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FROM FASHION TO FACTORY
A New Technological Age

Injection Moulded Biodegradable Polyurethane Shoe Soles: Development, Characterization and Process Optimization

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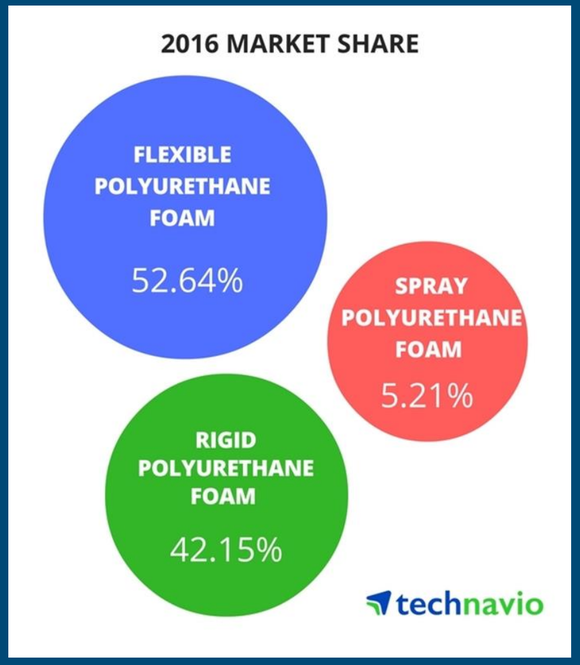
Background

➢ **Currently different types of soling material like leather, rubber, polyurethane, PVC, EVA, TPR and TPU have been used in footwear.**

➢ **PU soles have been replacing PVC soles in the past decade, and the majority of the formal and higher priced leather shoes use PU for soles.**

Advantage	• Versatile physical properties • Light weight • High Production Rate
Disadvantage	• Expensive comparing to other non-leather footwear



