New International Conference

Polymers in Defence and Aerospace Applications

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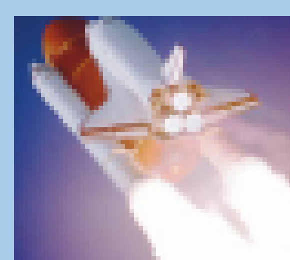


NOVEL NYLON/HALOGENATED BUTYL RUBBER BLENDS IN PROTECTION AGAINST WARFARE AGENTS

Marek Gnatowski, Polymer Engineering Company Ltd, Burnaby, B.C., Canada
J.D. (Jack) Van Dyke, Trinity Western University, Langley, B.C., Canada
Andrew Burczyk, Defence R&D Canada-Suffield, AB, Canada

Polymeric Materials in Protective Gear

Special Gear to Protect Humans and Resources Against an Aggressive and Hostile Environment

- Space
- Underwater
- Natural or man made disasters
- War

Polymeric Materials in Protective Gear

Polymeric Materials are Used in Protective Gear for the Following Reasons:

- Wide range of mechanical properties
- Relatively resistant to hostile and aggressive environment (if properly selected)
- Easy moulding
- Wide range of coefficient of friction
- Light weight
- Variety of colours

Polymeric Materials in Protective Gear

Materials Properties

Material	Elastomeric Behaviour	Modulus of Elasticity MPa	Density g/cm^3	Coefficient of Friction	Barrier Properties
Polymers	Yes (in selected materials)	10 – 40,000	0.8 – 2.3	0.05 - 4	Variable
Metals	No	300 – 400,000	2 - 20	0.15 - 5	Excellent
Ceramics and Glasses	No	200,000 – 450,000	2.5 - 6	0.6 - 1	Excellent

Polymeric Materials in Protective Gear

Properties of selected commercial polymeric materials

Material		Resistance to			Mechanical Behaviour		Processing Friendly
		CW[d]	Water*	Oil and Fuels	Engineered Plastic	Elastomer	
Butyl, Halogenated Butyl Rubber	(C,B) IIR	4	4	1	1	4	2-3
Natural Rubber (polyisoprene)	NR	1	1-3	1	1(3)[c]	4	2-3
Chloroprene	CR	1-2	2-3	4	1	4	2-3
Nitrile Rubber	NBR	1-2	3	4	1	4	2-3
Santoprene (PP/EPDM)	TPE	1	3	1-2	1	4	4
Polyurethane Elastomer	PU	1-2	2-3	3-4	1	4	3-4
Polyamides (Nylons)	PA	3-4	3 (1)[a]	4	4	1	3-4
Aromatic Polyesters (PBT, PET)	PET, PBT	4	4 (2)[a]	4	4	1	3-4
Polyvinyl Alcohol (PVOH)	PVA	2-4	1	4	3	1	1-3[b]
Polystyrene	PS	1	4	1	2-3	1	4
HDPE	HDPE	1	4	3-4	2-3	1	4

4 – excellent **3 – good** **2 – acceptable** **1 – unacceptable**

a. immersion in hot water
b. requires modification
c. ebonite
d. CW – chemical warfare agent
* long term exposure

Polymeric Materials in Protective Gear

Easy Moulding

- Compression moulding
- Injection moulding
- Extrusion

Materials Selection for Blending

A. Nylon 12

- Excellent barrier properties
- Excellent mechanical properties
- Relatively low processing temperature (190 – 220ºC)
- Commercially available

B. (Halogenated) Butyl Rubber

- Good mechanical properties
- Good warfare agent resistance
- Commercially available

Nylon Chlorobutyl Rubber Blend

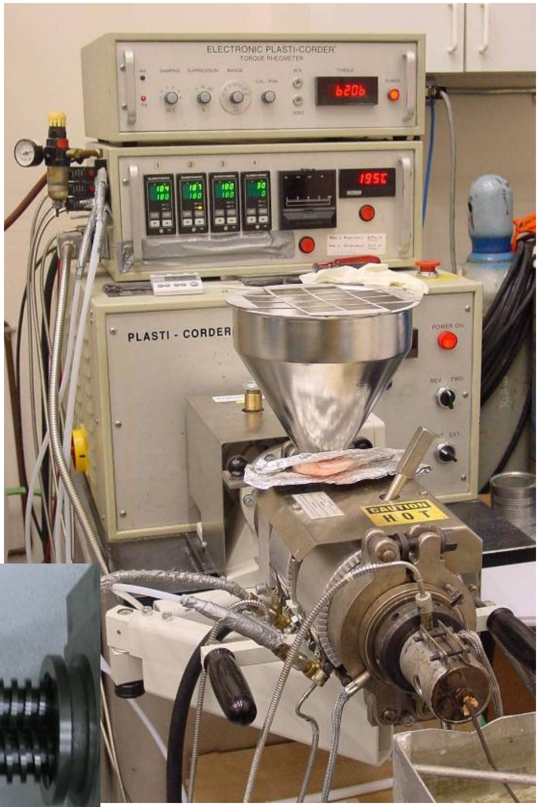
Challenges in Blending

- Physical incompatibility of nylon and halogenated butyl rubbers
- Incorporation of over 50% rubber into the blend
- Maintaining thermoplastic properties and good mechanical properties of blend

