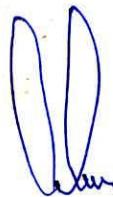


Received OW 01/09/2009



**Dr Laleen Karunanayake**  
BSc(SIP), PhD (North London)  
Senior Lecturer  
Department of Chemistry  
University of Sri Jayawardenapura

**Development of non marring glove for coated glass industry**

**By**

**Imihamy Mudiyanseelage Sanjeewa Herath**

**Thesis submitted to the University of Sri Jayewardenepura for the  
award of the Degree of Master of Science on Polymer Science and  
Technology.**

**MSc**

**2009**

## Declaration

The work described in this thesis was carried out by me under the supervision of Dr. Laleen Karunanayake, Senior lecturer in chemistry at University of Sri Jayewardenepura and a report on this has not been submitted in whole or in part to any university or any other institution for another Degree or Diploma.



I.M. Sanjeewa Herath.

25/08/2009

I certify that the above statement made by the candidate is true and that this thesis is suitable for submission to the University of Sri Jayewardenepura for the purpose of evaluation for the award of the M.Sc in polymer science and technology.



---

Dr. Laleen Karunanayake  
Senior lecturer  
Department of Chemistry  
University of Sri Jayewardenepura.

## Table of Contents

|  |            |
|--|------------|
| <i>Table of content</i>  | <i>i</i>   |
| <i>List of figures</i>   | <i>v</i>   |
| <i>List of Tables</i>  | <i>vii</i> |
| <i>Acknowledgement</i>   | <i>ix</i>  |
| <i>Abstract</i>  | <i>x</i>   |
| <br>   |            |
| <b>1.0 INTRODUCTION</b>  | <b>1</b>   |
| <br>   |            |
| <b>1.1 Coated glass industry and marring problem</b>             | <b>1</b>   |
| <br>   |            |
| <b>1.2 Objectives of the project</b>                             | <b>2</b>   |
| <br>   |            |
| <b>1.3 Background to the project work</b>                        | <b>2</b>   |
| <br>   |            |
| <b>2.0 LITERATURE REVIEW</b>                                     | <b>4</b>   |
| <br>   |            |
| <b>2.1 The basic category of the glove.</b>                      | <b>4</b>   |
| <br>   |            |
| <b>2.2 The basic pattern and the suitable former (mould).</b>    | <b>5</b>   |
| 2.2.1 BS EN 420:2003 General requirements for gloves.            | 5          |
| 2.2.2 Design principle- general                                  | 5          |
| 2.2.3 Type of formers.   | 6          |
| 2.2.4 Rough sketch of the glove developed on the<br>flat former. | 7          |

|            |   |           |
|------------|---|-----------|
| <b>2.3</b> | <b>Inner liner (shell) and cut resistance.</b>  | <b>8</b>  |
| 2.3.1      | Yarn plying.  | 11        |
| 2.3.2      | Cut resistant yarn.   | 12        |
| 2.3.2.1    | Kevlar (Product of Dupont)  | 12        |
| 2.3.2.2    | Dyneema (Product of DSM)  | 18        |
| 2.3.2.3    | Glass yarn  | 23        |
| 2.3.2.4    | Steel yarn  | 26        |
| 2.3.3      | Nylon yarn  | 29        |
| 2.3.4      | Cotton yarn   | 33        |
| <br>       |   |           |
| <b>2.4</b> | <b>NR lattice which provide acceptable abrasion resistance with minimum marring effect.</b> | <b>34</b> |
| 2.4.1      | The rubber phase  | 36        |
| 2.4.2      | The aqueous phase   | 36        |
| 2.4.2.1    | Carbohydrates   | 36        |
| 2.4.2.2    | Protein and amino acids   | 36        |
| 2.4.2.3    | Other serum constituents  | 37        |
| 2.4.3      | Lutoid and other particulate phases   | 37        |
| 2.4.4      | Type of latex lattices  | 37        |
| 2.4.4.1    | Unvulcanized latex (UV latex)   | 37        |
| 2.4.4.2    | Pre vulcanized latex (PV latex)   | 38        |
| 2.4.4.3    | Multiple centrifuged latex  | 38        |
| 2.4.4.4    | Clean latex   | 39        |
| <br>       |   |           |
| <b>2.5</b> | <b>Dipping process.</b>   | <b>39</b> |
| 2.5.1      | Coagulant dipping.  | 39        |
| 2.5.2      | Former cleaning, inner liner loading, coagulant dipping and air drying.                     | 42        |
| 2.5.3      | Latex dipping & air drying.   | 42        |