Problem Vs Solution

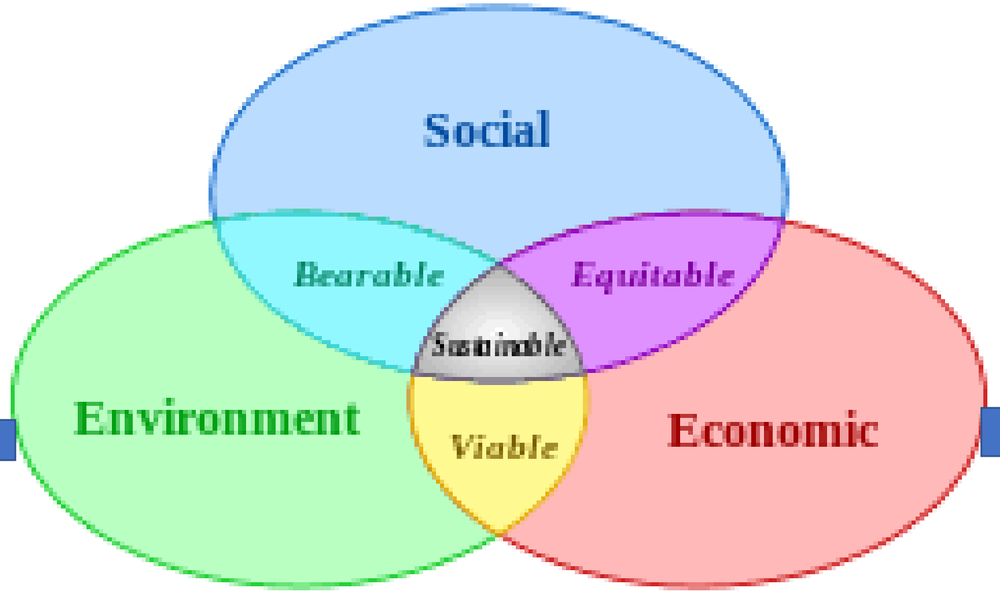
Growing Population of Universe

Increase in Waste Causes Disposal Problem

Escalating Consumption of Footwear

- Waste Management
  - Recycling
  - Biodegradation

sustainabilitv

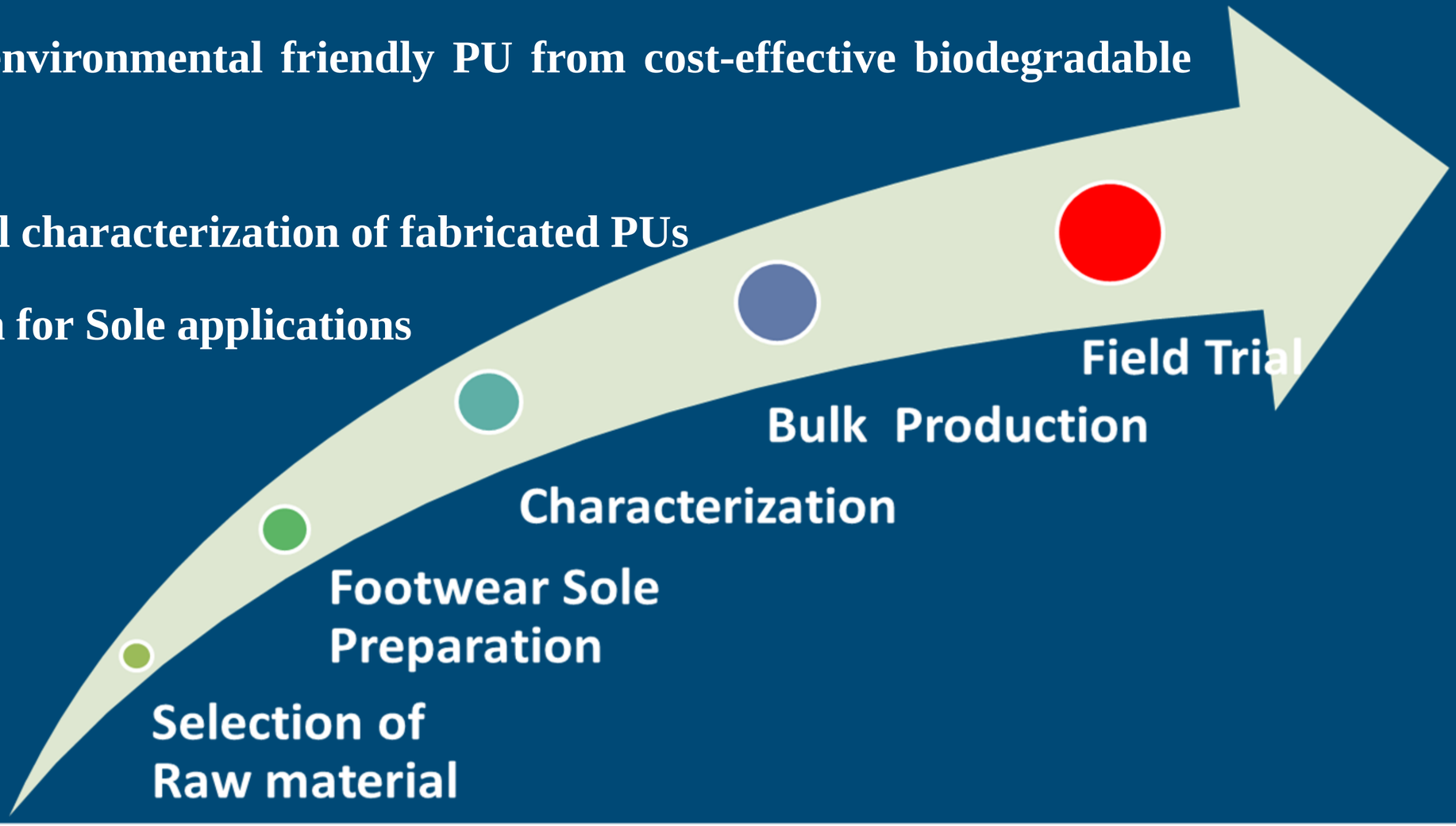


Biodegradable/ Renewable Precursors (expensive)

Polyurethane Foam

Objective

- ♠ Preparation of environmental friendly PU from cost-effective biodegradable polymer
- ♠ Physico-chemical characterization of fabricated PUs
- ♠ Characterization for Sole applications