Nylon Chlorobutyl Rubber Blend

Blending Procedure

Batch Mixing



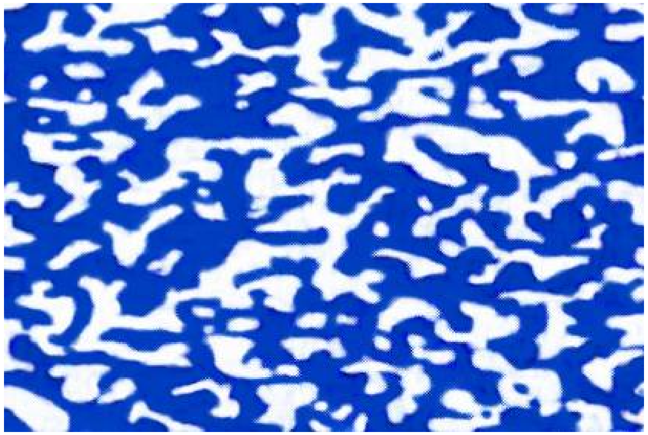
Extrusion

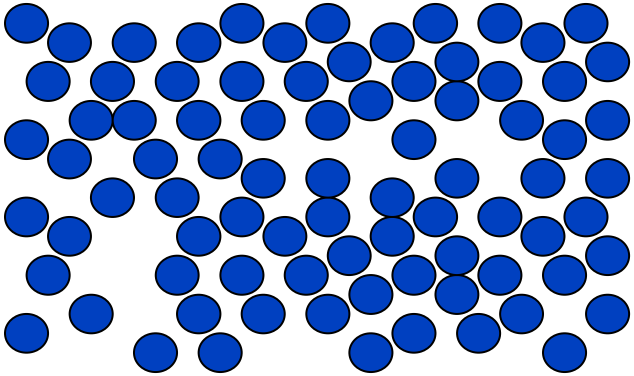
Nylon Chlorobutyl Rubber Blend

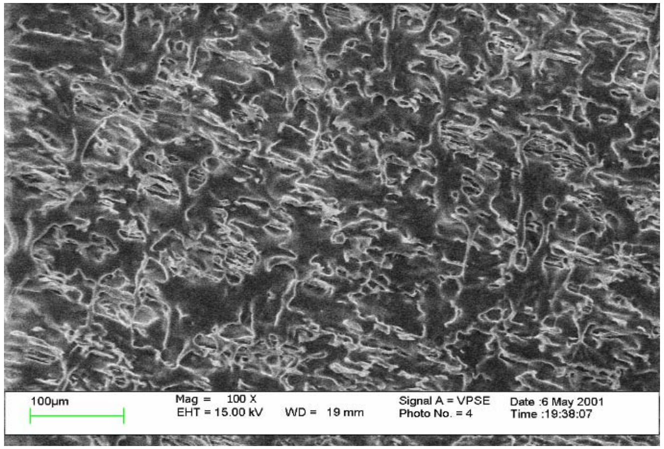
The Dynamic Vulcanization Process

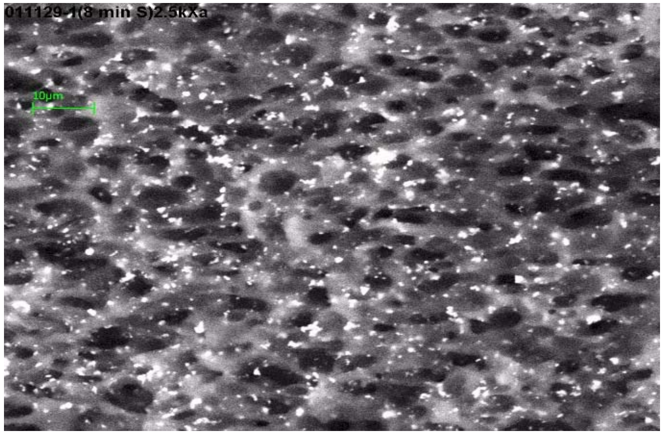
regular blending

dynamic vulcanization



