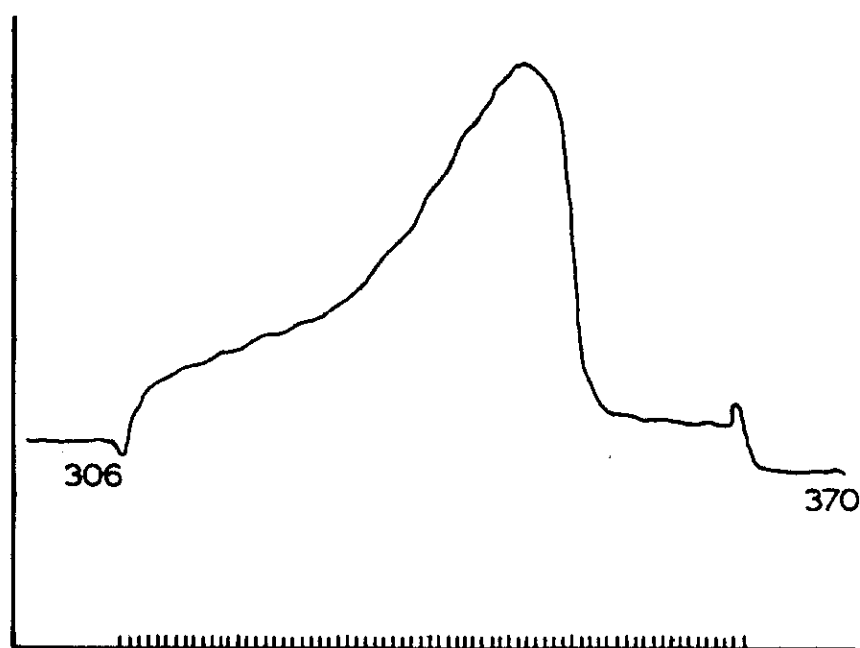


Fig. 2. DSC-curve for wax no. 1.

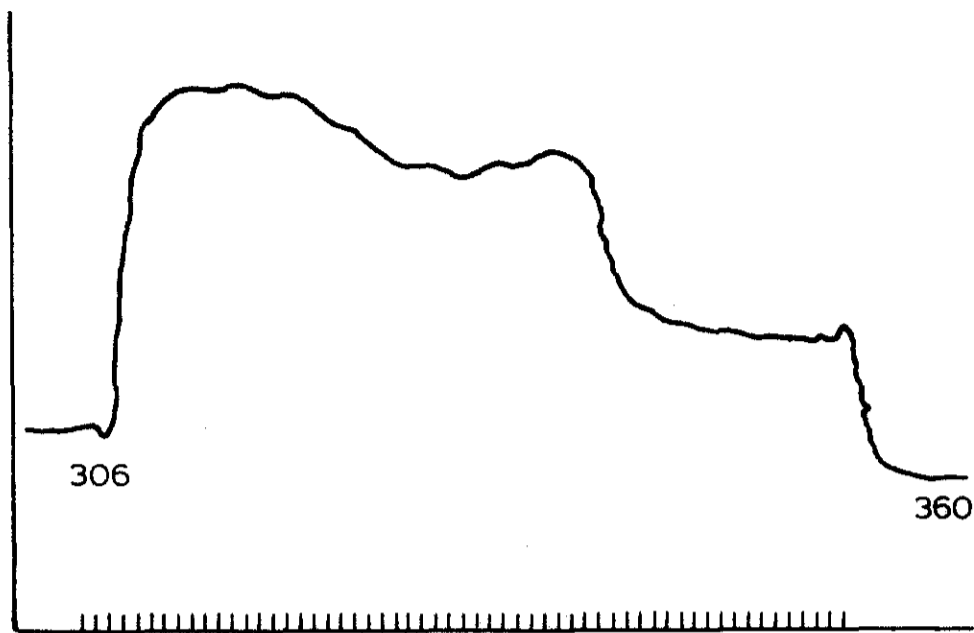


Fig. 3. DSC-curve for wax no. 2.

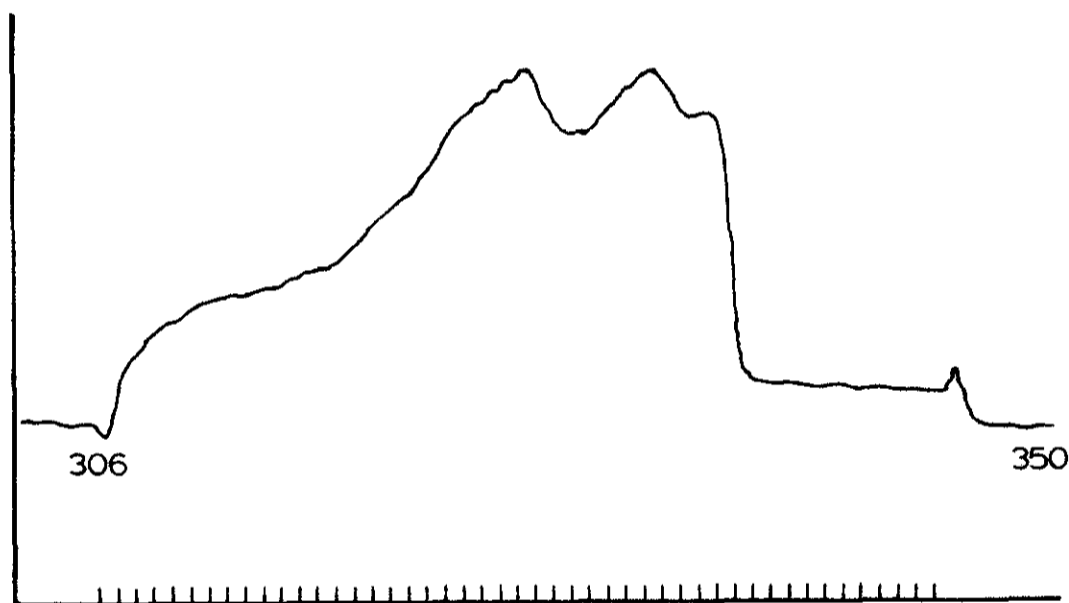


Fig. 4. DSC-curve for wax no. 3.