Selection of raw Material

- **Cost-effective**
- **Without modifying the existing production facilities**
- **Compatibility**
- **Environmental friendly**

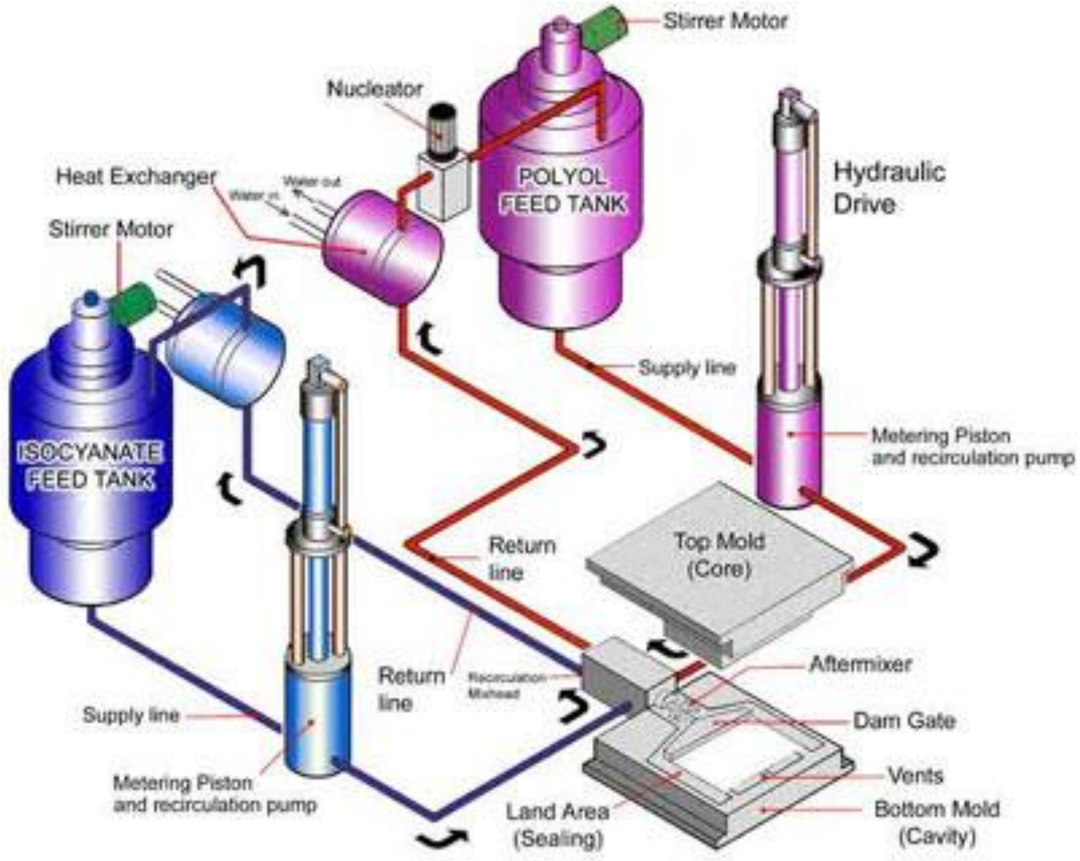
Challenges involved in selection of reactants

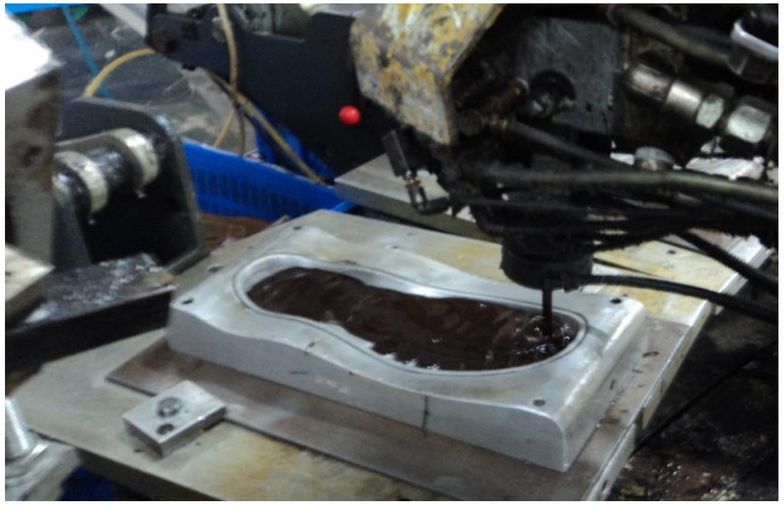
- Inherent properties of reactants
- Desirable physico-chemical properties of foams for footwear application
- Cost effective, compatibility with existing raw materials, biodegradability, biocompatibility

