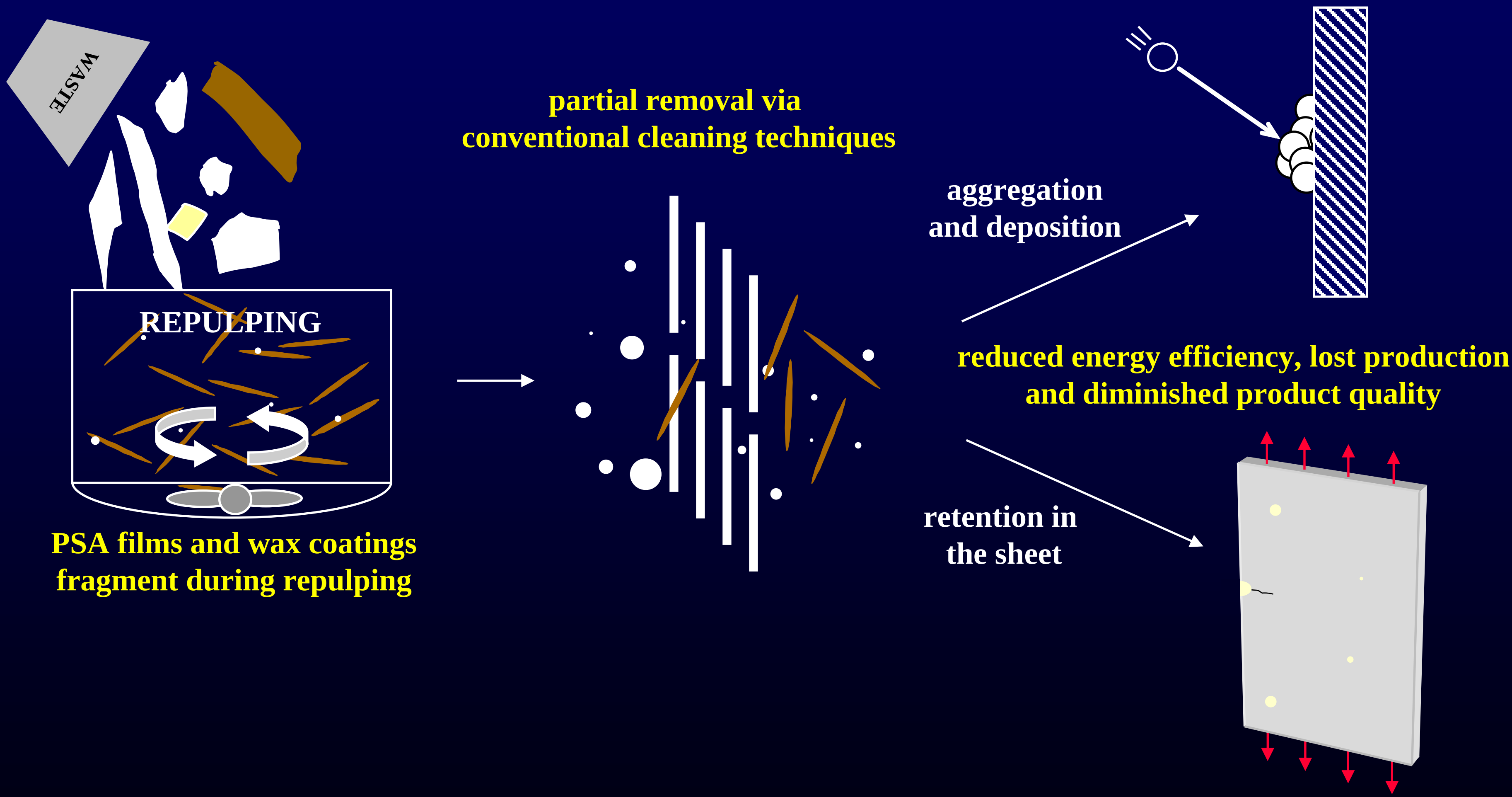
Development of Screenable Wax Coatings and Water-Based Pressure Sensitive Adhesives

Project DE-FC36-04GO14309

Principal Investigator:
Steve Severtson - University of Minnesota

Research Partners:
USDA FS Forest Products Laboratory
Franklin International
The International Group
Boise Cascade Corporation

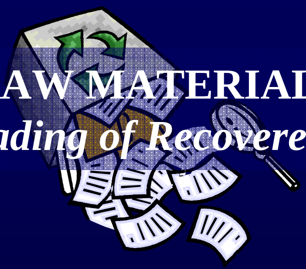
Generation of Contaminants from PSA Films and Wax Coatings



Annual Cost to U.S. Paper Producers

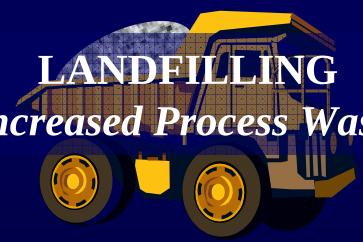
MILL PRODUCTION
Reduced Efficiency, Added Cleaning and Waste Handling Costs

$527 MM



RAW MATERIAL
Downgrading of Recovered Paper

$150 MM



LANDFILLING
Increased Process Waste

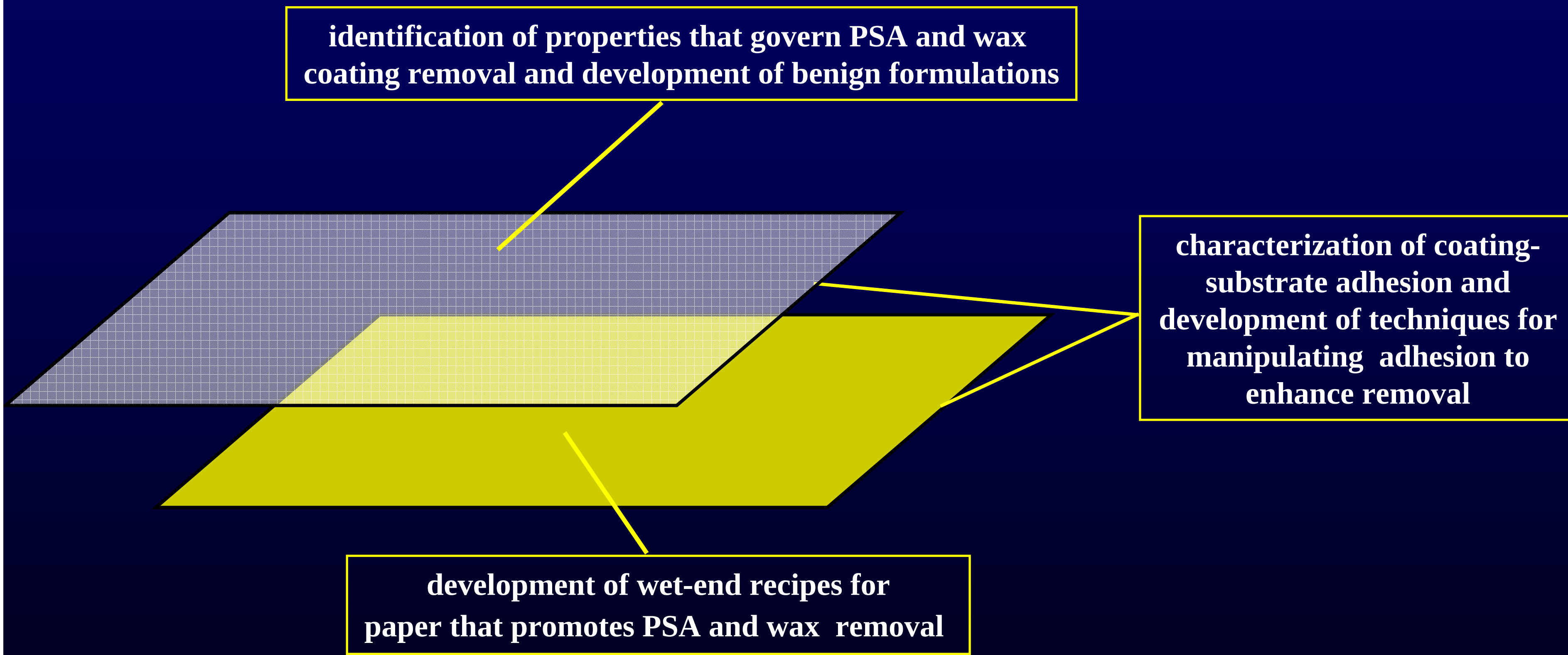
$14 MM

In addition to the economic impact, it is estimated that an extra 800 MWh are consumed by industry due to PSA and wax contamination and greater than 1 million additional tons of fiber is landfilled

Sources: Friberg, T., Progress Paper Recycling, 1996, 6, 70 . 2004 AF&PA Recycling Task Group Report, AF&PA/FBA Symposium, October 10, 1996, Chicago.