In general, waxes with a narrow melting range are more difficult to apply on the crystal surfaces than waxes with a broad melting range. The latter usually possess excellent coating properties, but on the other hand, it can then become more difficult to fulfill the military specifications regarding exudation.

Coating processes

For the preparation of wax phlegmatized explosives, there exist two practically applicable methods:

- A. Mechanical kneading of the components (wet or dry) at room temperature or above.
- B. Slurry processes in water.

Mixing processes, where the ingredients are dry, will not be treated here, since these processes are not used by us for safety reasons. Our product range of wax phlegmatized explosives is prepared by different types of slurry processes.

Basically, these processes are carried out in the following way: The explosive is suspended in water. For this operation, vessels equipped with cooling

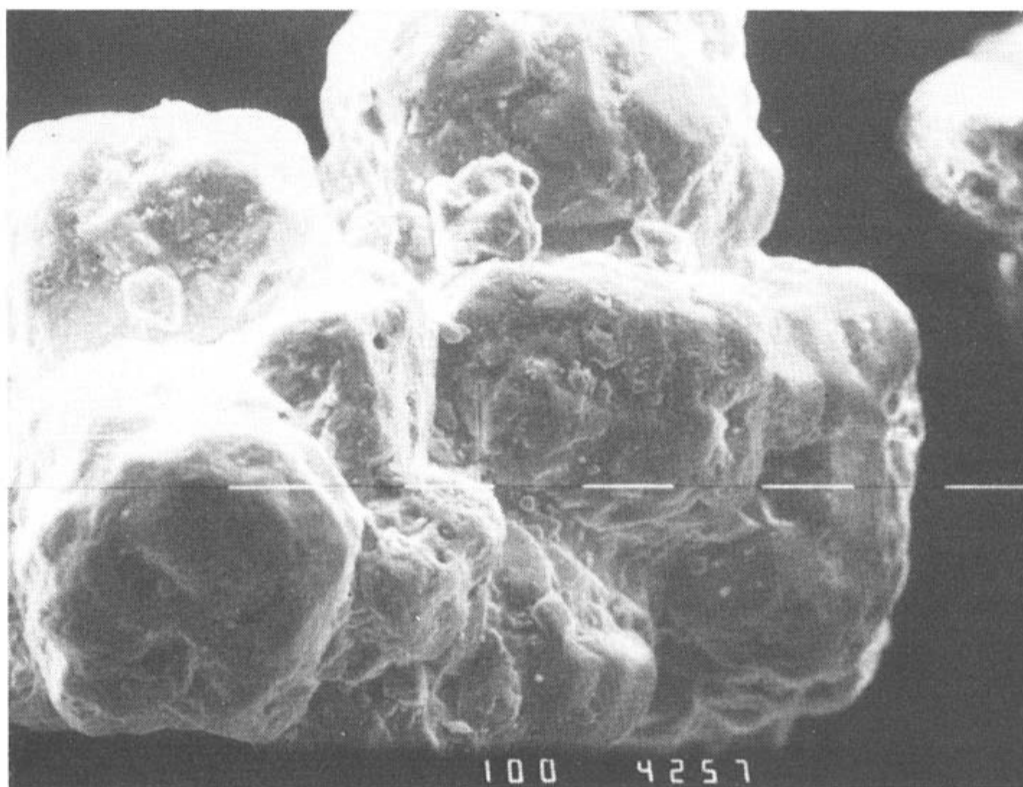


Fig. 5. PETN coated with wax no. 1.