Why Polycaprolactonediol?

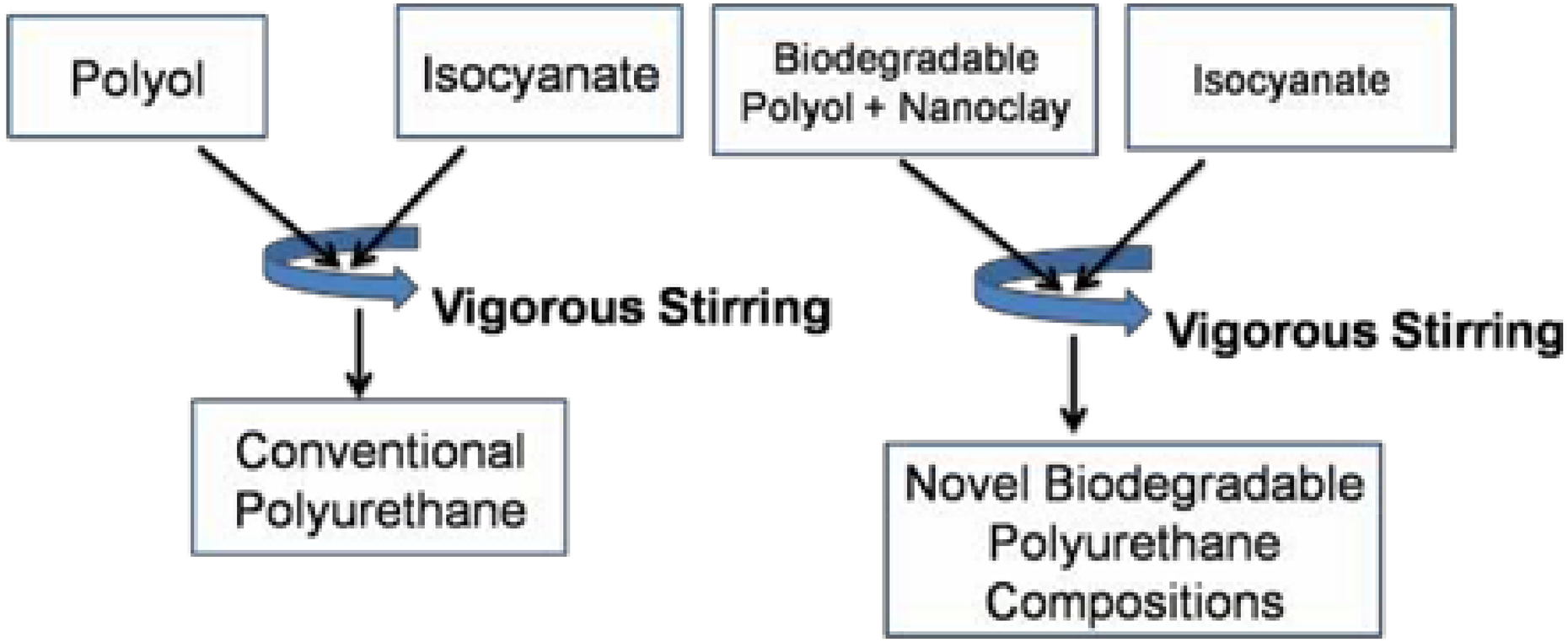
- ♠ Cost effectiveness
- ♠ Biodegradability
- ♠ Polyester based PU > Polyether based PU
- ♠ Environmental friendly
- ♠ Availability

