

THEORETICAL EXPLANATIONS ON SOME UNIQUE PROPERTIES OF NITRILE LATEX AND FILM

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ABSTRACT

Due to increasing demand for synthetic examination gloves, the use of nitrile latex to manufacture examination glove is getting popular these days. Like natural rubber (NR) latex, nitrile latex can be used to produce high quality examination gloves, meeting the requirements of different international standards. Despite these, there are several unique properties of nitrile latex and film, which are not found in those of natural rubber latex. These include better ozone resistance and thermal aging resistance, thinner film than those of NR gloves. Nitrile latex is also known to have higher surfactant and poorer wet gel strength than NR latex. Unlike NR latex, which can be fully prevulcanised in latex state, a fully prevulcanised nitrile latex appears to be more difficult to achieve. This paper intends to explain these unique properties based on the theoretical understanding of the latex and film systems.

BACKGROUND

NR latex has been used as a material for the commercial production of NR gloves for a long time and the demand for such products remains high until today. However, due to the NR protein allergy issue, the market share and growth rate of synthetic rubber gloves are also significantly high in recent years. Currently, the most widely

used synthetic rubber gloves are nitrile examination gloves. The technology for producing nitrile examination gloves is very similar to that of NR gloves. The gloves are able to meet the requirements of major international standards for examination gloves such as EN455 series, ASTM D6719 and ISO 11193. Despite these, there are several unique properties of nitrile examination gloves, which are not found in the NR gloves. This paper intends to offer some possible explanations for these properties. A better understanding on the latex and film properties is expected to help in the new product design, production process as well as trouble-shooting.

THICKNESS

It is a well-known fact that nitrile examination gloves can be made much thinner than NR examination gloves. Generally, when a thinner latex film is made, the defect rate is expected to increase significantly. This is because impact of the surface imperfection on quality of a thin film is much higher than that on a thick film. The ability of nitrile latex to form thinner film than NR latex is most likely due to two reasons. Firstly, the particle size of nitrile latex [1] is about 8-10 times smaller than that of NR latex concentrate [2]. A smaller particle size means that the number of particle layers stacking up is also 8-10 times higher than that of NR latex to form the same thickness. Therefore, any imperfection on the nitrile film surface, such as absence of a few layers of particle, is expected to have less impact on cracks formation and the physical properties such as tensile strength, compared to that on the NR film surface.

Due to its narrower particle size distribution, the latex particles in the wet gel of nitrile latex are in loose packing form compared to wet gel of NR latex, which is more compact. This, in combination with the lower dry rubber content used, leads to nitrile latex film to have a higher shrinkage rate than that of NR latex film during drying. This does not favour the formation of thin film because it will result in high stress and lead to cracks formation particularly at the finger crotch areas. However, nitrile rubber is able to reduce the stress that is generated by the shrinkage via the stress relaxation, a property that is not found in NR, reducing the tendency of the film to crack during the drying process. Therefore, it is possible to produce thinner nitrile gloves without any issue.

OZONE CRACKING

Ozone attack on rubber may lead to ozone cracking problem. This problem is normally found in NR gloves but rarely in nitrile gloves, despite that nitrile rubber also contains unsaturated carbon-carbon double bonds, i.e. the butadiene repeating units. At the initial stage of ozone attack on the NR double bonds, it occurs very rapidly on the exposed surface. If there is stress applied to the NR surface during the reaction, degradation at the areas of high strain creates a retractive force causing the underlying rubber chains to become exposed to the surface and therefore ozone on the exposed rubber continues [3]. This eventually leads to the formation of ozone cracks. In the case of NR gloves, the folded edge is the area where it is under stress when the gloves are stacked up and packed in a non-airtight dispenser box. Therefore, ozone cracking normally occurs at the folded edge during storage. Due to

stress relaxation properties of nitrile glove, the folded edge of nitrile gloves, on the other hand, is not significantly strained and therefore the retractive force is minimum or absent. This could explain the lower tendency of nitrile gloves to have ozone cracking issue during storage.

AGEING PROFILE

The tensile properties such as force at break and ultimate tensile strength of NR gloves normally decrease with accelerated ageing time or real time ageing during the shelf life study. In the case of nitrile gloves, however, the tensile properties increase at the initial stage of ageing, and then decrease on prolonged ageing [4]. In the previous ageing studies on nitrile rubbers and gloves, it was found that the carbonyl formation was initially fast and quickly became stagnant after some time, indicating low level or unavailability of oxygen [5]. This is because the acrylonitrile group imparts the low gas permeability property to the nitrile rubber. Therefore, a high unsaturation level of nitrile rubber has been found to favour the formation of crosslinking types of reactions during ageing due to the formation of more radicals and subsequently recombination of the radicals to form crosslinks. On prolonged ageing, degradation that started on the surface spreads to the inner part of the rubber and therefore the tensile properties starts to deteriorate. On the other hand, the gas permeability of NR gloves is known to be high, as indicated by the inability of an inflated balloon to retain the air inside over a day. During the ageing, the relatively fast permeation of oxygen facilitates the degradation reactions.