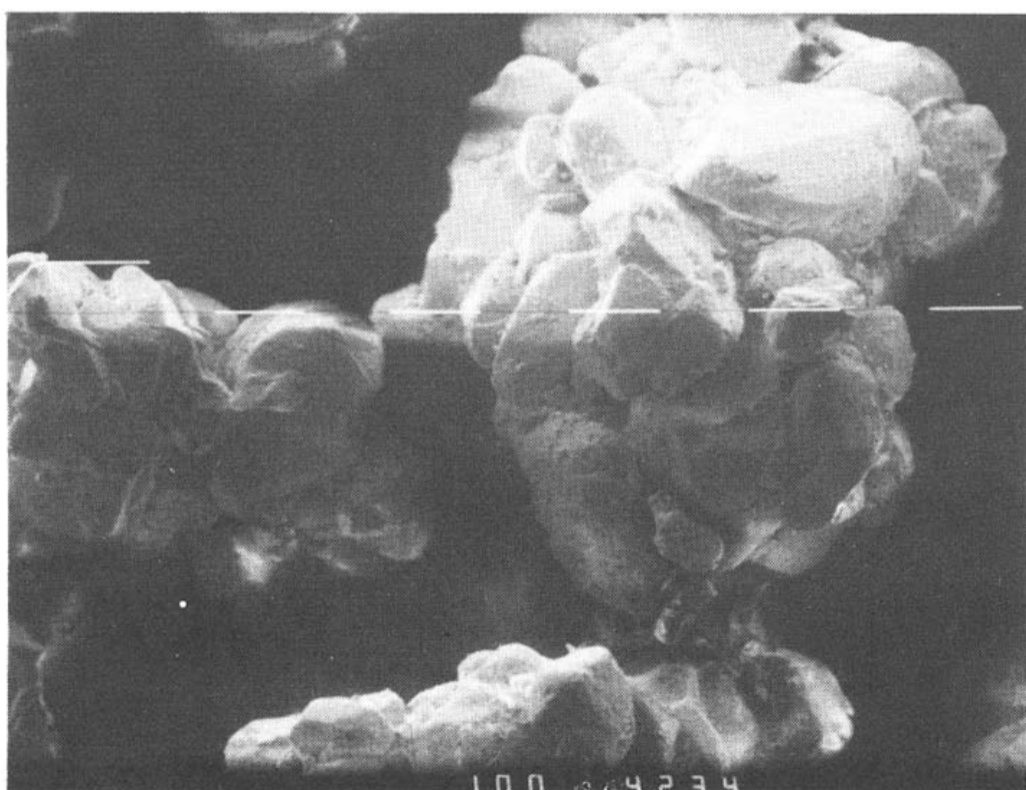


Fig. 6. RDX coated with wax no. 1.

and heating, are used. The wax is added and the temperature is then raised to about 10–20°C above the highest melting point of the wax components. The mixture is then slowly cooled with stirring to room temperature. Before and during the cooling phase, further operations can be added, which improve the uniform coating of the wax around the explosive crystals. Depending on the wax composition, the process conditions, the explosive and its particle size distribution, very diverse phlegmatization results can be obtained. The scanning electron micrographs (Figs. 5–6) demonstrate the difference in coating with the same wax type (wax no. 1) between PETN and RDX. This is a wax type with a narrow melting range. With PETN a good phlegmatization result is obtained, while RDX gives a less satisfactory result with the same wax. With wax no. 2 (same as wax no. 3 but from a different manufacturer), excellent results are obtained for both PETN and RDX with 4% wax. By extremely small variations (additives of only 0.001–0.01% of wax), considerable and important improvements can be obtained. An example of this is shown in Fig. 7 in which a wax similar to wax no. 1 has been used for coating RDX.

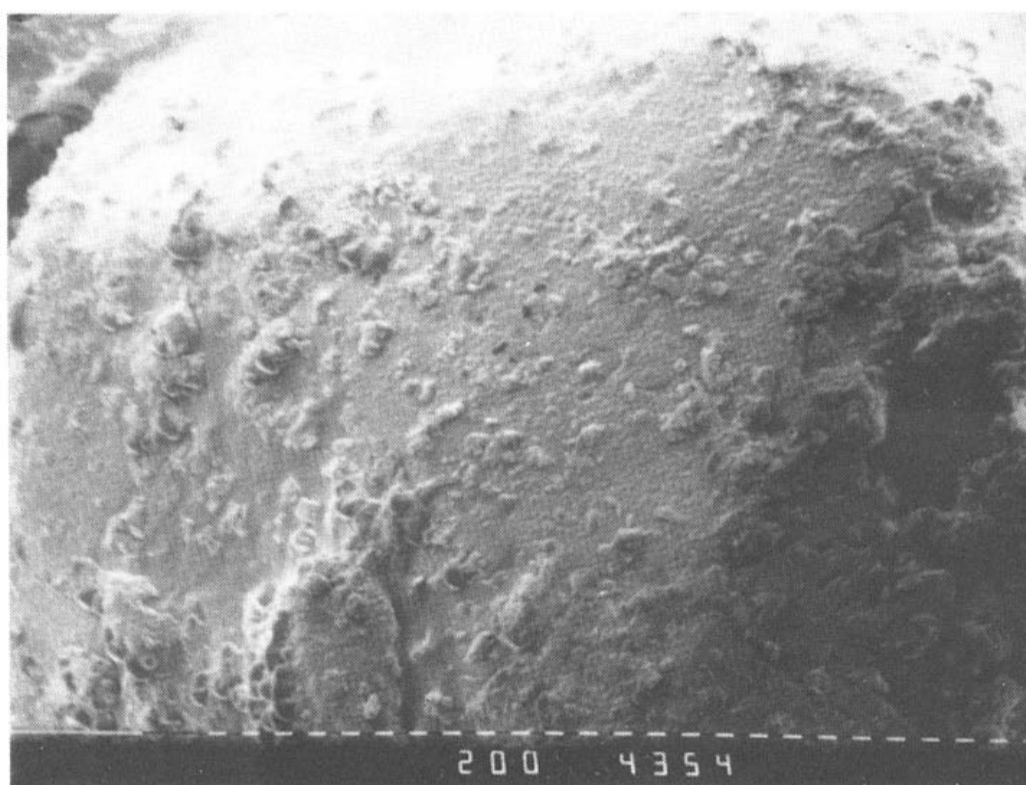


Fig. 7. RDX coated with special wax.