|            |   |           |
|------------|---|-----------|
| 2.5.4      | Solvent dipping   | 42        |
| 2.5.5      | Leaching process.   | 43        |
| 2.5.6      | Drying & curing.  | 45        |
| 2.5.7      | Chlorination process.   | 46        |
| <b>2.6</b> | <b>Formulations for coagulant and compound.</b>                           | <b>49</b> |
| 2.6.1      | Pre coagulant formula.  | 49        |
| 2.6.2      | Compound formula.   | 50        |
| 2.6.3      | Post coagulant formula.   | 54        |
| <b>3.0</b> | <b>METHDOLOGY</b>   | <b>55</b> |
| <b>3.1</b> | <b>Experimental procedure</b>   | <b>55</b> |
| 3.1.1      | Research study A-Cut resistant machine knit inner liner development       | 55        |
| 3.1.2      | Research study B-Non marring outer coating development                    | 56        |
| 3.1.2.1    | Experiment carried out changing the pre leaching time & temperature.      | 58        |
| 3.1.2.2    | Experiment carried out changing the polymer lattice.                      | 59        |
| 3.1.2.3    | Experiment carried out introducing DI water and HCl for pre leaching tank | 61        |
| 3.1.2.4    | Experiment carried out introducing chlorination.                          | 61        |
| 3.1.2.5    | Experiment carried out introducing post leaching.                         | 62        |
| <b>3.2</b> | <b>Test methods</b>   | <b>63</b> |
| 3.2.1      | Non marring test method   | 63        |
| 3.2.1.1    | Special instructions for handling glass during the test.                  | 63        |
| 3.2.1.2    | Visible oil stain test on paper wrapping.                                 | 63        |
| 3.2.1.3    | First contact test  | 64        |
| 3.2.1.4    | Pull test   | 65        |

|  |           |
|--|-----------|
| 3.2.1.5 Adhesion test  | 67        |
| 3.2.2 Mechanical test methods  | 67        |
| <b>4.0 EXPERIMENTAL RESULTS AND DISCUSSION</b>   | <b>69</b> |
| <b>4.1 Research study A- Results and discussion</b>  | <b>69</b> |
| <b>4.2 Research study B- Results and discussion</b>  | <b>71</b> |
| 4.2.1 Results and discussion- Experiment changing the pre leaching time and temperature      | 71        |
| 4.2.2 Results and discussion- Experiment changing the polymer lattices                       | 76        |
| 4.2.3 Results and discussion- Experiment introducing DI water and HCl for pre leaching tank. | 81        |
| 4.2.4 Results and discussion- Experiment introducing chlorination.                           | 83        |
| 4.2.5 Results and discussion- Experiment introducing post leaching.                          | 86        |
| <b>5.0 CONCLUSION</b>  | <b>89</b> |
| <b>Reference</b>   | <b>90</b> |

## List of figures

| No.of figure | Title   |
|--------------|---|
| Figure 2.1   | Gauntlet formers are used to produce gloves which, relative to the wrist gloves provides additional protection for the wrist and part of or the whole of the arm. |
| Figure 2.2   | Knit wrist formers are used to produce wrist length gloves providing covering for the hand and wrist, having separate fingers.                                    |
| Figure 2.3   | Flat former are usually used to produce palm coated gloves with open finish.  |
| Figure 2.4   | Sketch of the basic type of the glove.  |
| Figure 2.5   | A cut and sewn liner made with woven fabric.  |
| Figure 2.6   | A machine knit liner made on flat bed knitting machine.   |
| Figure 2.7   | A 10gg L2 Flat bed knitting machine.  |
| Figure 2.8.1 | Plying machine.   |
| Figure 2.8.2 | Yarn moving through the core.   |
| Figure 2.9   | Plying and knitting mechanism.  |
| Figure 2.10  | Structure of Kevlar   |
| Figure 2.11  | Molecular arrangements in Kevlar  |
| Figure 2.12  | Difference between liquid crystalline polymers and flexible melt polymers.  |
| Figure 2.13  | Relationship between cis and trans conformation with molecular arrangement of Nylon 6,6   |
| Figure 2.14  | Trans conformation in Kevlar  |
| Figure 2.15  | Phenyl hydrogen and trans conformation.   |
| Figure 2.16  | Molecular structure of Dyneema(Ultra High Molecular Wt Poly ethylene monomer)   |
| Figure 2.17  | UHMWPE polymer structure  |
| Figure 2.18  | Bundle of fiber glass   |
| Figure 2.19  | Glass yarn corns.   |