Project Objective

Development of product engineering approaches to provide for enhanced PSA and wax coating removal during the screening of recycled fiber

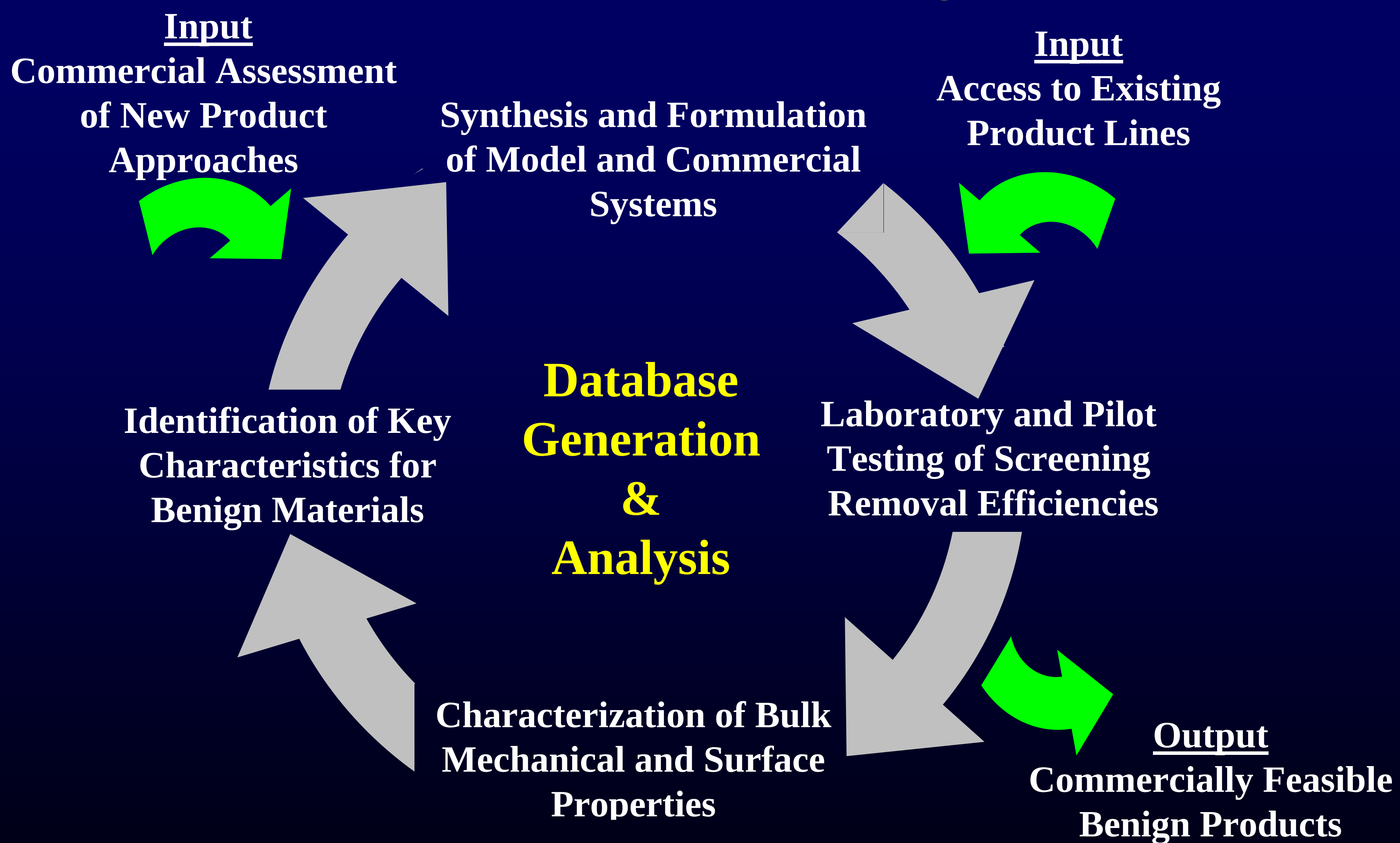


The impact on paper recycling operations should be a design parameter in the development of all adhesive and coating systems formulated for paper applications

Project Structure

A Complimentary Partnership

Research Strategy

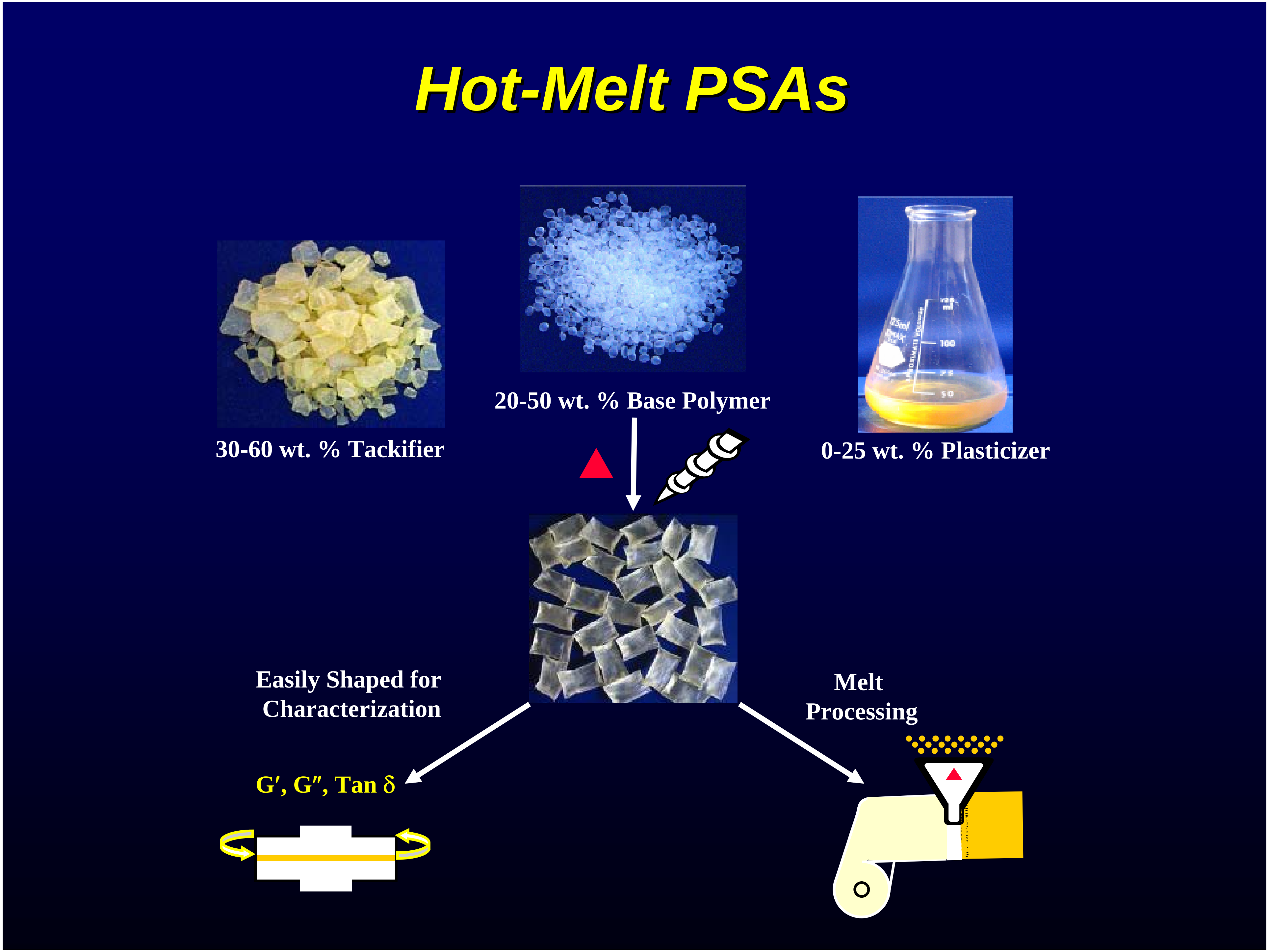


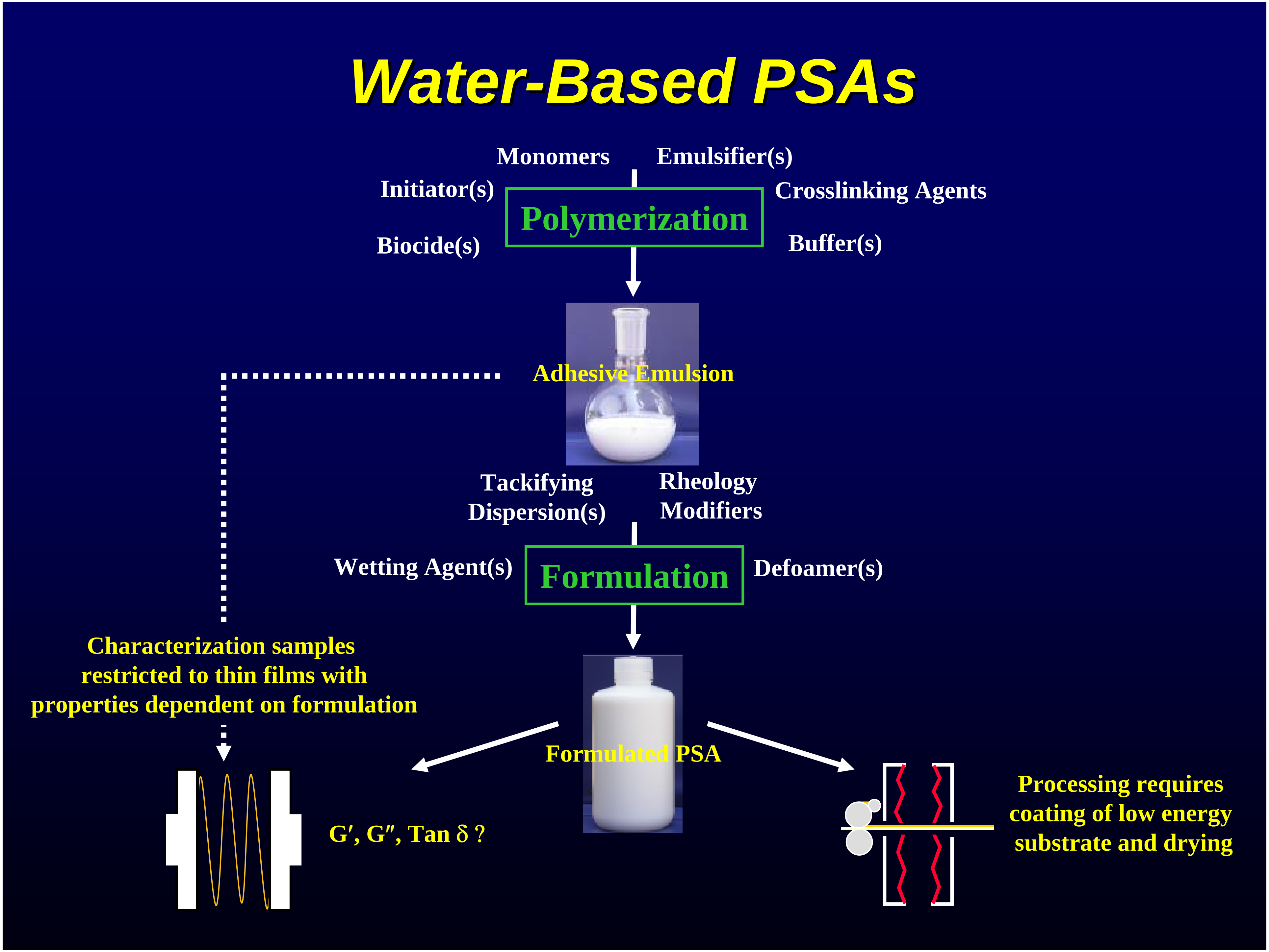
Commercialization of Benign Hot-Melt PSA