Foowear Sole Preparation- Reaction Injection Molding





Development of Biodegradable PU- nano-clay based Shoe soles



Development of Injection molded Biodegradable PU-nano-clay based Shoe soles

- **RIM unit in Coim India Pvt Ltd, Bahadurgaur, Haryana, India**
- **The polyurethane soles are manufactured with different nanoclay percentages like (0.5%, 1%, 1.5%, 2% and 3%) and with different isocyanate index like (78, 85, 95, 100, 105 and 110) and cup test is performed in order to check the sole properties using indentometer.**

Raw Materials	Brand Name	amount
Polyol	CAPA7201A	100 %
Isocyanate	T400	85 (ICN index)
Catalyst	C2LPE20	12.2%

Optimization of Process

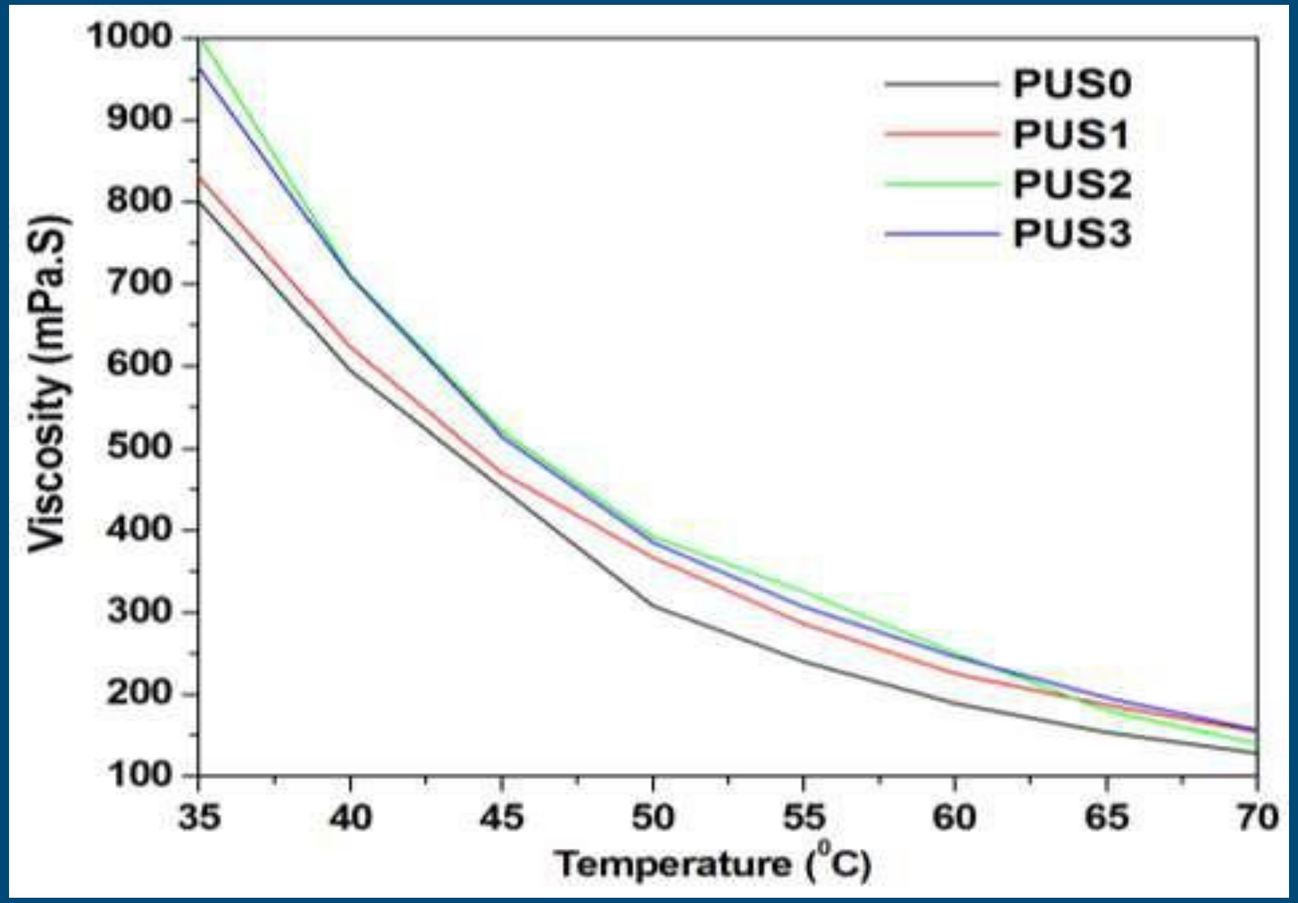
Description	Setting	Description	Setting
Material	PCL+ Catalyst+ Water+ ISO+ NP (1%)	Poly delivery	28.08 g/sec
Mixing Ratio	100:95	Poly speed pump	1798 rpm
Poly tank Temp	48°C	ISO delivery	21.92 g/ sec
Poly pipe Temp	45	ISO speed pump	911 rpm
Poly Temp	48	Cream time	5 sec
ISO tank Temp	42	Tact Free time	22 sec
ISO pipe Temp	39	Pinch time	39 sec
ISO Temp	42	Free Rise Density	0.174 g/cc
Mould Temp	62	Demolding time	6 minutes