|             |  |
|-------------|--|
| Figure 2.20 | Stainless steel yarn corn.                                   |
| Figure 2.21 | Molecular structure of Kevlar (para aramid polyamide)        |
| Figure 2.22 | Molecular structure of Nomex (meta aramid polyamide)         |
| Figure 2.23 | Crystal structure of Nylon 6 and Nylon 66                    |
| Figure 2.24 | Repeating unit of cellulose                                  |
| Figure 2.25 | Structure of vulcanized unstreched rubber.                   |
| Figure 2.26 | Isoprene unit  |
| Figure 2.27 | Latex centrifuging machine                                   |
| Figure 2.28 | Standard process flow chart                                  |
| Figure 2.29 | Rough crinkle finished glove and smooth plane finished glove |
| Figure 2.30 | Off line chlorination tanks                                  |
| Figure 2.31 | On line chlorination tanks                                   |
| Figure 3.1  | Standard process flow chart used in the experiment # 01.     |
| Figure 3.2  | The correct method of handling glasses.                      |
| Figure 3.3  | The method of wrapping to identify oil stains.               |
| Figure 3.4  | The first contact test.                                      |
| Figure 3.5  | The pull test.   |
| Figure 4.1  | Stain versus time graph –Test A                              |
| Figure 4.2  | Stain versus time graph – Test B                             |
| Figure 4.3  | Stain versus time graph – Test C                             |
| Figure 4.4  | Fingers are stick together                                   |
| Figure 4.5  | Stain comparisons versus time with various polymers.         |
| Figure 4.6  | Marring level comparison in first contact test               |
| Figure 4.7  | Marring and smearing level comparison in pull test           |
| Figure 4.8  | Splits observed on the surface                               |
| Figure 4.9  | Stain versus time with different leaching options            |
| Figure 4.10 | Stain versus time with different chlorination options.       |
| Figure 4.11 | Discoloration observed due to high chlorine levels           |
| Figure 4.12 | Comparison of post leaching trial test results.              |
| Figure 4.13 | The final product  |

## List of tables

| No.of Table | Title  |
|-------------|--|
| Table 2.1   | Comparison of physical properties of Kevlar with other yarn                              |
| Table 2.2   | Comparison of specific strength versus Modulus of Dyneema with other yarn.               |
| Table 2.3   | Density of some fibers.  |
| Table 2.4   | Comparison of energy absorption of Dyneema with Aramid and Polyamide.                    |
| Table 2.5   | Comparison of abrasion resistance and flex life of Dyneema with Carbon and Aramid.       |
| Table 2.6   | Light stability of Dyneema.  |
| Table 2.7   | Chemical stability of Dyneema.   |
| Table 2.8   | Comparison of typical properties of some common fibers.                                  |
| Table 2.9   | Comparison of the performance of high cut resistant yarn with other yarns.               |
| Table 2.10  | Comparison of Tg and Tm of Kevlar and Nomex.   |
| Table 2.11  | Constitution of fresh and ammonia preserved natural rubber latex.                        |
| Table 2.12  | ISO specification for latex concentrates (centrifuged)                                   |
| Table 2.13  | Standard process parameters for coagulant dip machine knit supported gloves.             |
| Table 2.14  | Parameters of chlorination process.  |
| Table 2.15  | Laboratory equipments used to control p H, Viscosity and SG                              |
| Table 2.16  | Various coagulant solutions proposed by T.D.Pendle in “Natural latex dipping technology” |
| Table 2.17  | Standard pre coagulant formula used in machine knit supported glove dipping process.     |
| Table 2.18  | Process formulations proposed by T.D.Pendle for various glove styles.                    |
| Table 2.19  | Dipping compound formula which is suitable for balloons, gloves, teats.. etc.            |