All products give excellent agglomeration especially for small explosive crystals. In this context it should be mentioned, that the particle size distribution of the explosive is also of great importance for the coating result. The affinity between the dispersed wax particles and the smaller suspended explosive particles appears to be the most important factor. A strong interaction disturbs the coating of the coarser crystals. Figures 8 and 9 show the results from the coating of PETN and RDX with wax no. 3 (a wax type with

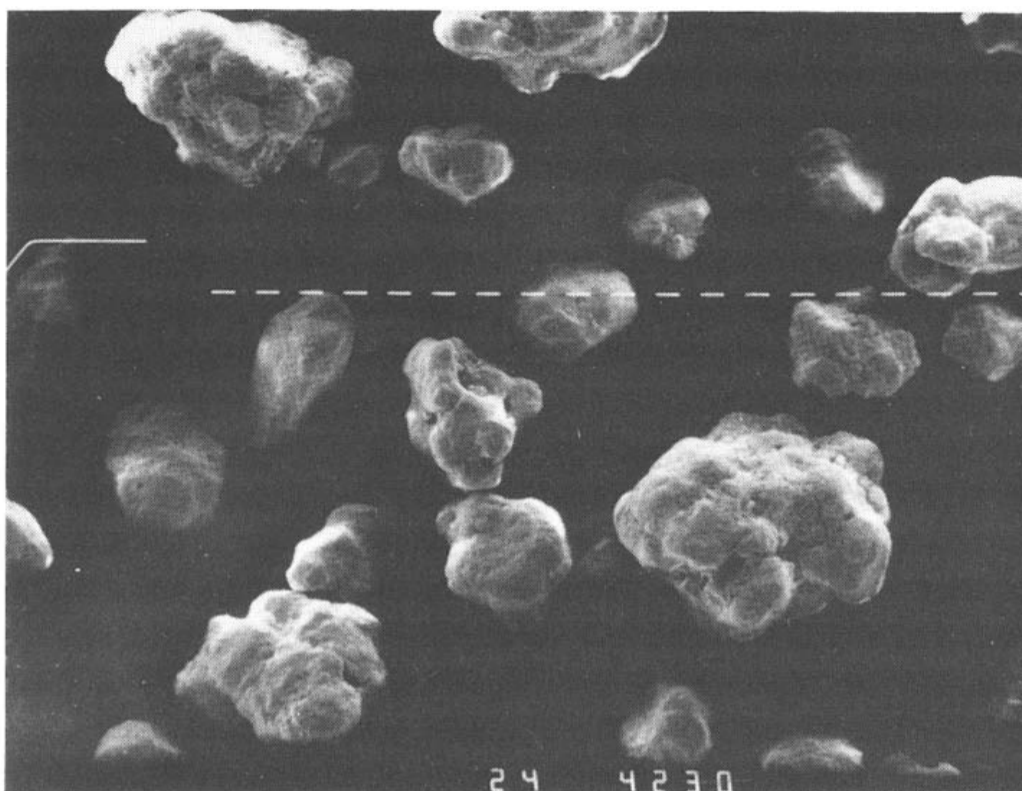


Fig. 8. PETN coated with wax no. 3.

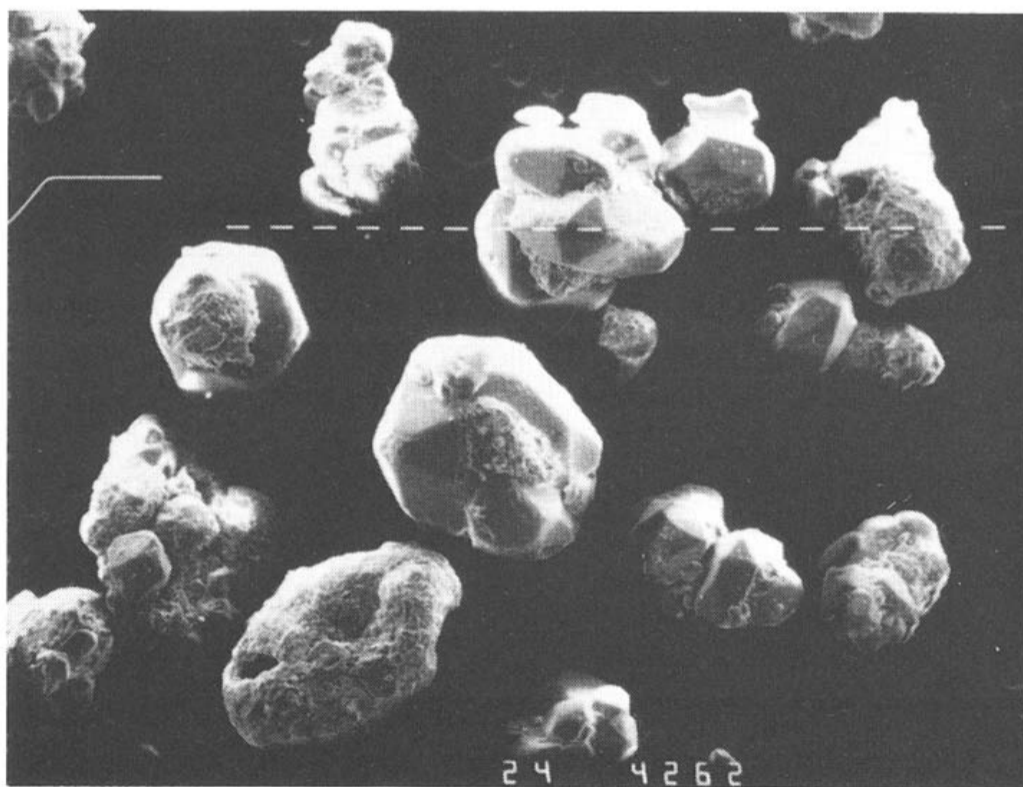


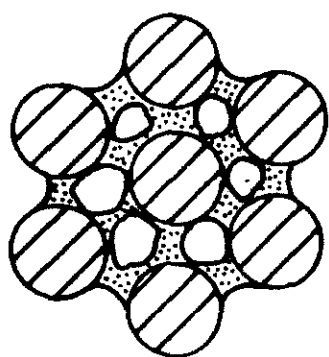
Fig. 9. RDX coated with wax no. 3.

comparatively broad melting range). PETN gives an excellent coating, while RDX gives a very poor result. For both PETN and RDX the agglomeration of the explosive crystals is worse than for waxes nos. 1 and 2. The conclusion to be drawn from these observations is that even the explosives molecular structure is very significant for the addition of the wax molecules.