Project DE-FC07-00ID13881

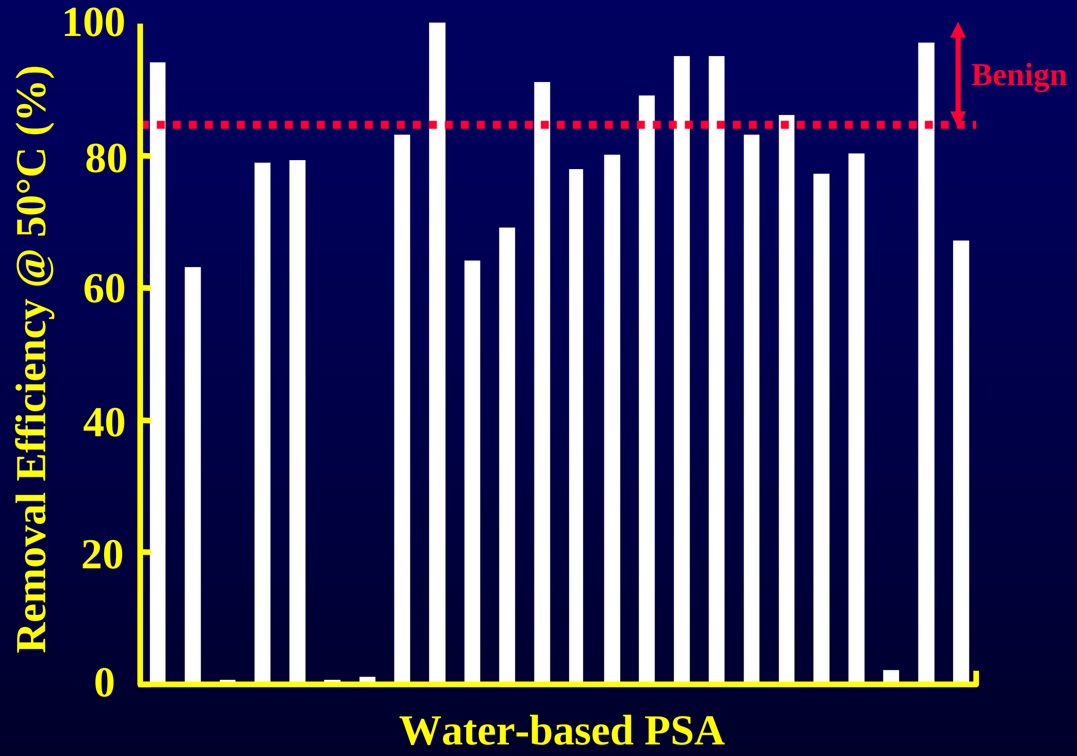
PS Laminate Engineering - matching the right PSA with the facestock properties required to eliminate the negative impact of the adhesive on paper recycling

Research on water-based PSAs and coating wax are an extension of this project.


Hot-Melt PSAs
30-60 wt. % Tackifier
20-50 wt. % Base Polymer
0-25 wt. % Plasticizer
Easily Shaped for
Characterization
Melt
Processing
G′, G″, Tan δ


Water-Based PSAs
Monomers
Emulsifier(s)
Initiator(s)
Crosslinking Agents
Polymerization
Biocide(s)
Buffer(s)
Adhesive Emulsion
Tackifying Dispersion(s)
Rheology Modifiers
Wetting Agent(s)
Formulation
Defoamer(s)
Characterization samples restricted to thin films with properties dependent on formulation
Formulated PSA
G′, G″, Tan δ ?
Processing requires coating of low energy substrate and drying

Removal Efficiency for Base Emulsions

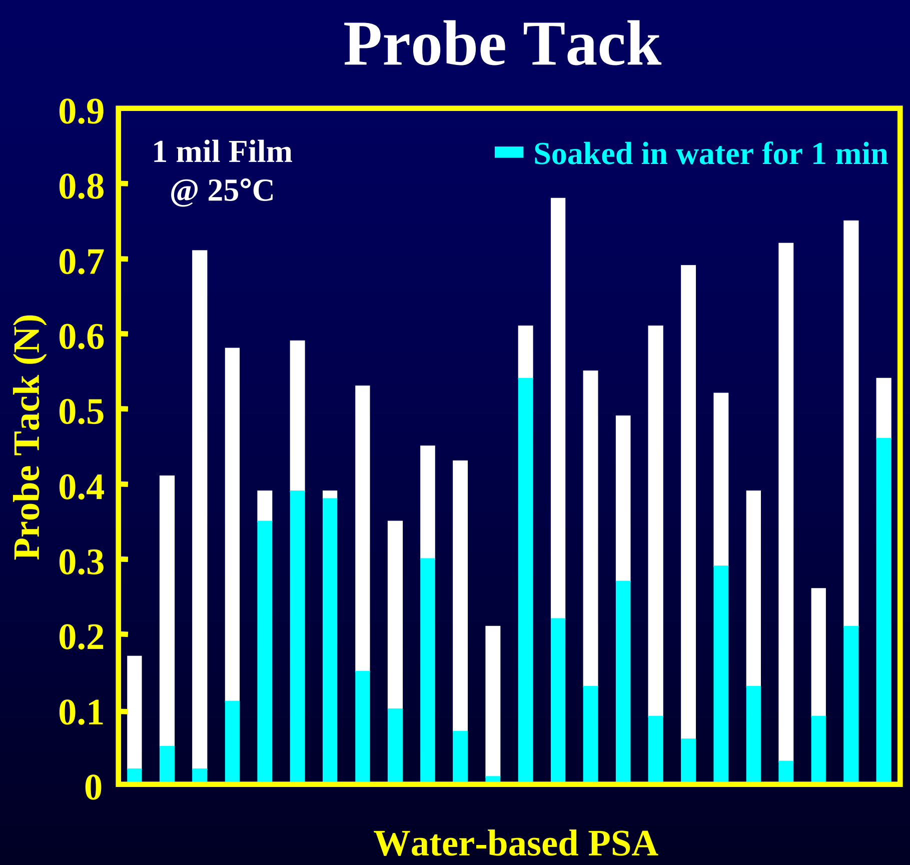


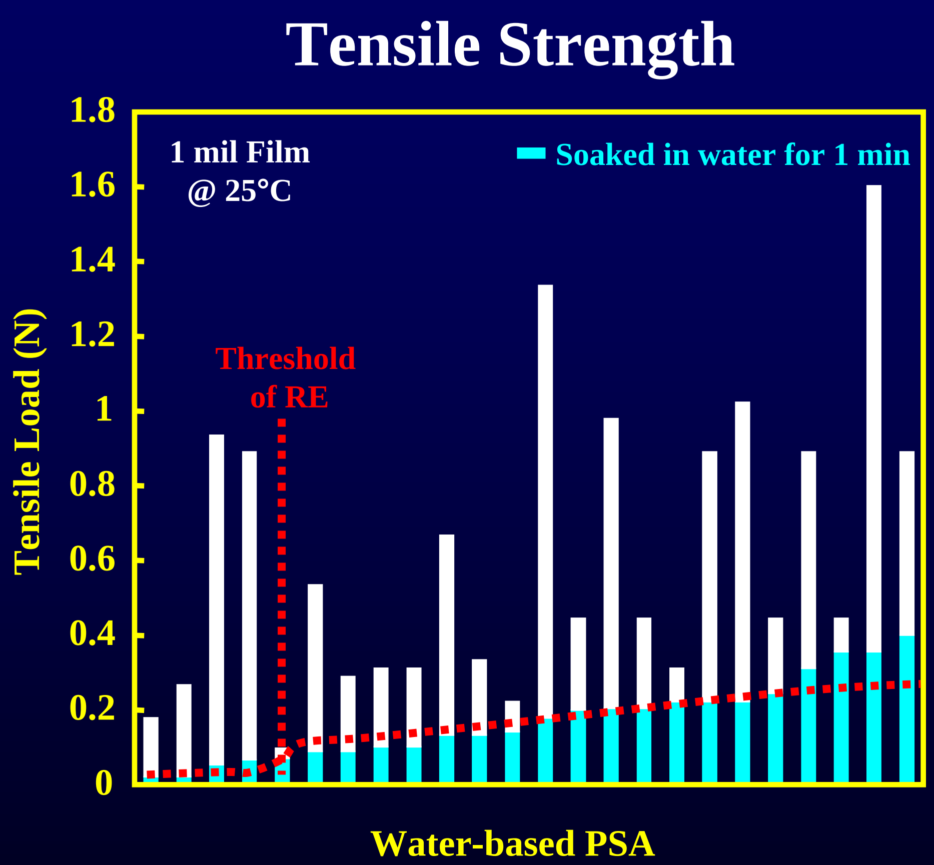
No evidence for dependence of screening removal efficiency on PSA properties such as

- **Tack**
- **Peel**
- **Shear**
- **Tensile Properties (E, TS,%EL,…)**
- **Glass Transition Temperature**
- **Surface Energy**