|            |   |
|------------|---|
| Table 2.20 | Standard compound formula designed for the glove which are produced according to the ISO 9000:2003 certification.   |
| Table 2.21 | Basic compounding formula designed for non marring trials. All the unnecessary additives were taken out from the formula.   |
| Table 2.22 | Standard post coagulant formula designed for non marring trials.  |
| Table 3.1  | Yarn compositions of various types of yarn combinations.  |
| Table 3.2  | Cross reference table.  |
| Table 3.3  | Standard process parameters followed in the experiment # 01.  |
| Table 3.4  | Leaching time versus leaching temperatures.   |
| Table 3.5  | Various formulations used with various latex types for the experiment # 02.   |
| Table 3.6  | Raw water/DI water versus 2% HCl in raw water/ 2% HCl in DI water.  |
| Table 3.7  | Trials carried out with normal water, hot water & DI water under various timings.   |
| Table 3.8  | Summary of mechanical properties studied  |
| Table 3.9  | Table shows the performance of gloves against abrasion, blade cut tear & puncture classified according to the minimum requirements for each level. BS EN 388 Standard <sup>33</sup> |
| Table 3.10 | ASTM CPPT Standard <sup>34,35</sup>   |
| Table 4.1  | Performance comparison chart of various liners developed  |
| Table 4.2  | Performance comparison chart of experiment # 01   |
| Table 4.3  | Effect of wet gel leaching on extractable protein of gloves made from pre vulcanized NR latex   |
| Table 4.4  | Performance comparison chart of experiment # 02   |
| Table 4.5  | Extractable protein content of normal and re centrifuged pre vulcanized NR lattices.  |
| Table 4.6  | Performance comparison chart of experiment # 03   |
| Table 4.7  | Performance comparison chart of experiment # 04   |
| Table 4.8  | Performance comparison chart of experiment # 05   |
| Table 4.9  | Extractable protein content in latex gloves with different leaching time.   |

## **Acknowledgements**

It gives me special pleasure to be able to place on record my deepest appreciation to at least some of the many people who have made the completion of this thesis possible.

Firstly, I am deeply indebted to my supervisor, Dr. Lalin Karunanayake, BSc, PhD, Senior lecturer in Chemistry, University of Sri Jayawardenepura, for the invaluable advice and unfailing encouragement he has given through out this course of research and whom I have been fortunate to have as a supervisor. I would like to express my gratitude and offer my best wishes to him for the future.

I am very grateful to Dr. Sudantha Liyanage and Dr. M.P.Deeyamulla for the encouragement and motivation that was given through out my course work.

This thesis could not have been completed without the help of Mr.C.Radesh (Manager Operations- Work Wear Lanka (PVT) LTD) is greatly acknowledged.

Special thanks go to Mr. R.M.G.B.Rajanayake and Mr. T.D.Ranasinghe who made a remarkable influence on my entire course during the whole tenure of my research.

## **Development of non marring glove for coated glass industry**

**I.M.Sanjeewa Herath**

### **ABSTRACT**

There has been an increasing demand for specialty gloves during the last decade. The coated glass industry required a special Natural Rubber (NR) glove which provides cut resistance and abrasion resistance along with non marring features, which means preventing marks on any kind of object surface. Cut and abrasion resistance are required to protect the workers hand from glass and non marring features are required to protect the glass surface from the glove.

The presence of various substances in the latex and compounding ingredients, that migrate on to the glove coating surface is the main cause suspected for leaving marks on the surface of the glass.

After introducing a smooth latex coating and removing unnecessary chemicals, a series of glove samples were developed in various trials.

Industrial latex gloves are produced with rough surface coating to enhance the grip. The purpose of introduction of smooth coating was to avoid the physical impact of rough surface of the glove on the coated glass. There are some additives in the glove formulations to provide additional features such as color, odor which are not necessary for the function of the glove. Such unnecessary chemicals were also removed in this study.

Trials were carried out changing the leaching process, changing the type of NR lattice, introducing deionized (DI) water and adding 2% Hydrochloric acid to the leaching tank, introducing chlorination and introducing post leaching.

Though the formulation is modified removing unnecessary chemicals, migration of materials can not controlled completely. Therefore, the leaching process is introduced changing the temperature and leaching time. Further, leaching trials were carried out with deionized water to minimize the effect of ions in normal water. 2%HCl was introduced to the leaching tank to see whether the water soluble proteins could be removed from the latex which may cause for marring.

Natural latex also contains various substances. These substances migrate on to the glove surface and may cause for marring. There are various types of purified latex in the market which are called clean latex. This latex contains less protein, ions and other materials compared to the natural latex. Several types of clean lattices were used for the study.

Post leaching was also introduced to study the possibility of further improvements.

Introduction of chlorination process for supported gloves was found to introduce the best quality gloves which provide non marring features on the coated glasses.

The most suitable yarn type was selected from the information obtained from the literature survey and the best suitable yarn combination was identified and inner liner was knitted in order to achieve the best cut resistance.