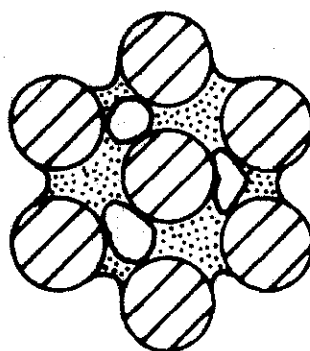
In composition A-5, RDX is phlegmatized with stearic acid, and this gives excellent results. In Fig. 10 different types of model forms which can be obtained in the agglomeration process, are shown.

From a safety point of view the process should be controlled in such a way that capillary or droplet forms are obtained at the end of the process. The formation of these agglomerate forms is to a considerable degree influenced by the design of the reaction vessel, the stirrer, the stirring speed, the possible addition of surface active agents, heating and cooling speeds and to a certain extent by the batch size.

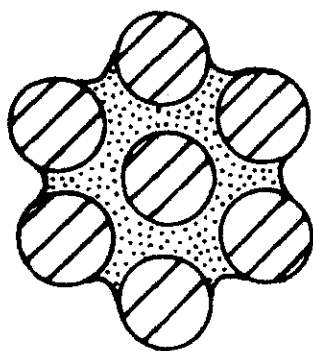
Phlegmatized explosives are tested by the usual general methods such as fall hammer test and friction test. Phlegmatization does not always give the desired safety characteristics. The results of the fall hammer tests for some special cases of HMX and RDX show that they were more sensitive after the coating with 5% wax than before. These are not isolated cases but are reproducible. It is of course vital that one obtains reliable information regarding the safety of the product. Our present theory to elucidate these phenomena is that pendular or funicular forms (Fig. 10) of the granules are formed during the agglomeration process. Consequently the agglomerates contain entrapped air together with poor phlegmatization in the center of the granules. It should be noted, that it is not the concentration of the wax



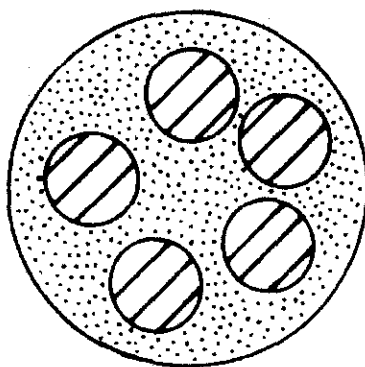
Pendular



Funicular



Capillary



Droplets

Fig. 10. Agglomeration forms.

which gives a high safety level, but the way the surface of the crystals is coated by the binder.

Polymers as binders

A very interesting phlegmatization of PETN is shown in Fig. 11. The coating substance is a liquid consisting of several components which can polymerize. This product is under development and is obtained by solid phase separation. The amount of the coating substance is 5.9%, the product is a free running powder and can be used as such or can be transformed into a solid mass by addition- or radical-polymerization.