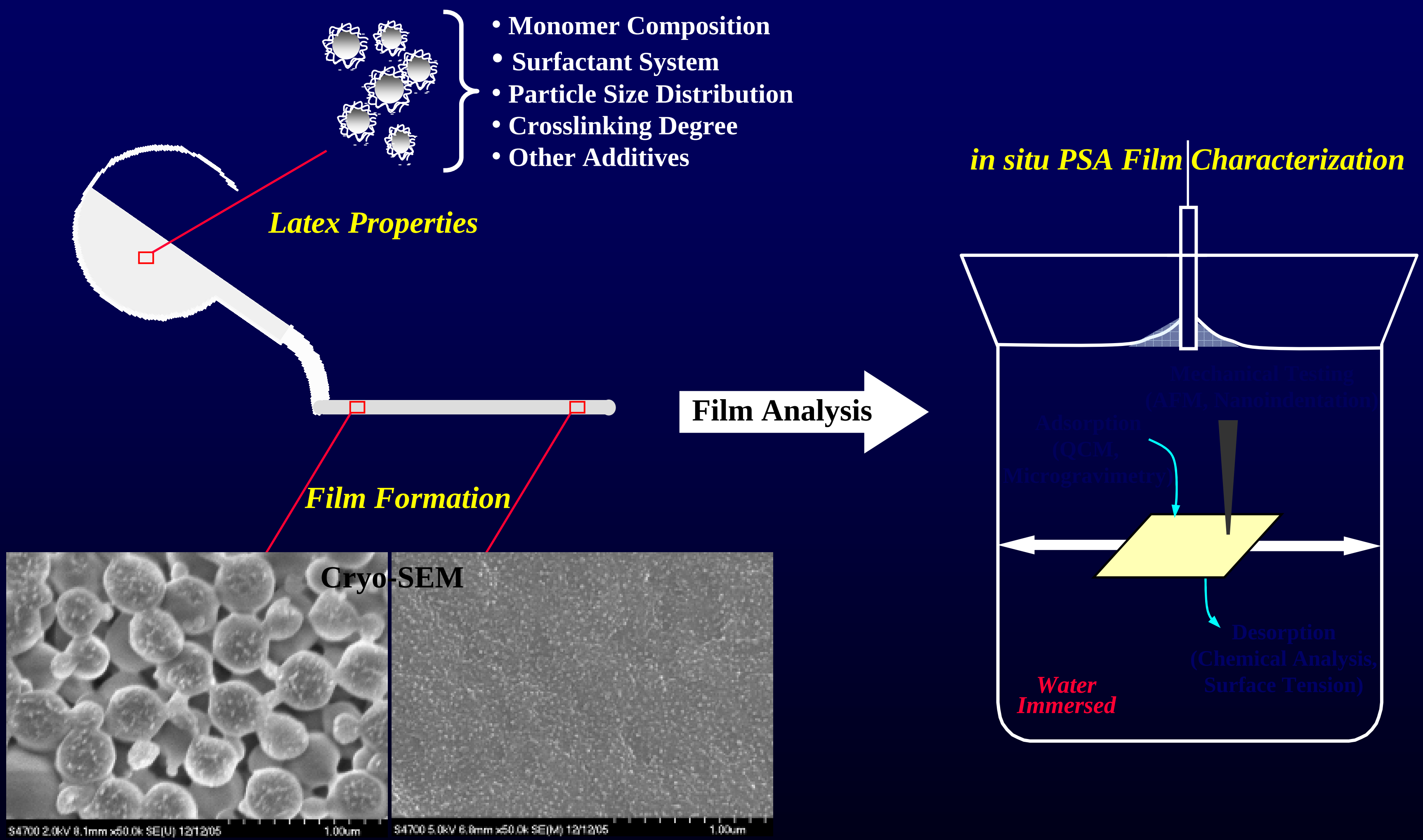
Unlike that found for hot-melt PSA, dry mechanical properties and phase behavior for water-based PSA do not correlate with repulping and screening performance

PSA Properties and Wet Processing





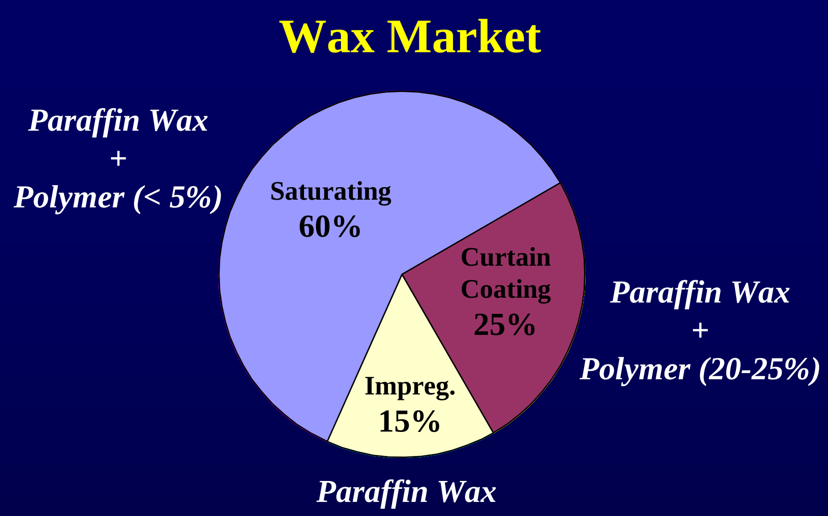
Monitoring Influence of Moisture

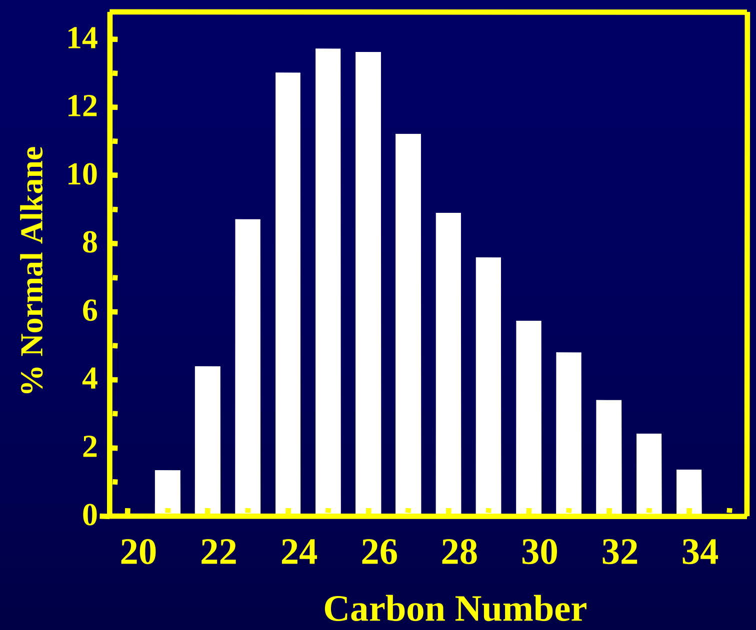


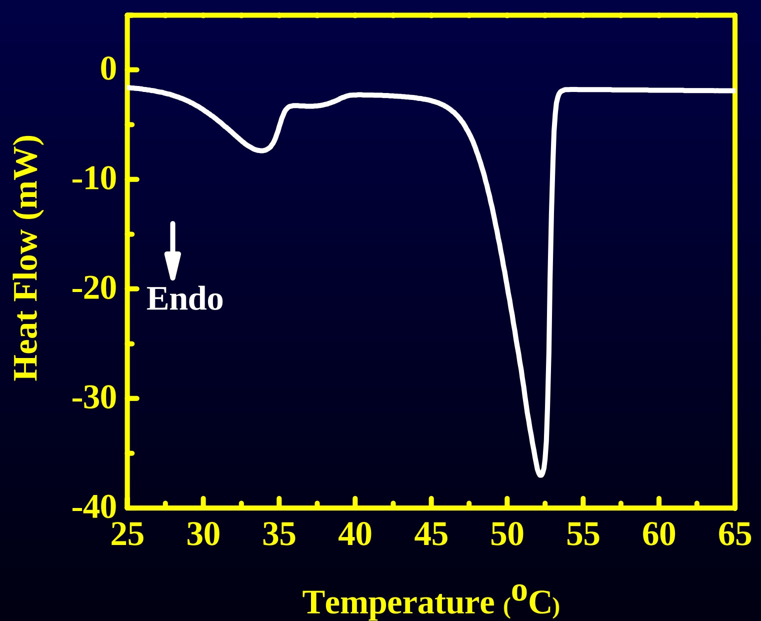
Current Status of Project

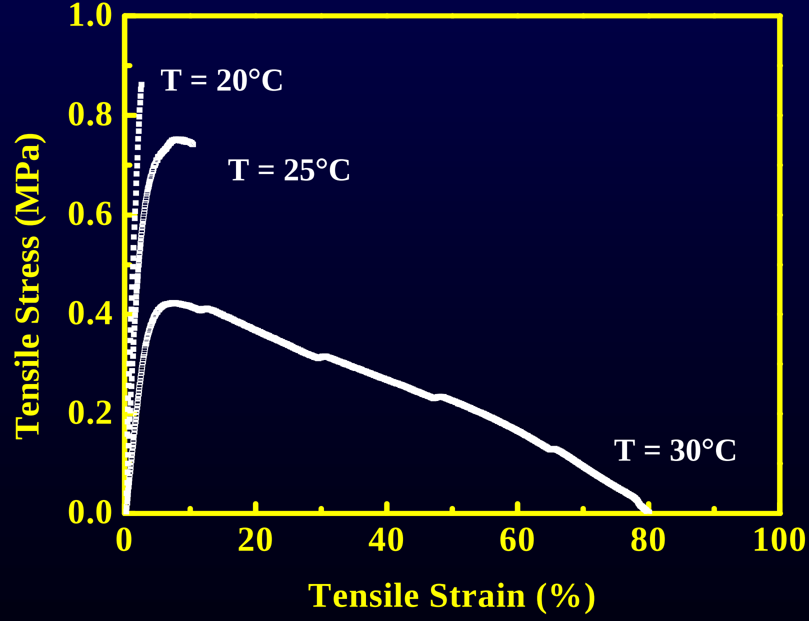
- **Influence of processing additives on PSA film properties and on screening removal efficiencies was examined.**
- **Approach developed for preparing laboratory PSA films for transfer coating containing only the adhesive latex.**
- **Properties and removal efficiencies of >25 commercial water-based PSAs were measured. This required the development of new "*in-situ*" tests involving the building of in-house equipment not commercially available.**
- **Potential dominant properties governing removal efficiencies were identified and are currently being pursued through model formulations.**
- **Several model water-based PSAs are currently under study.**