Developed PU Soles

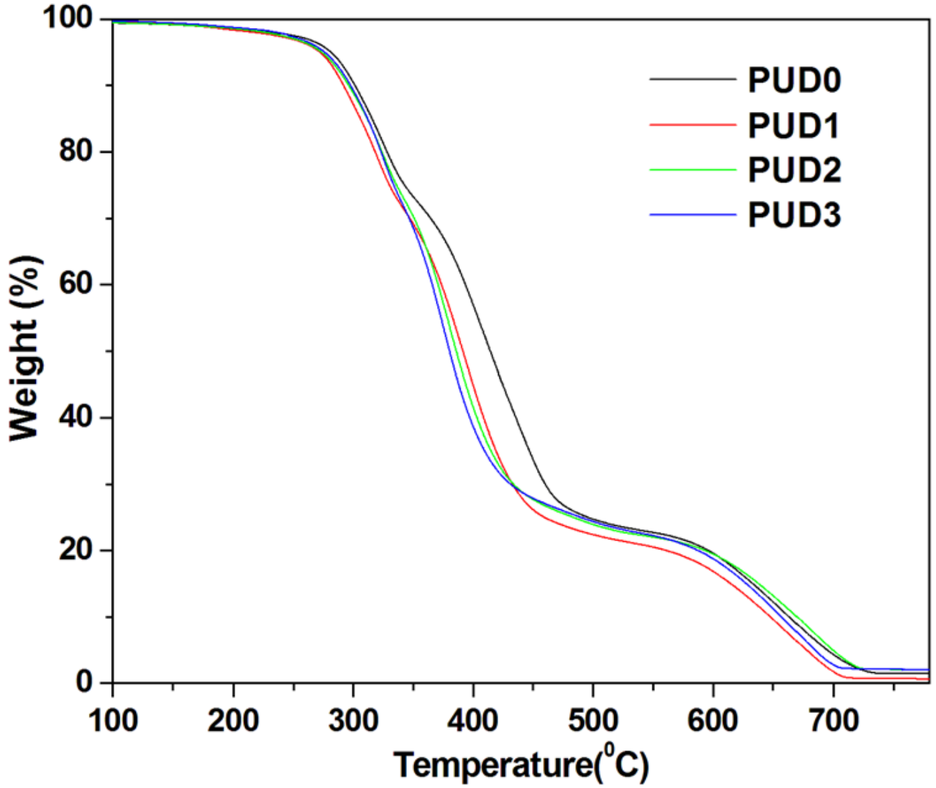
Physical Properties

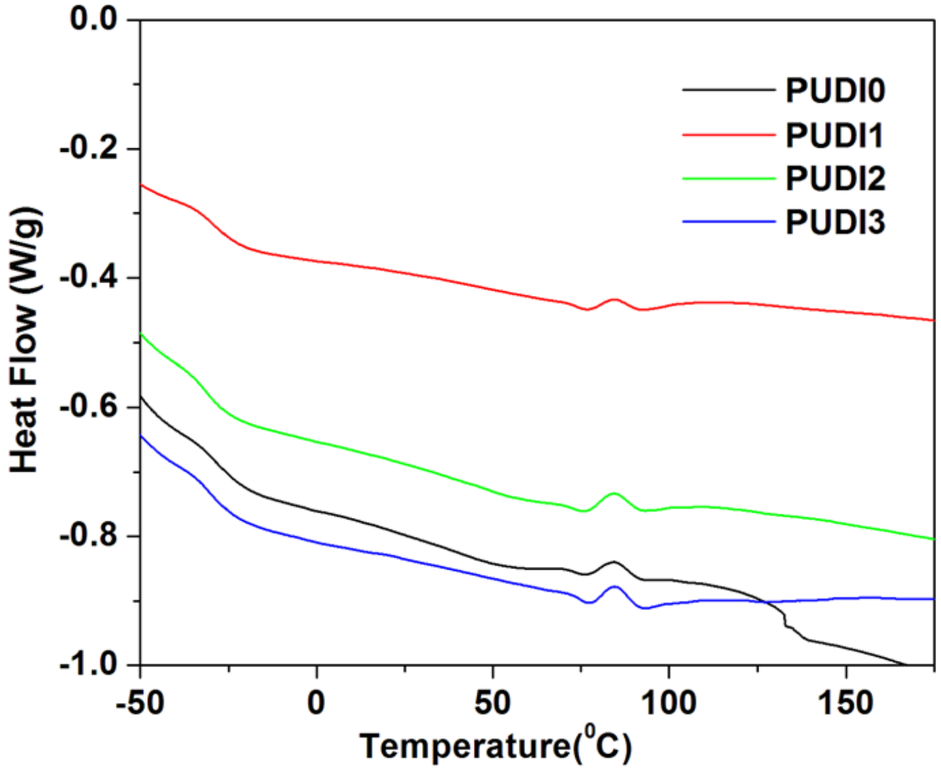
Sample ID	% nanoclay	Shore A Hardness	Density (g/cc)	Abrasion (mm^3)	Tensile Strength (Mpa)	Elongation at Break (%)	Flexing resistance (cycles)	ICN Index
PUBC0	0	60	0.43	50.0	7.8	261	10000	85
PUBC1	0.5	45	0.44	137.7	2.7	175	30000	87
PUBC2	1	47	0.43	159.6	4.8	235	20000	47
PUBC3	2	52	0.45	142.3	4.2	167	5000	52