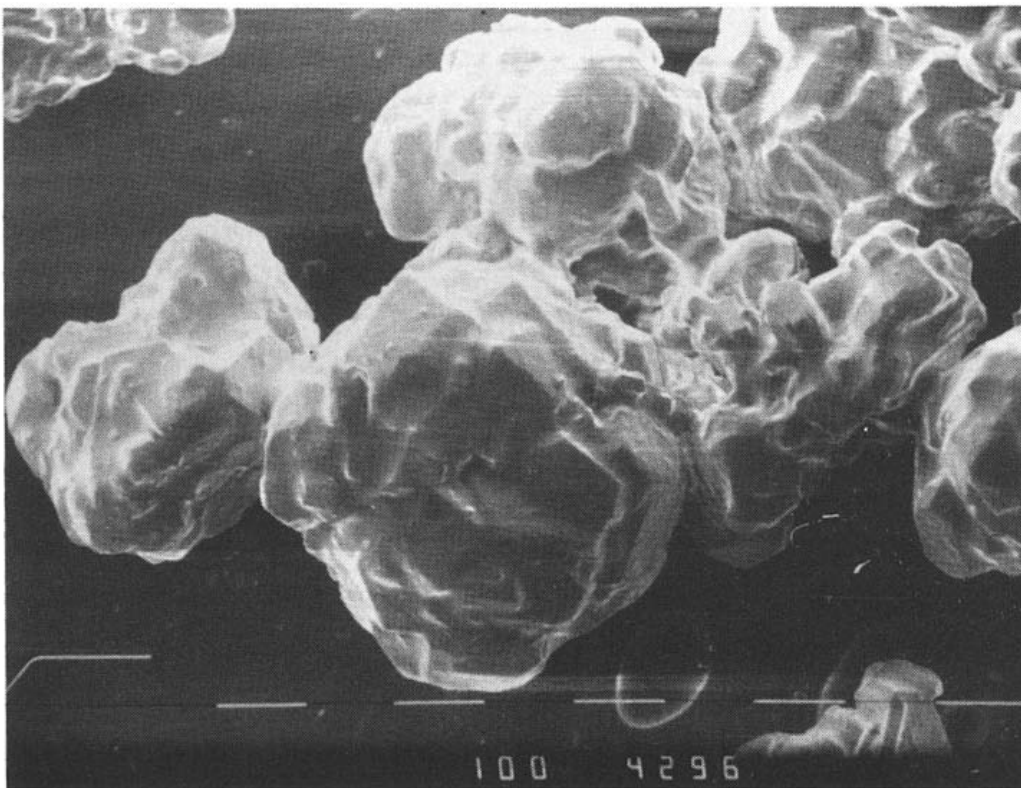


Fig. 11. PETN phlegmatized with a polymerizable substance.

In addition to the fact that a suitable choice of wax composition can lead to the formation of a system of wax surfaces, certain polymers can be incorporated into the surface film. Polymers have excellent properties as adhesion promoting substances, and by incorporating these substances, it is possible to get good adhesion between the wax surface and for example metal powder particles. Figure 12 shows an example of an explosive, Hexal, with 40% aluminium content. Both the wax coating process and the application of the metal are made in a slurry process in a single operation. In order to coat explosives with different types of polymers we use only the slurry processes. The explosive is first suspended in an excess of water. The polymers, which can either exist in dispersion or emulsion form, or as a solution, are then successively precipitated onto the surface of the crystals of the explosive.

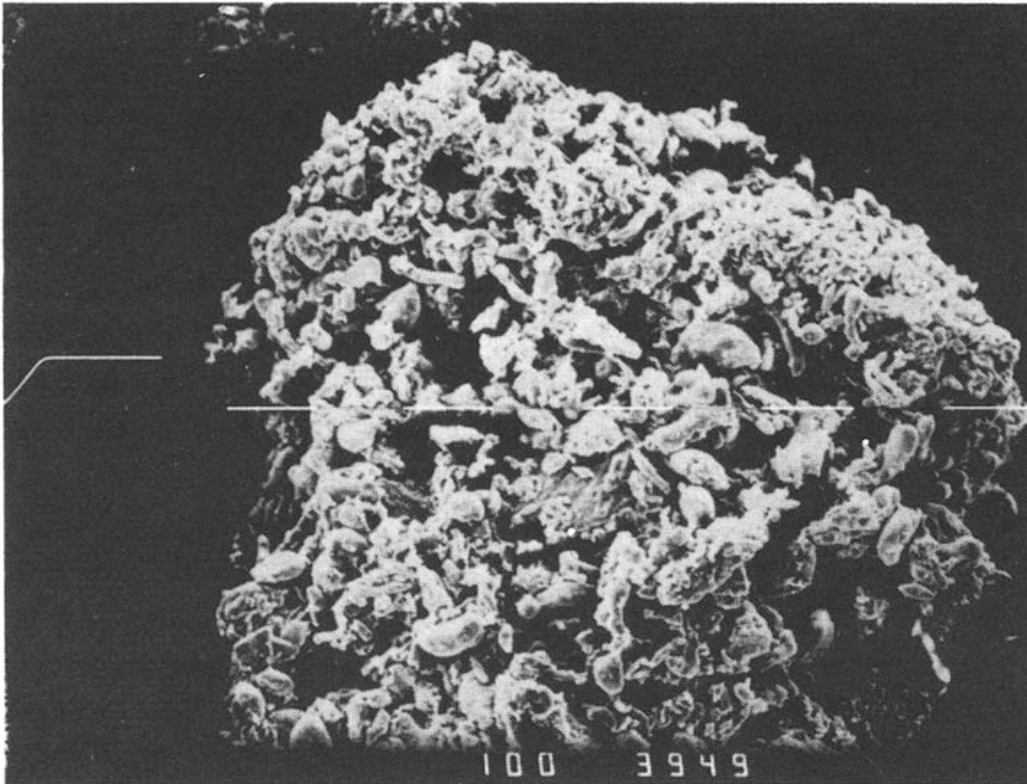


Fig. 12. Hexal.