Paraffin Wax Coatings

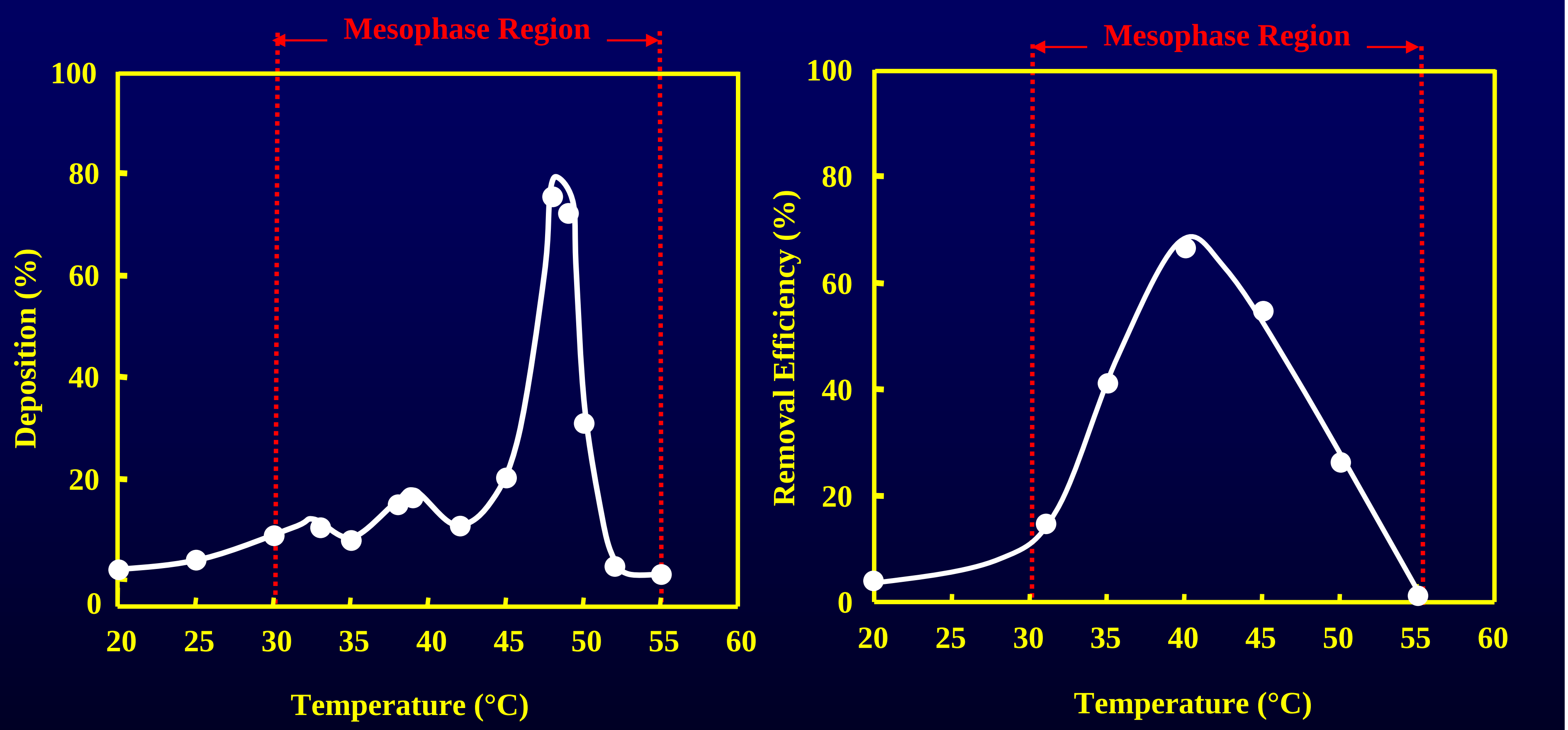






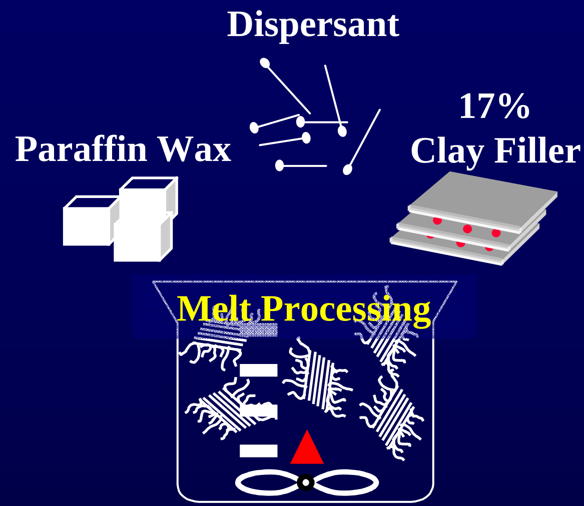


Wax Deposition and Removal

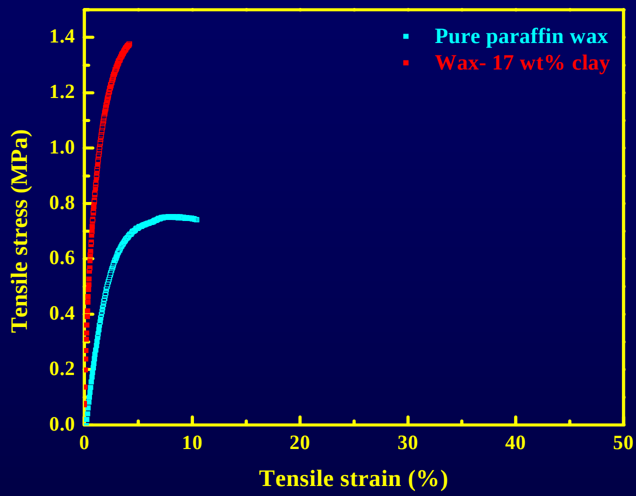


Wax Composite and Nanocomposite

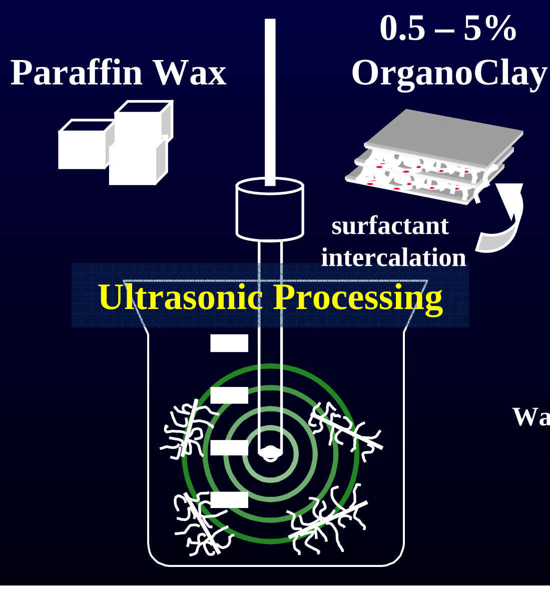
Composite



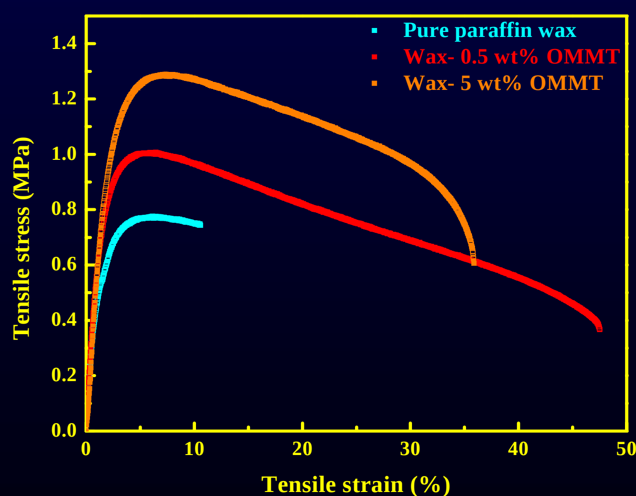
Tensile Properties



Nanocomposite



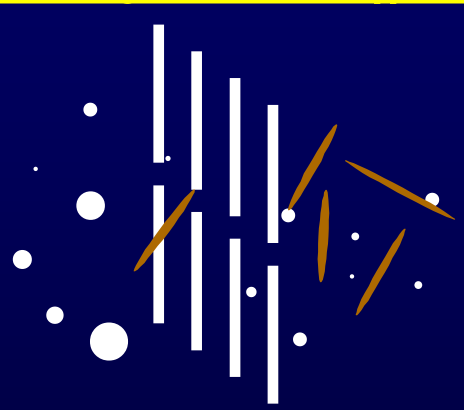
Tensile Properties



Wang, J., Severtson, S. J., Stein, A., *Advanced Materials*, In Press.