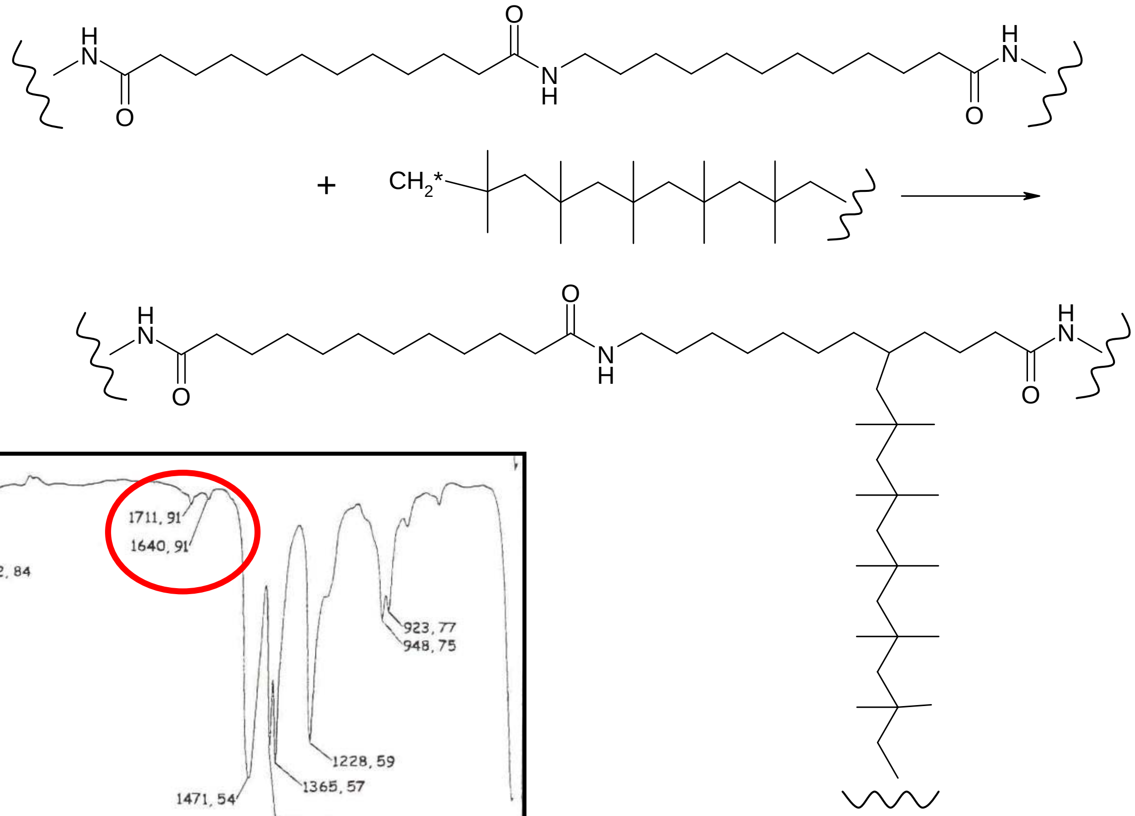


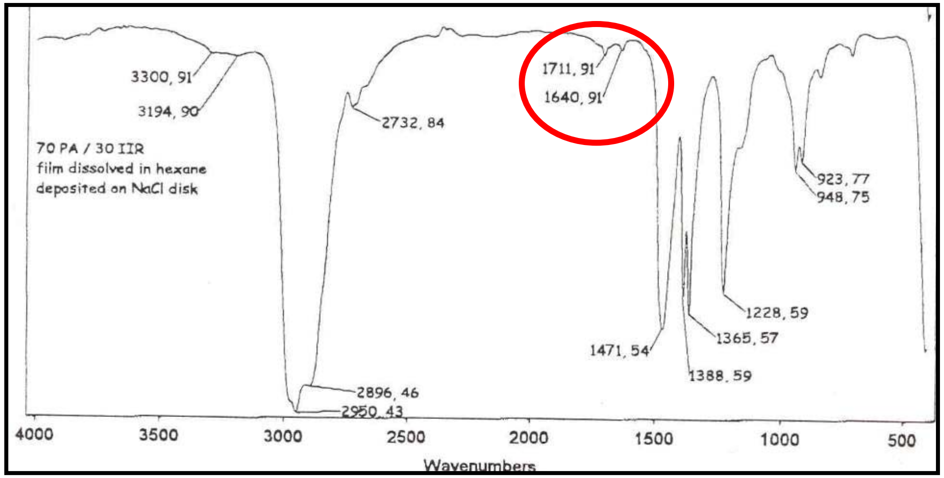




Nylon Chlorobutyl Rubber Blend

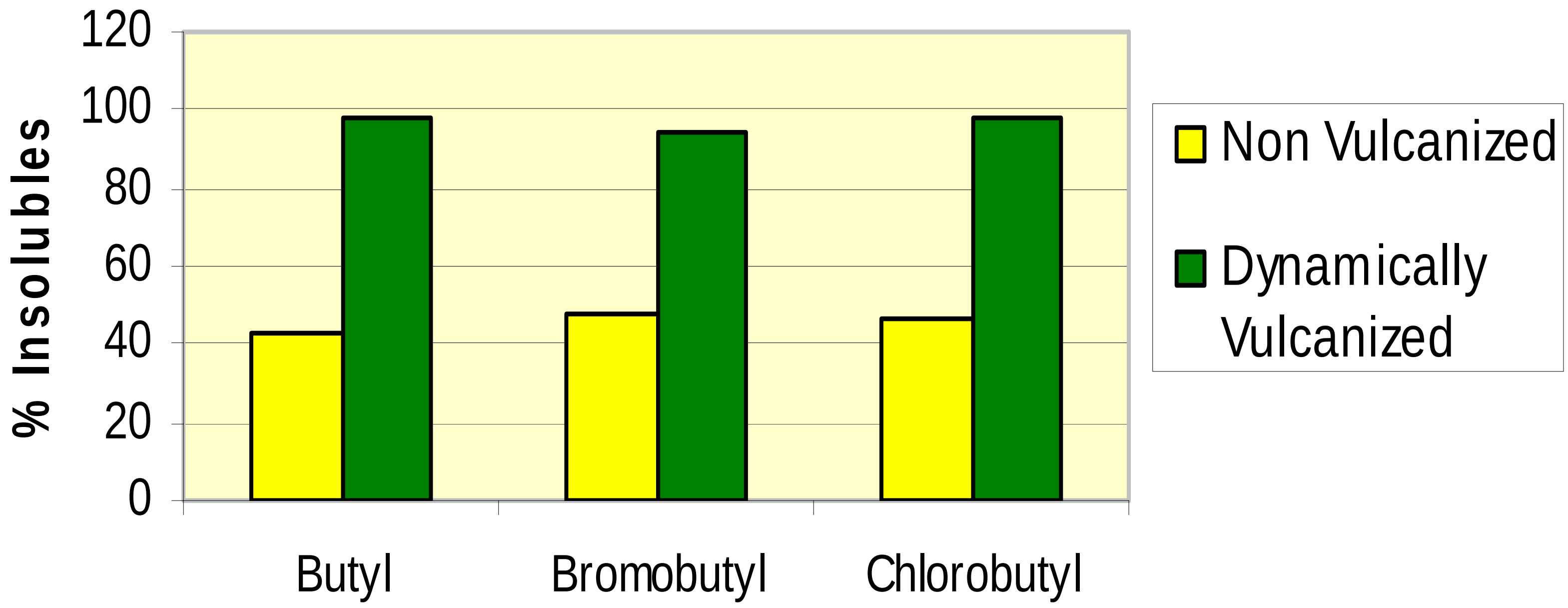
Potential Compatibilization of Blend





Nylon Chlorobutyl Rubber Blend

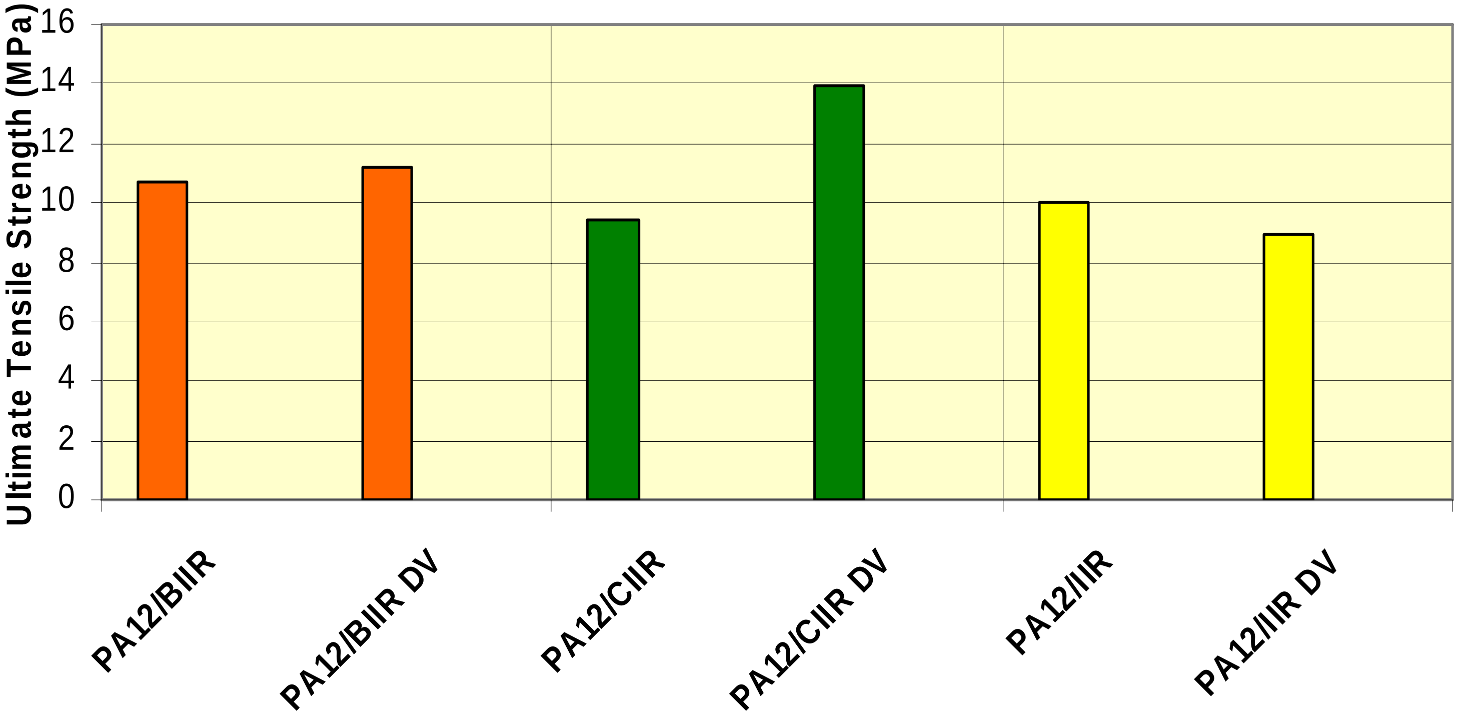
% Insolubles – Non-vulcanized vs. Dynamically Vulcanized