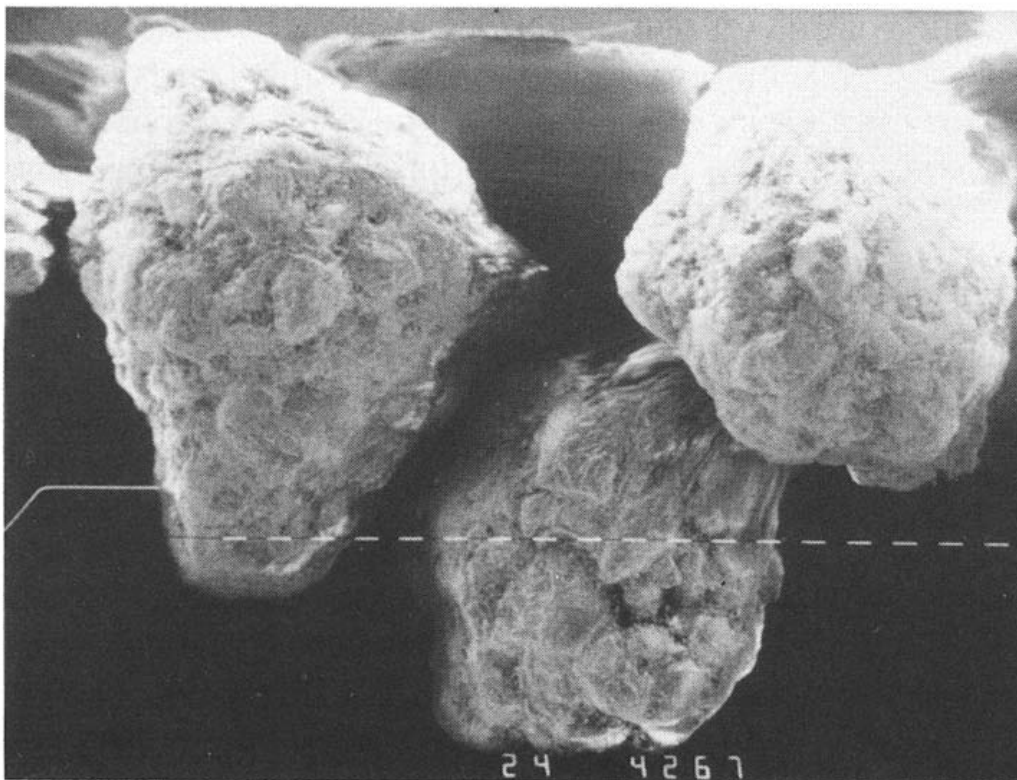


Fig. 13. HMX coated with 3% Estane (LX-14).

In many cases the solubility properties of the polymers allow one to control the process to obtain a particular granule size. In general the preparation of PBX by a slurry process is more difficult than wax coating. Some of the most used polymers are Sylgard 182, Kel-F 800, Vitone A, Estane, polyamides and Teflon. Figure 13 shows HMX coated with 3% Estane.

Figure 14 shows HMX coated with 3% of a linear polyurethane. An important factor in the coating of explosives with different types of polymers, is the affinity between the crystals and the polymer. Phlegmatization with different polyurethane systems is comparatively simple, but in other cases the process can be more difficult to perform.



Fig. 14. HMX coated with 3% linear polyurethane.

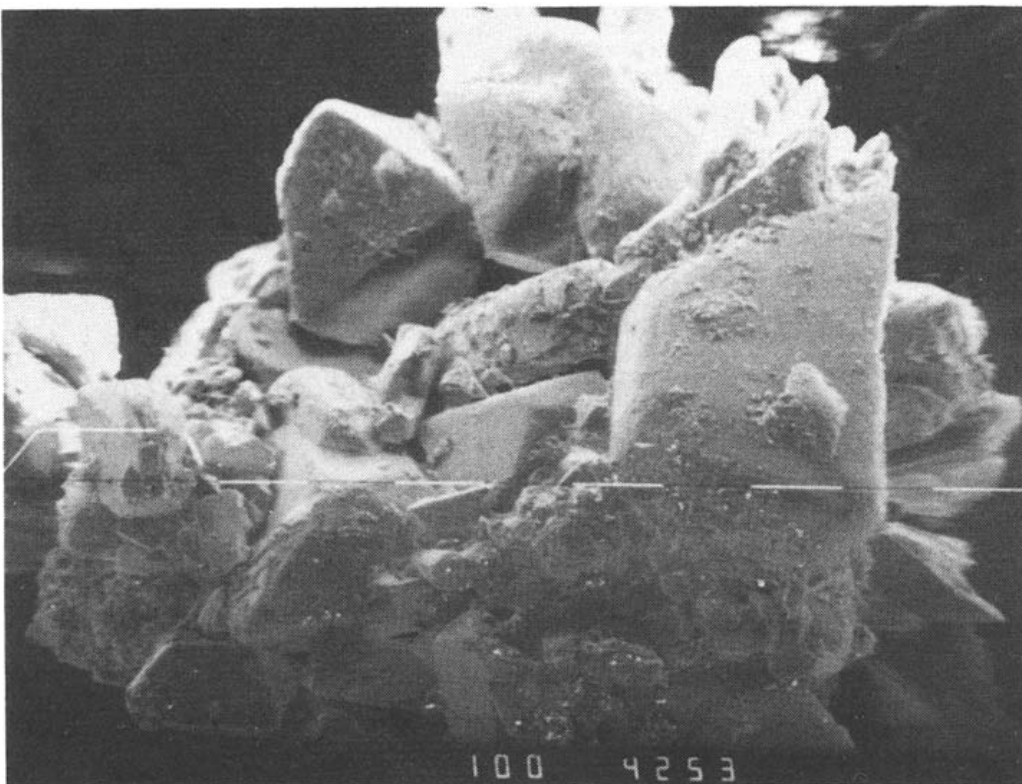


Fig. 15. HMX coated with 5% Vitone A (PBXN-5).

The coating of HMX with Vitone A (PBXN-5) is one such, and this is undoubtedly due to the structure of Vitone. The process conditions are very important and have a great influence on the product. Figure 15 shows a very poor product, while Fig. 16 shows an excellent product, suitable for pressed charges. These charges also give very good results during subsequent mechanical treatment, such as lathing and cutting.