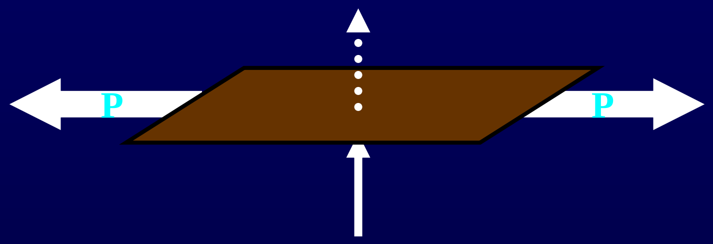
Performance Testing of Nanocomposite and Scale Up

Screening Removal Efficiency



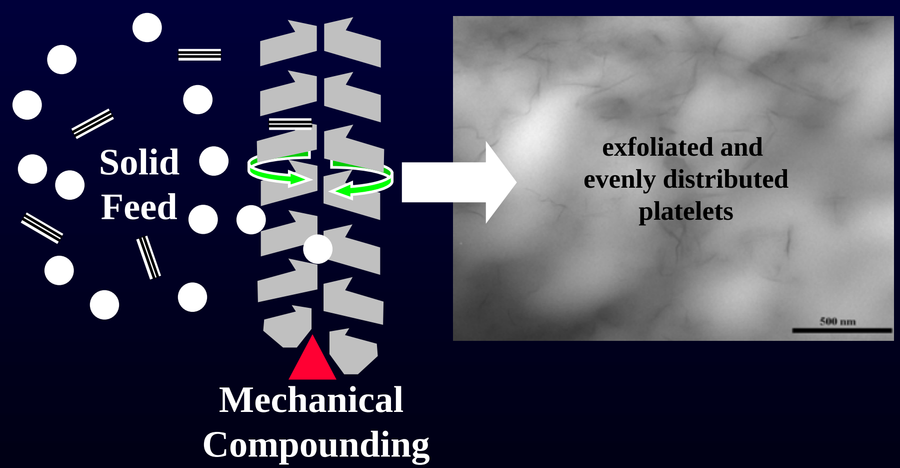
Both Laboratory and Pilot-Scale Testing

Barrier and Strength Properties



Permeation of Gasses and Liquids
and Influence of Exposure on Strength

Commercially Feasible Compounding



Current Status of Project

- Both laboratory and pilot scale tests developed for gauging screening removal efficiencies.
- Structure (molecular, nano- and micro-) and bulk mechanical and surface properties of IGI commercial coating waxes were characterized.
- Screening removal efficiencies and deposition tendencies were measured as a function of temperature.
- Clay-wax composite properties and performance were examined. This included pilot-scale testing of the IGI product. Results led to the development of an organoclay-wax nanocomposite produced via sonication.
- Mechanical properties of the composite and melt were characterized and its compounding using a laboratory compounding equipment below the melt point was demonstrated.

Current Milestone Chart

ID No.	Description	Planned Completion Date	Actual Completion Date
1	Characterization and removal testing of Franklin label grade water-based PSAs	10/05	10/05
2	Characterization and removal testing of standard wax coatings	10/05	10/05
3	Characterization and removal testing of new model water-based PSAs *Criterion for proceeding* – Properties identified as those governing fragmentation are confirmed	10/06	
4	Study on the role of facestock properties in determining removal of PSAs	10/06	
5	Characterization and removal testing of new model wax coatings *Criterion for proceeding* – Properties identified as those governing removal are confirmed	04/07	
6	Development of new benign commercial PS labels *Criterion for proceeding – Laboratory results confirmed for PS labels at pilot scale*	11/07	
7	Study on the role of board properties in determining removal of wax coatings	08/07	
8	Development of new benign commercial treated corrugated containers	11/07	

Acknowledgements

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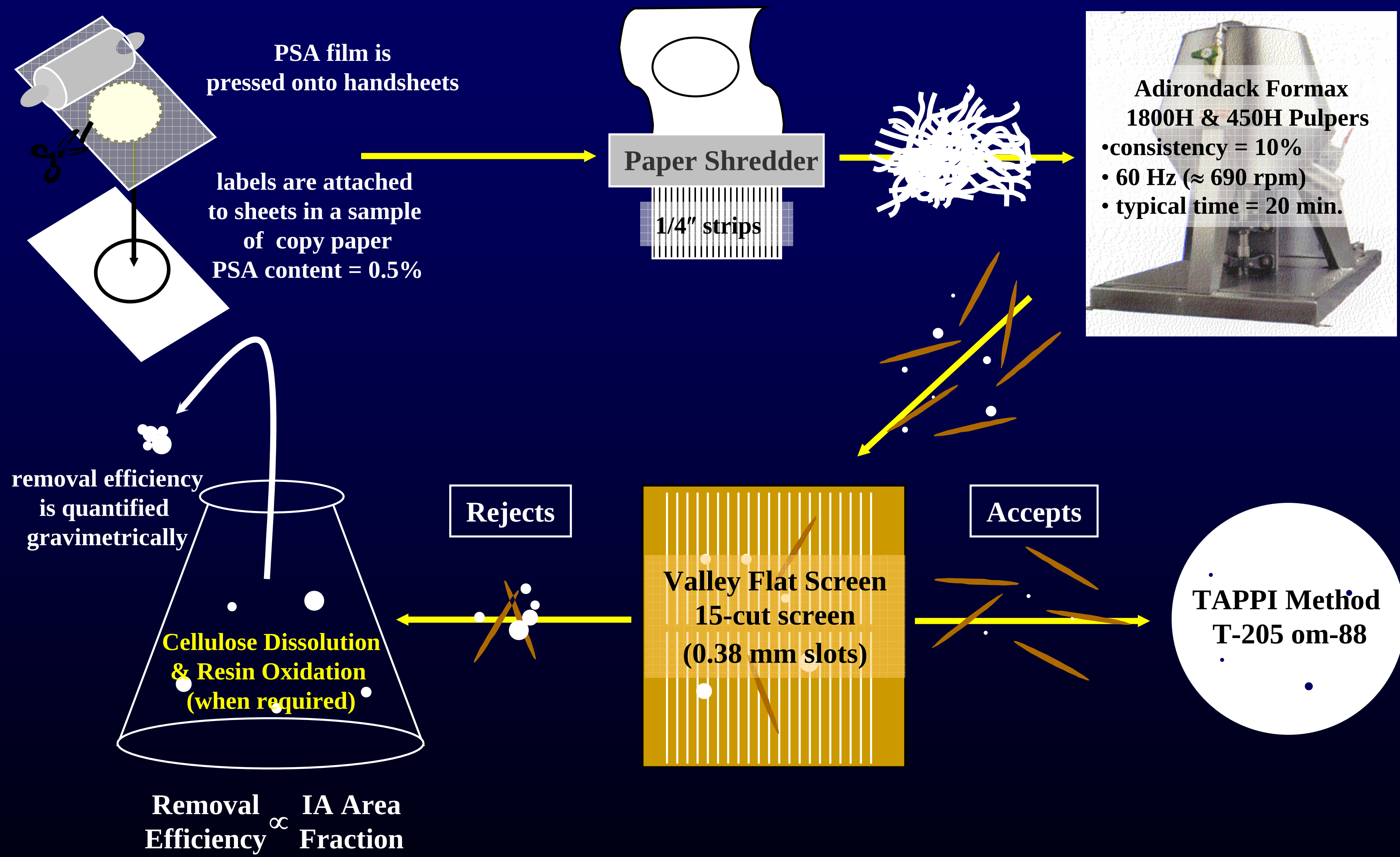
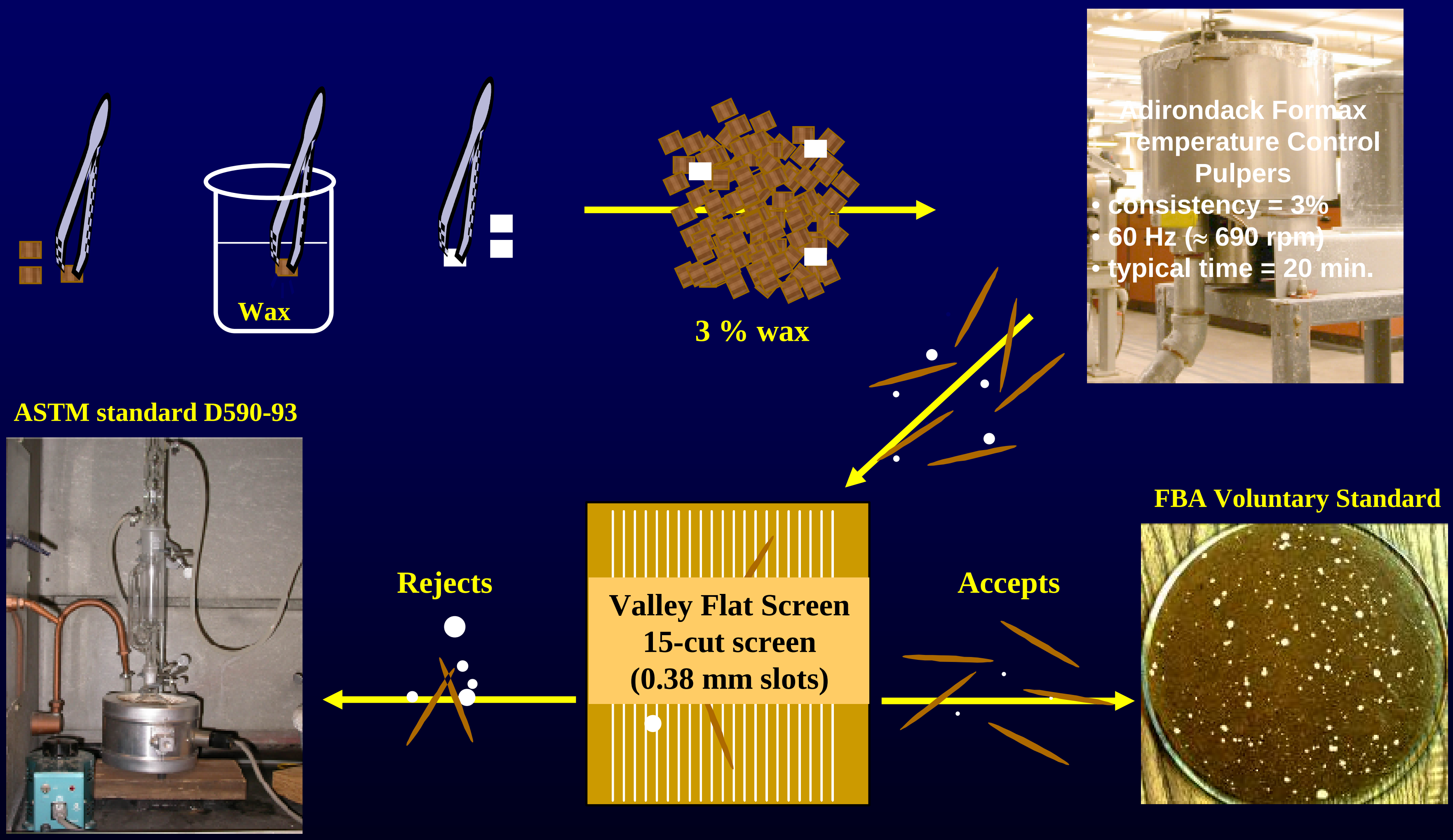
- Karen Scallon (FPL)
- Jamie Kalyta (IGI)
- Roman Kinasz (IGI)
- Fei Wang (IGI)
- Jennifer Lien (Boise)
- Keith Hays (Penford Products)