Nylon Chlorobutyl Rubber Blend

Comparison of Tensile Strength

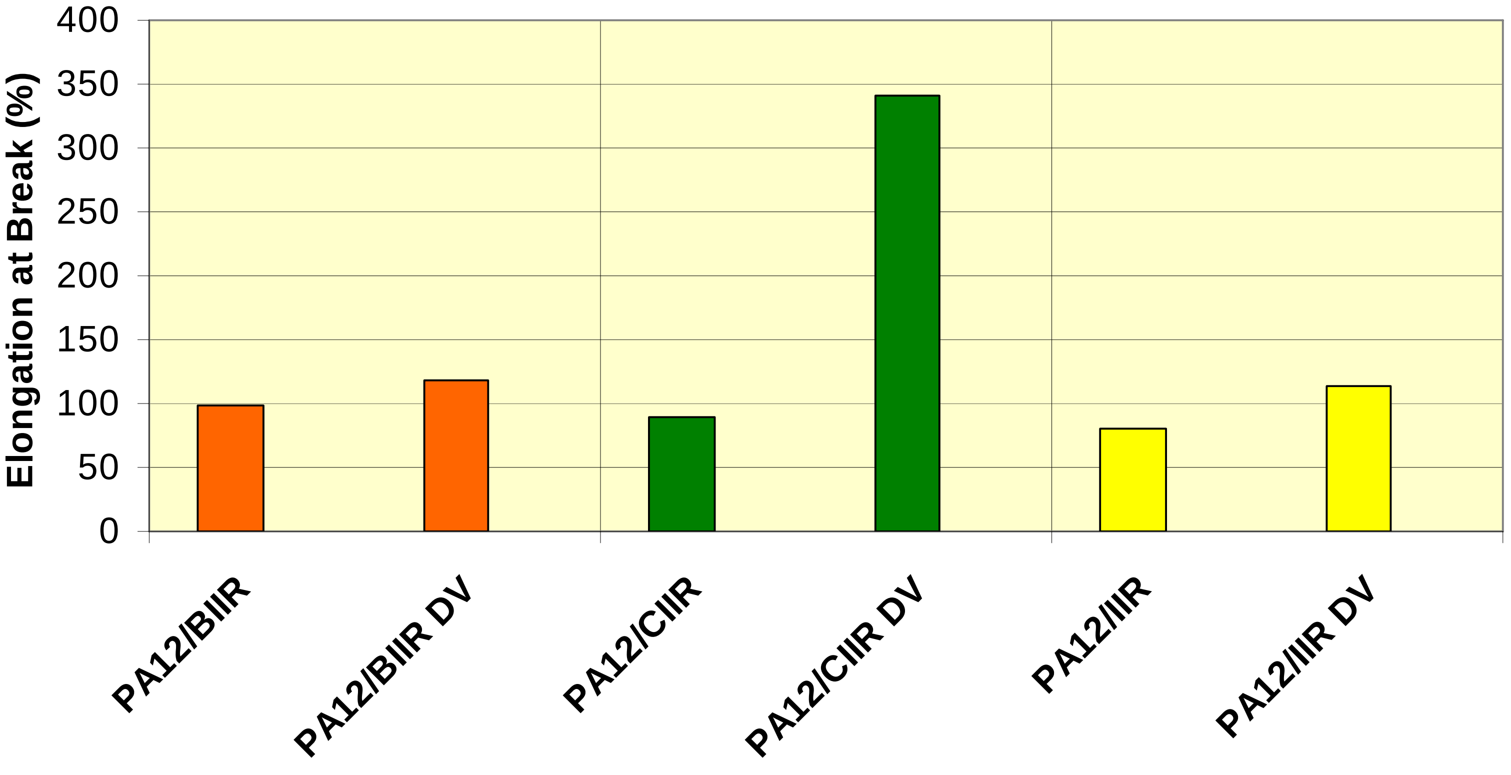
Non-vulcanized vs. Dynamically Vulcanized