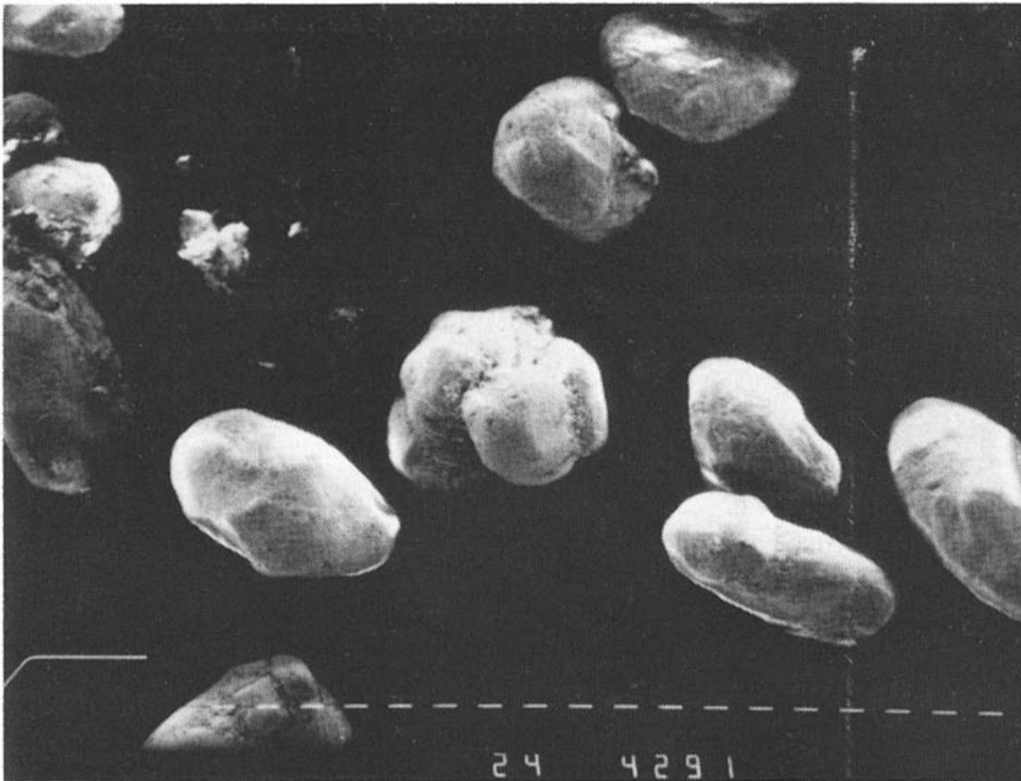


Fig. 16. HMX coated with 5% Vitone A (PBXN-5).

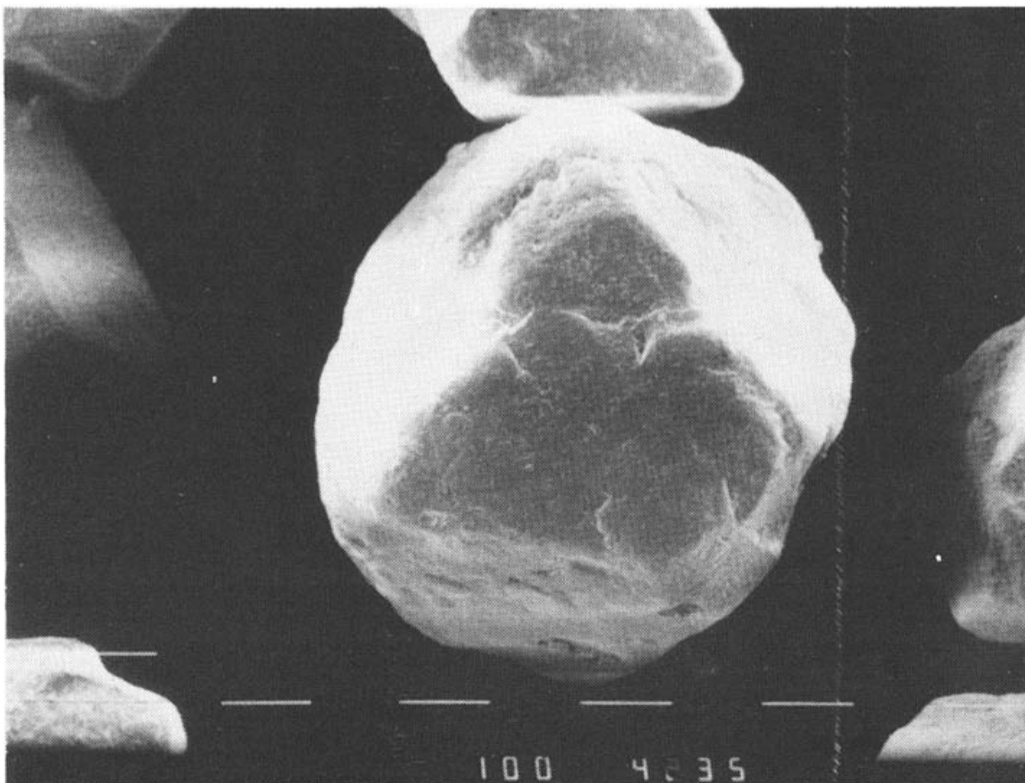


Fig. 17. PETN coated with 2.0% wax.

Figure 17 shows PETN phlegmatized with 2.0% wax by a completely new technique. This method is still under development, but in principal it should be applicable to most waxes and polymers.

Future research

From this brief survey of coating of explosives, it is obvious that there exists a large number of different wax types and many possible variations of polymer formulations. Unfortunately, existing process technology does not allow all of them to be used as phlegmatizing agents. The research departments at Nobel Chemicals AB, Nobel Industries Sweden, are therefore actively working on the development of new application technologies.

In the future, the demands from the users of coated explosives will increase drastically, especially concerning safety during firing and resistance to mass detonation.