Questions and Discussion

Testing PSA Removal Efficiency



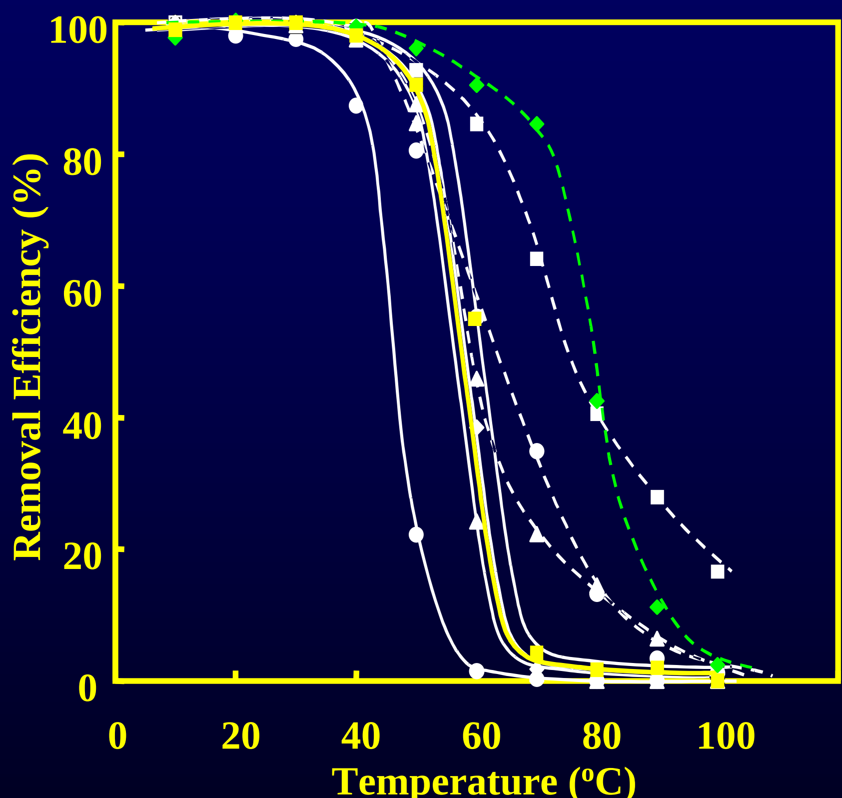
Testing the Removal Efficiency of Wax



$$\textbf{Wax removal efficiency} = \frac{\text{Weight of wax screening rejects}}{\text{Weight of initial wax in wax-coated boards}} \times 100\%$$

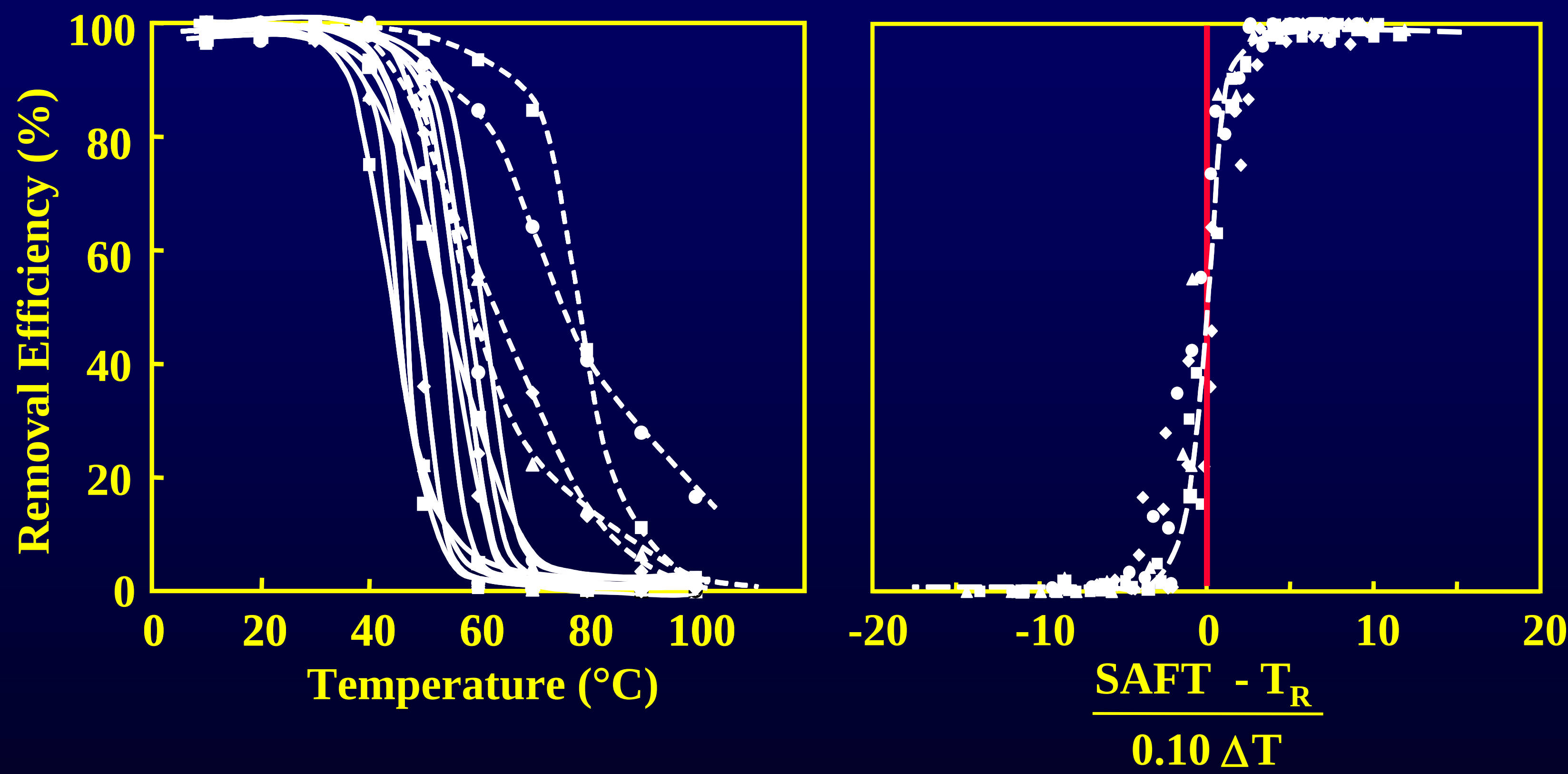
Modeling the Fragmentation Behavior of Thermoplastic PSA Formulations

PSA	T_{50}(°C)	α(°C)	SAFT(°C)	0.10ΔT(°C)
PSA 1	58	3.6	57	4.7
PSA 2	46	3.2	47	3.7
PSA 3	61	3.8	57	3.9
PSA 4	48	3.9	51	4.4
PSA 5	55	3.0	56	4.0
PSA 6	45	4.1	49	4.6
PSA 7	46	2.3	49	3.8
PSA 8	54	6.1	54	5.9
PSA 9	52	1.9	51	4.2
PSA 10	56	3.2	53	4.7
PSA 1b	78	5.7	74	7.1
PSA 2b	63	8.7	58	7.0
PSA 3b	78	11.7	72	7.3
PSA 10b	61	7.5	62	6.9



$$\text{Removal Efficiency} = \frac{\exp\left(\frac{T_{50} - T_R}{\alpha}\right)}{1 + \exp\left(\frac{T_{50} - T_R}{\alpha}\right)} \times 100\,\%$$