Nylon Chlorobutyl Rubber Blend

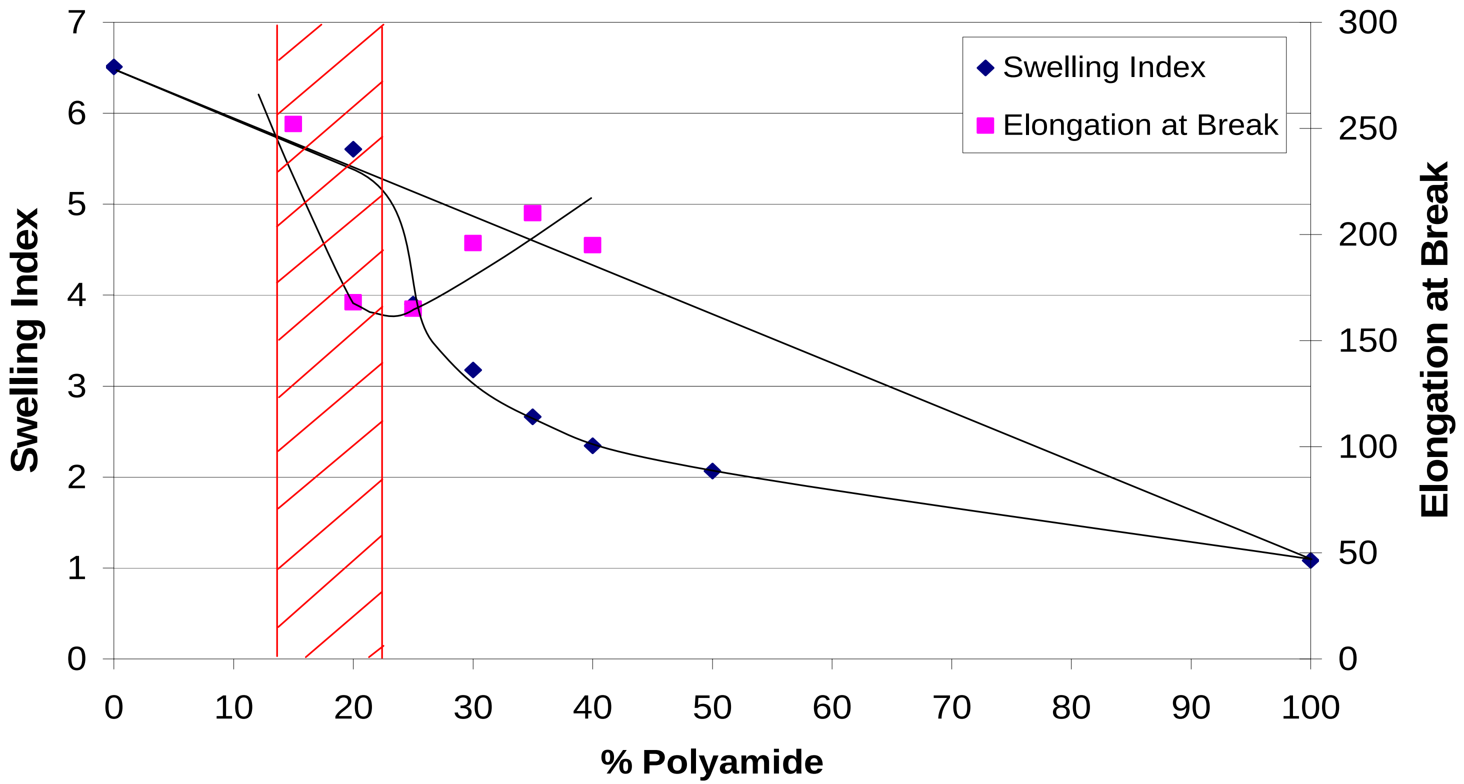
Comparison of Elongation

Non-vulcanized and Dynamically Vulcanized



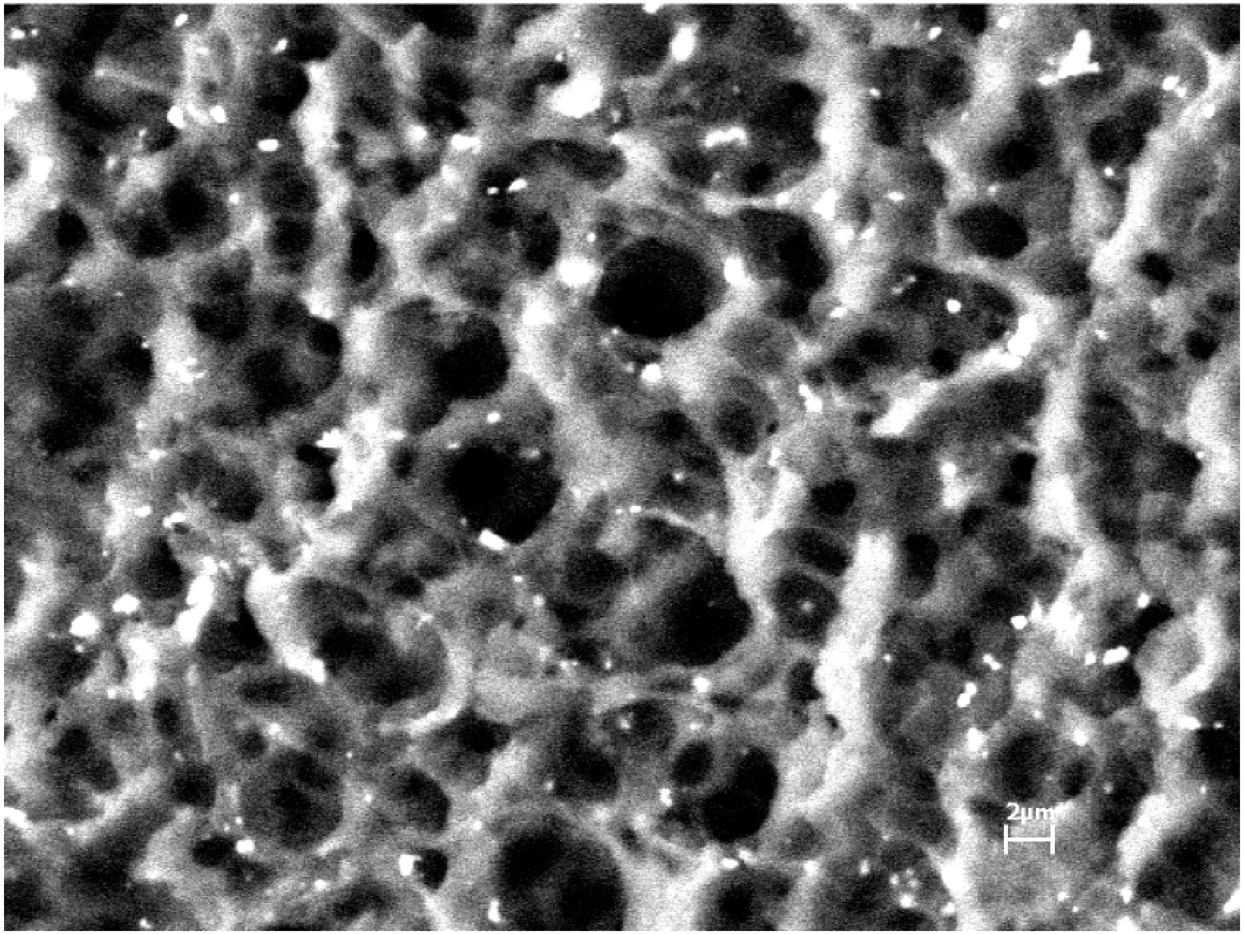
Nylon Halogenated Rubber Blend

Swelling index and elongation at break for dynamically vulcanized blends in $CHCl_3$