Viscosity Study



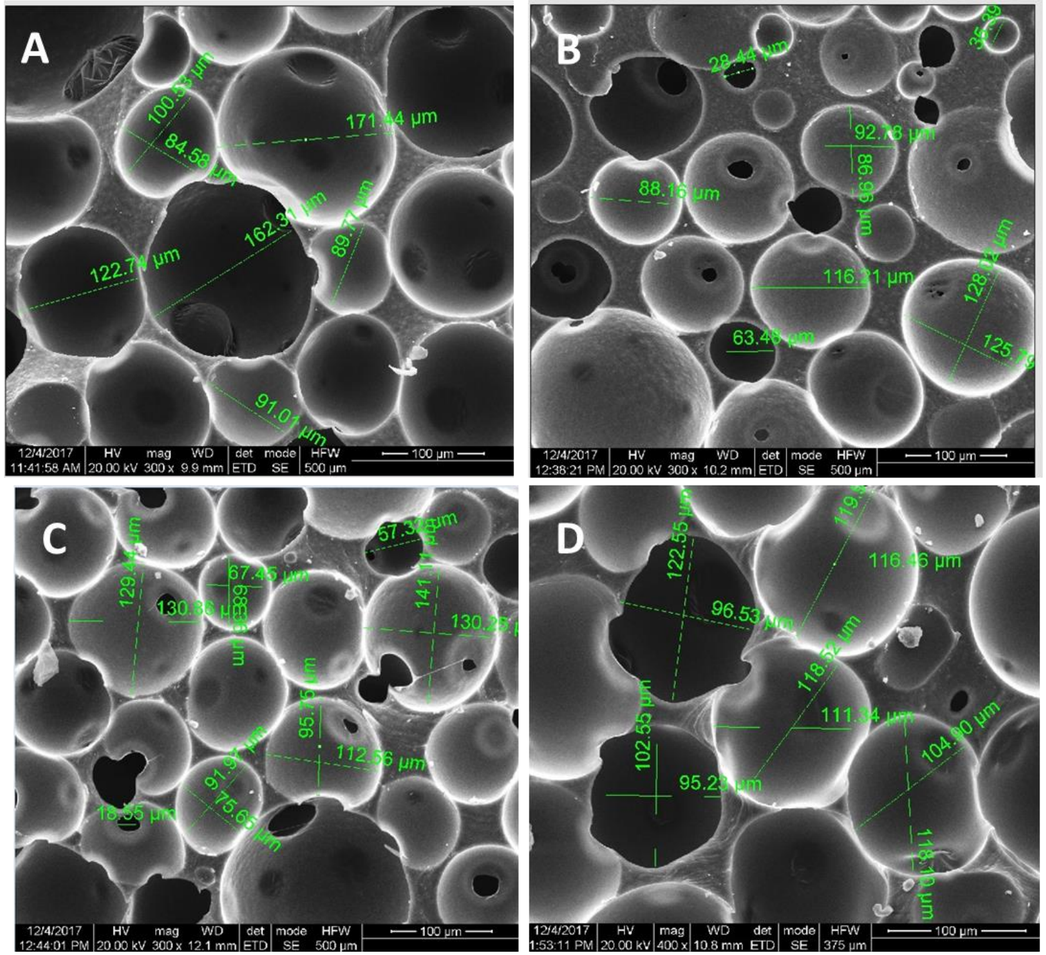
TGA & DSC





There is no significant change in TGA and DSC of PU with Nanoclay as the nanoclay content is less.

SEM pictures of cross section at 300 X magnification of Samples A) PUBS, B) PUBS-0.5 NP, C) PUBS-1% NP, D) PUBS-3% NP



Bulk Production - Physical Properties

120 pairs of footwear were developed at Manjeet Plastics Industries, Bahadurgaur, Haryana, India for distribution to different professionals and for testing the used footwear after 3, 6 and 9 months of regular usage.

Properties	Commercial PU	Biodegradable PU (0 % Nanoclay)	Biodegradable PU (0.5 % Nanoclay) (-5 g weight)
Hardness, Shore A	53-57	52- 56	55- 59
Density, g/cc	0.4	0.39	0.35
Abrasion (mm^3)	120	90	110

Field Trial

- The injection molded PU footwear based on biodegradable polyol using the existing RIM facilities in PU footwear industry are distributed to CLRI staff, research scholars and contract workers and also to school students. After 50 days of regular usage, feedback is good and the footwear and sole are intact.

Conclusions

- From the above results, it can be concluded that biodegradable polyol based PU shoe soles have been developed which is suitable for PU footwear application.
- The optimized process can be used for making direct injection molded PU footwear using biodegradable polyol without changing the existing facilities of PU footwear industries.
- To reduce the cost of polyol, nanoclay based blowing agent is added and the properties of PU clay composite based soling materials are developed and characterized .

Conclusions

- As volume is increasing and free rise density is decreasing with the addition of nanoparticles, it can implicit that the interlayer water molecule is reacting with isocyanate and generates foaming.
- So the appropriate adjustment of isocyanate index was also performed in our present invention to reduce the quantity of polyol used.
- Thus the developed technology is cost effective and can be implemented without affecting the existing industrial production facilities.

Acknowledgment

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- Manjeet Plastics Industries
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- Co- PI of this project- Dr. Sujata Mandal, Senior Scientist, & Dr. BN Das, Chief Scientist, CSIR-CLRI

ctcp Portuguese Footwear Technological Centre | APICCAPS Portuguese Footwear, Components and Leather Goods Manufacturers' Association | UITIC International Union of Shoe Industry Technicians

Thanks for your kind Attention!!!

Obrigado pela vossa atenção!!!

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