PUNCTURE RESISTANCE

The puncture resistance of rubber gloves depends on the test method used. The ASTM F1342 and EN388 methods use a probe with a rounded tip while ASTM F2878 uses a hypodermic needle with a sharp tip [6,7]. Nitrile gloves are known to have a better puncture resistance than NR gloves when a rounded probe is used. This is because when a blunt probe is used, the puncture is controlled by a local deformation or failure strain. Therefore, when puncture occurs instantly at maximum load where the strain at the probe tip reaches the failure value. It is well known that the force required to puncture rubber increases with increasing thickness. Because nitrile gloves are stiffer and less stretchable than NR gloves, the thickness at the strained area is higher, allowing a higher load before the failure strain is achieved. However, when tested against sharp objects such as hypodermic needles, the puncture resistance of nitrile gloves is comparable to that of NR gloves. This is because the needles penetrate gradually through the sample thickness; after the force reaches a maximum value, it diminishes slightly before reaching a plateau. The “thickness effect” that is due to the rubber deformation is not an important factor in determining the puncture force but it is the needle penetration through the rubber layer that leads to the puncture.

PREVULCANISATION

Prevulcanisation is a crosslinking reaction of rubber molecules in latex state. Because the rubber molecules in latex are confined in the particles, the crosslinking reactions among the rubber molecules can only take place within the same latex particles. In commercial prevulcanised latex, upon completion of the reactions, the unreacted vulcanizing agents are normally removed by clarification or centrifugation. Because of low level of unreacted vulcanizing agents, the prevulcanised latex remains stable, over a longer period of time, i.e. in terms of the shelf life and pot-life. Since the rubber molecules in prevulcanised latex are optimally vulcanized in latex state for product applications, no further vulcanization is required during the processing of latex to form products. Unlike post vulcanization system where the oven temperature fluctuation could impact the crosslink density and consequently the physical properties of the rubber product, this is not the case for prevulcanised latex. So far, only NR latex can be fully prevulcanised in latex state. Attempt to commercially produce prevulcanised synthetic latexes has so far been unsuccessful. One of the reasons for this is due to the high surfactant level in synthetic latexes which could inhibit inter-particles integration after prevulcanisation. In the case of nitrile latex, the problem is compounded by the relatively high glass transition temperature of nitrile rubber (-27°C) compared to NR (-70°C) which has low segmental mobility which becomes less mobile upon prevulcanisation. This is expected to further hinder the inter-particles integration, leading to the film cracking issue after the rubber is fully prevulcanised. Inter-particles integration or film formation could be improved via several methods; namely 1) increasing the drying temperature; 2) reducing the surfactant content; 3) reducing the glass transition temperature by incorporating suitable plasticisers, which could be achieved via the following approaches: (a) increasing hydrophilic properties of the rubber to allow the retained water to act as a plasticiser; (b) using surfactant that is compatible with the rubber to plasticise the rubber. Increasing the drying temperature may lead to a sudden film shrinkage which leads to the film cracking issue. Plasticising the nitrile rubber appears to be a viable solution for the prevulcanisation of nitrile latex.

WET GEL STRENGTH

Wet-gel strength is the strength of a dipped latex film in wet state after dipping but before drying and curing. It is important for latex film to have certain degree of wet gel strength during processing such as leaching and beading to maintain the latex film integrity. NR latex is known to have good wet-gel strength. Synthetic latexes including nitrile latex, on the other hand, have inferior wet-gel strength. This is because of the narrow particle size distribution which leads to a more loose packing configuration of the wet gel with higher a water content. In a loose packing configuration, the particles are not well linked to each other. In addition, the presence of high surfactant in nitrile latex further inhibits the latex particles from forming a strong wet gel structure. In contrast, NR latex consists both large and small particles where a close packing structure of wet gel can be formed. In addition, the surfactant level of NR latex is much lower than that of nitrile latex, making it easier to form a compact and strong wet gel. This has been demonstrated in a study where the small rubber particles were removed from NR latex, the wet gel was found to be

significantly weakened and the film cracked easily upon drying, indicating the role of NR small rubber particles in forming good wet gel strength. [8]

CONCLUDING REMARKS

In summary, the unique properties of nitrile gloves which are absent in NR gloves are due to the following reasons:

- 1) the small particle size and narrow particle size distribution of nitrile latex;
- 2) the high surfactant content of nitrile ;
- 3) the high tendency of the nitrile rubber to undergo stress relaxation process;
- 4) the low gas permeability properties of nitrile rubber.

A better understanding on the properties of nitrile latex and rubber will help one to adopt the right strategy in improving the performance of nitrile gloves.

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