Nylon Halogenated Rubber Blend

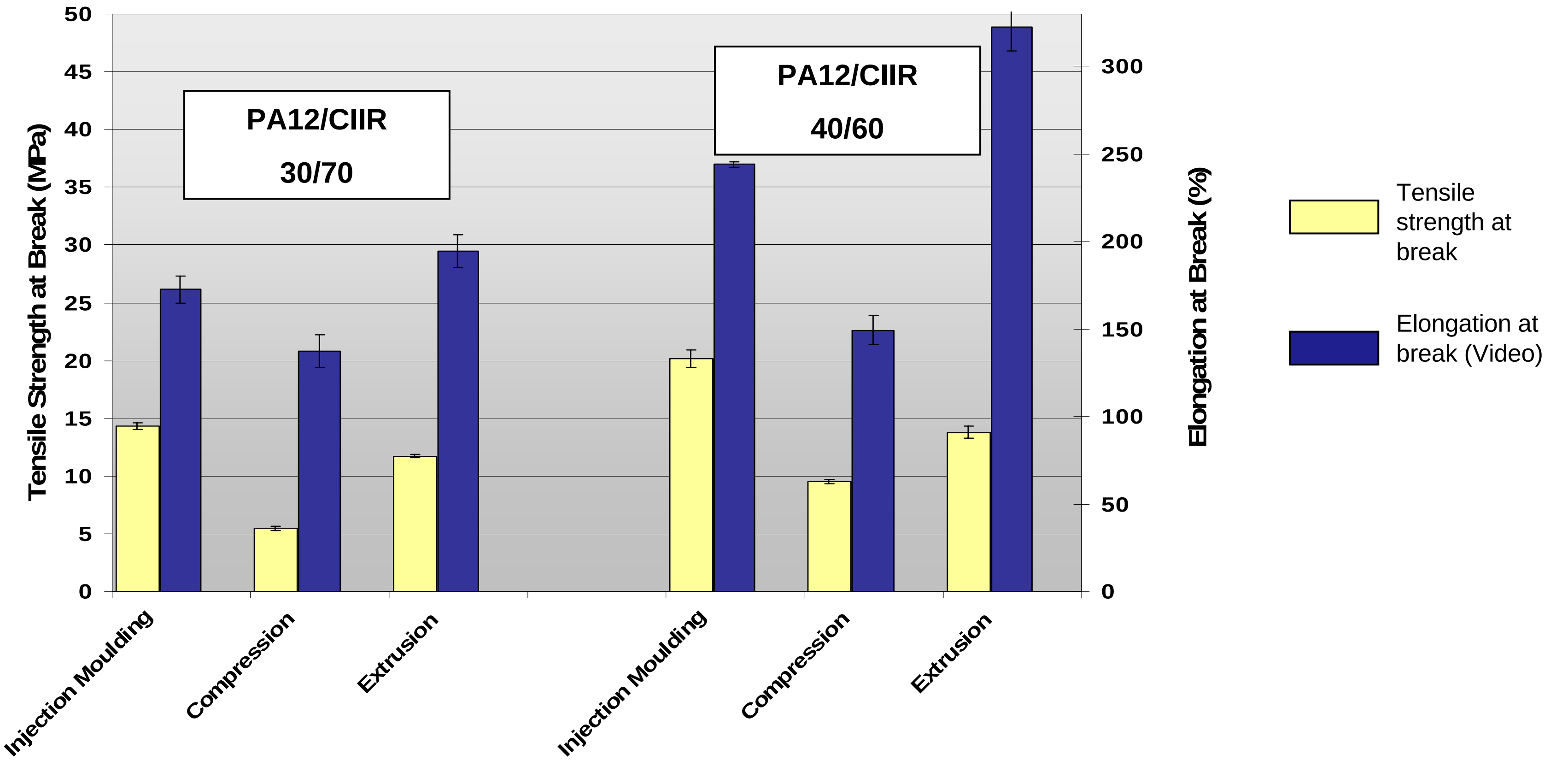
Blend Microstructure



Nylon-Chlorinated Butyl Rubber Blend

Effect of Moulding Conditions on Tensile Strength and Elongation at Break

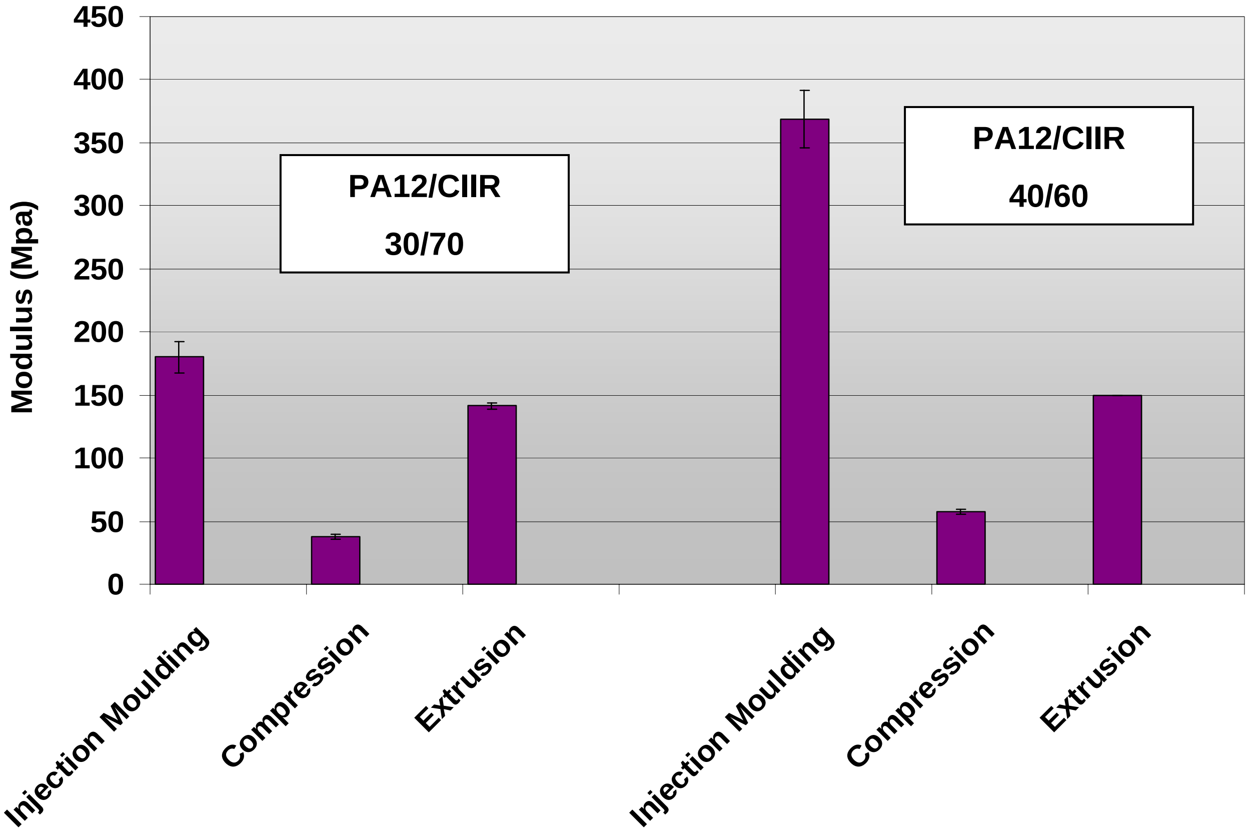
Testing according to ASTM D 638M, specimen type M-III