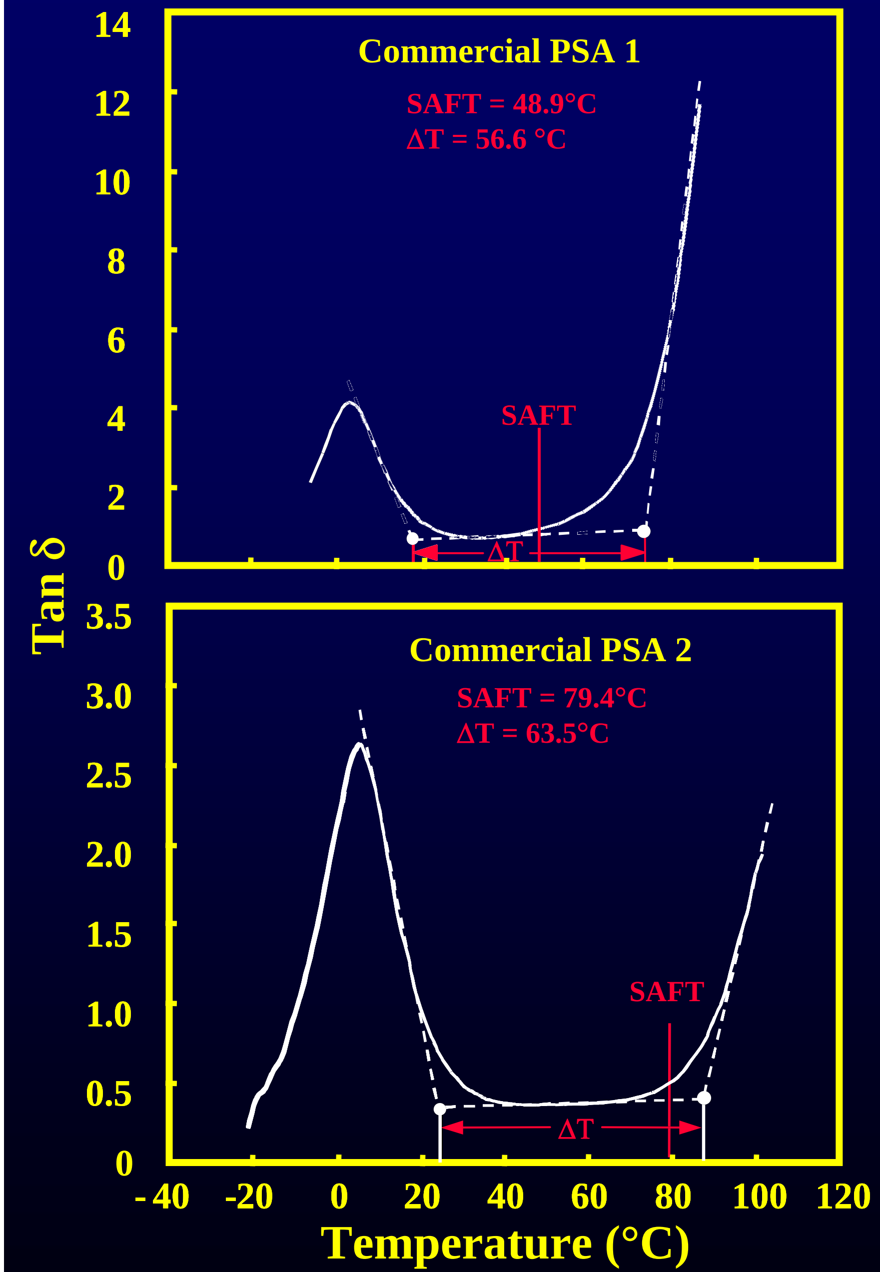
Temperature-Dependent Repulping Results

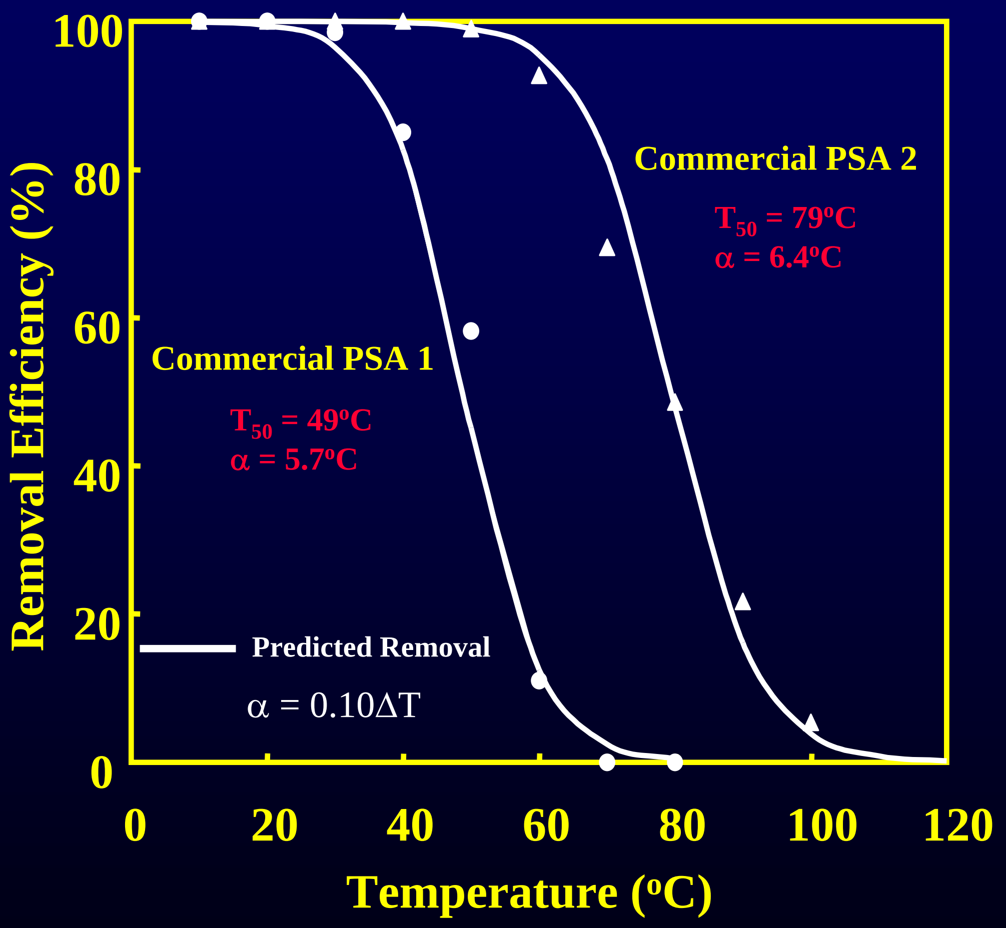


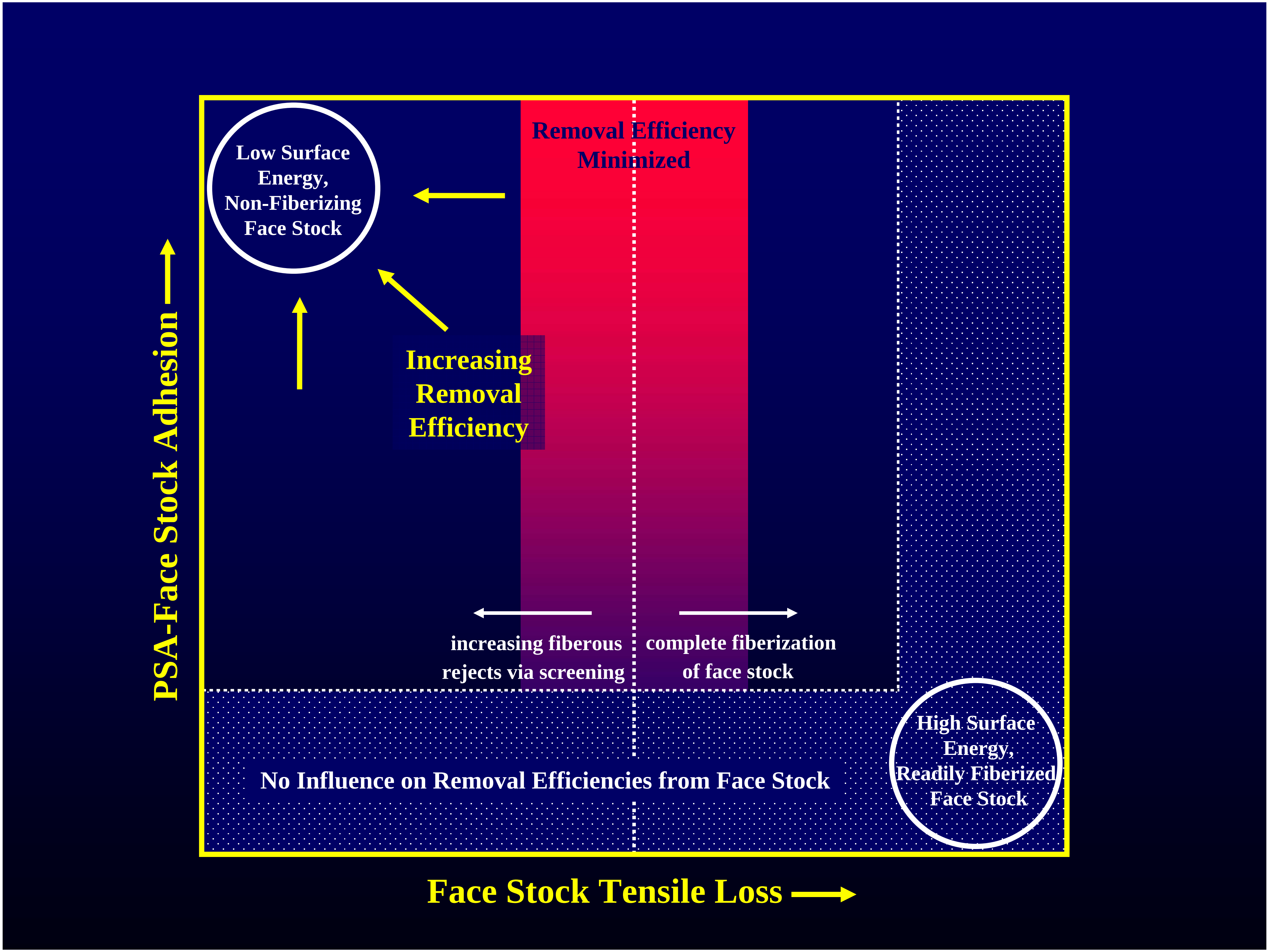
* 14 Thermoplastic PSA formulations with rosin ester and C_5 hydrocarbon tackifying resin systems

* Predicted removal efficiency –vs- experimental removal efficiency ⇒ Slope = 0.99, Intercept = 0.07, R^2 = 0.98 (140 points)

Predicting Thermoplastic PSA Recycling Performance






Low Surface Energy, Non-Fiberizing Face Stock
Removal Efficiency Minimized
Increasing Removal Efficiency
increasing fiberous rejects via screening
complete fiberization of face stock
No Influence on Removal Efficiencies from Face Stock
High Surface Energy, Readily Fiberized Face Stock
PSA-Face Stock Adhesion
Face Stock Tensile Loss