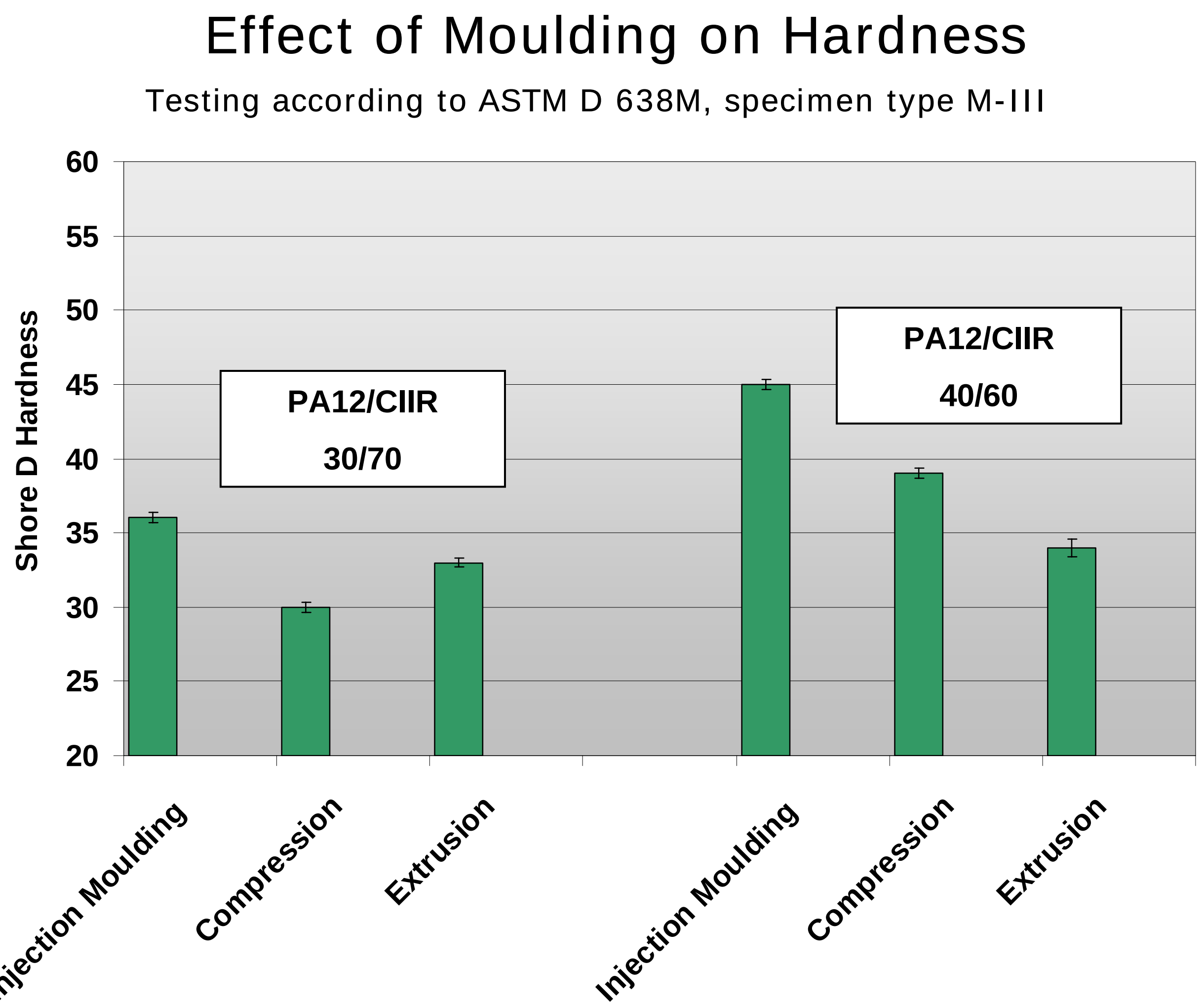
Nylon-Chlorinated Butyl Rubber Blend

Effect of Moulding Conditions on Tensile Modulus

Testing according to ASTM D 638M, specimen type M-III

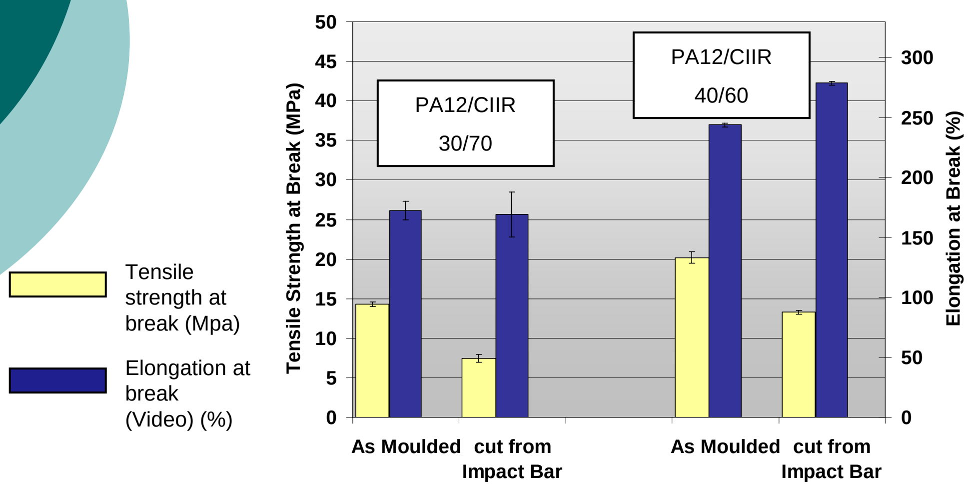


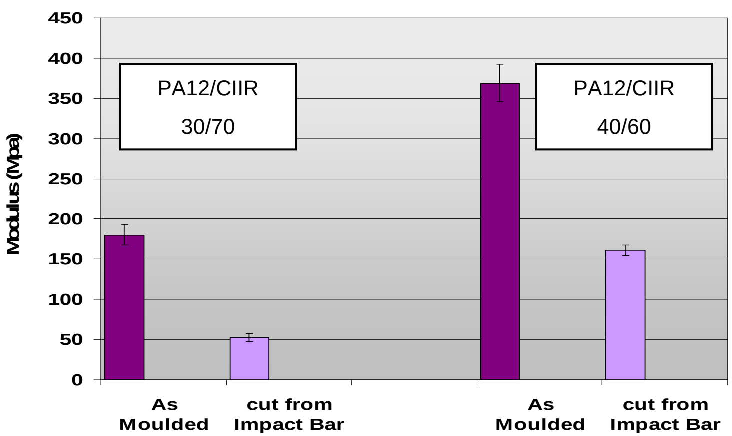
Nylon-Chlorinated Butyl Rubber Blend

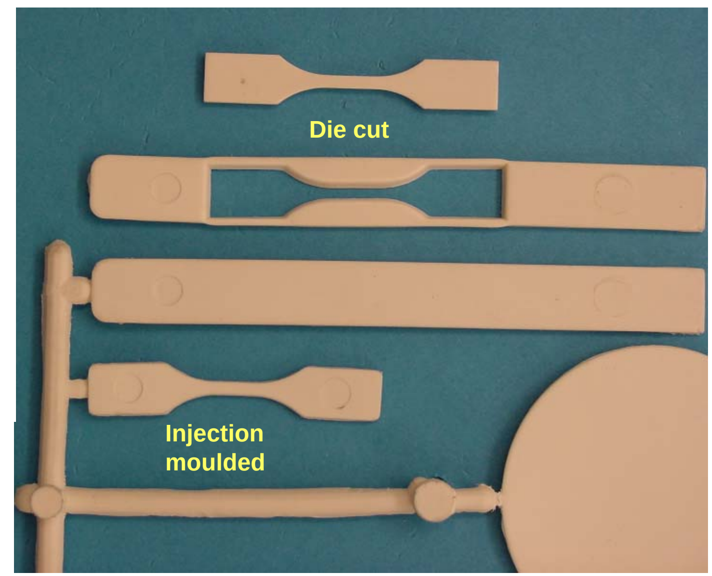


Nylon-Chlorinated Butyl Rubber Blend

Effect of Flow in Mould on Mechanical Properties

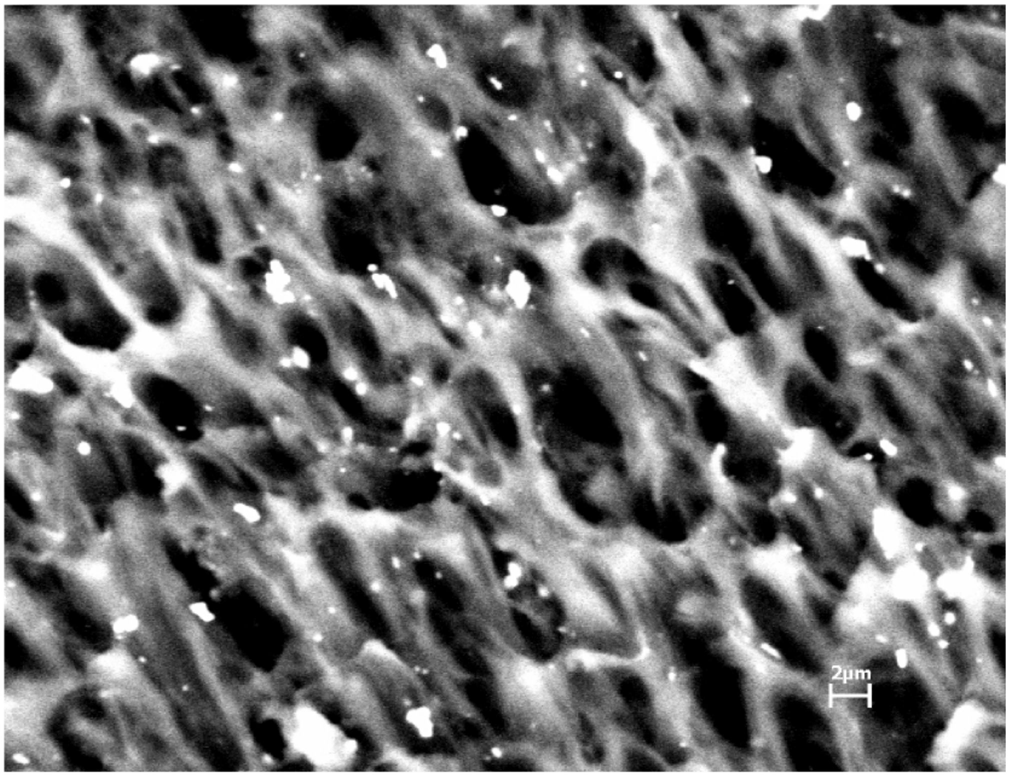


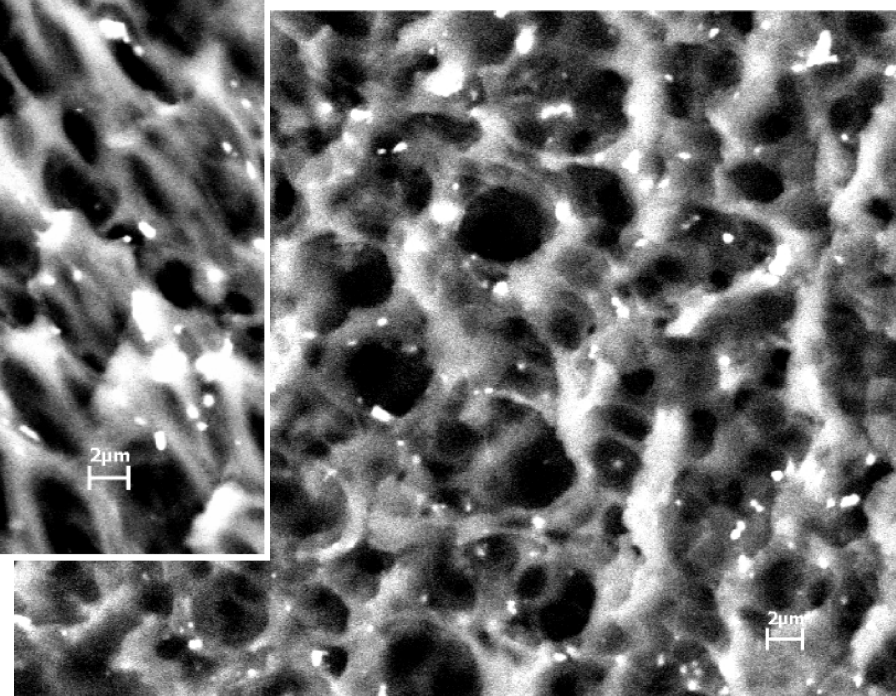




Nylon-Chlorinated Butyl Rubber Blend

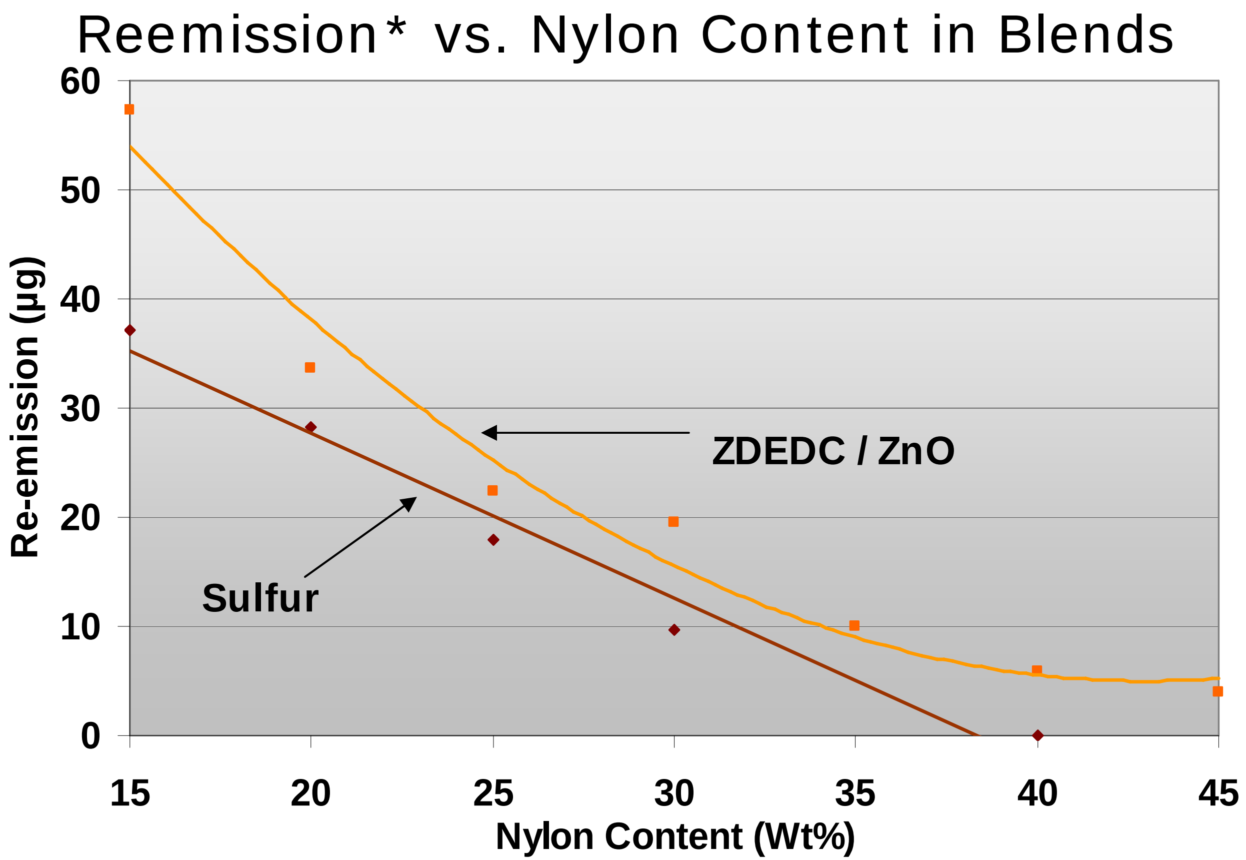
Effect of Flow on Blend Microstructure





Nylon-Chlorinated Butyl Rubber Blend

Penetration* for all samples was 0 µg at testing conditions



*method of testing described in C.L. Stevens presentation "Nylon-12 Nanocomposite Thin Films as Protective Barriers"

Polymeric Materials in Protective Gear

New Development of Special Polymeric Materials Will Bring Revolutionary Changes to Protective Equipment

- Increase protection efficiency
- Decrease the burden on personnel
- Decrease manufacturing costs

Post World War II

1980's

The Future

Conclusions

1. Nylon can be blended with butyl or halogenated butyl rubber to obtain material with thermoplastic elastomer properties

2. Properties of the blends depend on nylon/rubber ratio, mixing conditions, and vulcanizing agent used

3. Mechanical properties also depend on moulding conditions and mould geometry

4. Nylon-chlorobutyl thermoplastic elastomers showed excellent resistance to penetration and reemission of warfare agents

5. Nylon-chlorobutyl blends showed significantly better resistance to hydrocarbon and chlorinated hydrocarbon solvents than could be expected from the rubber content in the blend

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DRDC – Suffield

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