
***Technical Approaches to Improving
the Scratch Resistance of TPO's
Part I: Surface Lubrication***

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Outline

- Introduction
- Migratory Slip Additives
- Coadditives for Migratory Slip Additives
- Nonmigratory Slip Additives
- Conclusions and Areas for Improvement

Introduction

Surface Lubrication & Scratch Resistance

- Surface lubrication has been successfully employed as a strategy to improve the scratch resistance of TPO's
- “Slip additives” reduce the coefficient of friction (CoF) at part surfaces
 - Maximum tensile stress during scratching is decreased → *less brittle scratch damage*
 - Yielded zone size from scratching is reduced → *less scratch visibility*

Migratory Slip Additives

Examples of Commercial Slip Additives



oleamide



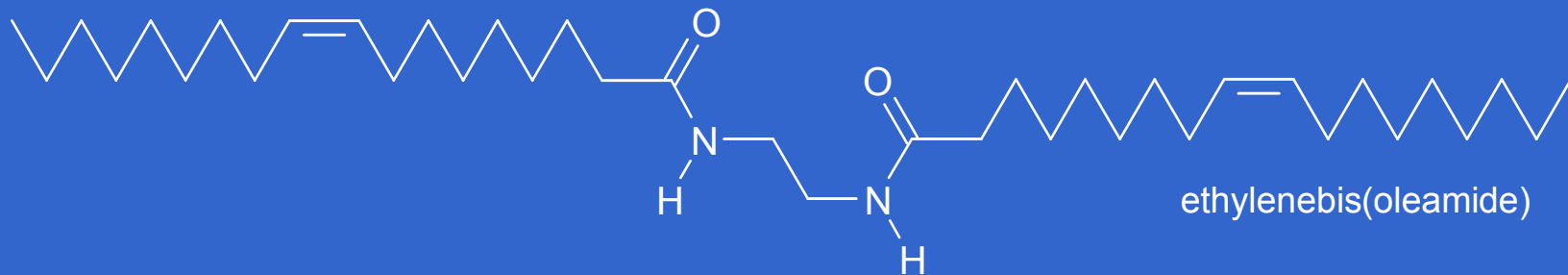
erucamide



stearyl erucamide



oleyl palmitamide

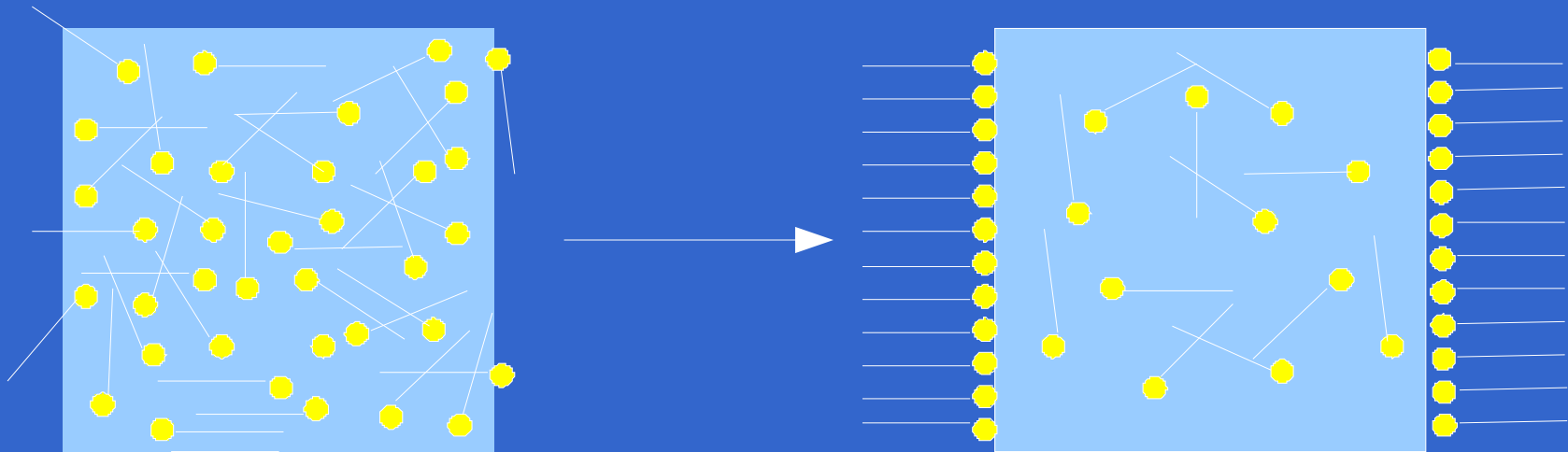


ethylenebis(oleamide)

Migratory Slip Additives

- Used successfully for over 50 years to reduce CoF at polymer surfaces
- Must migrate to the surface to be effective
 - “Lag time” before onset of effect
- Lubricating layer is very weakly bound to the surface
 - Easily lost but can be replenished by migration
- Effect on CoF of rough or textured surfaces is complex
 - Generally more effective for smooth surfaces

Slip Additive Migration



A. J. G. Allan, *J. Colloid Sci.*, **1959**, *14*, 206-221

Antiscratch Performance

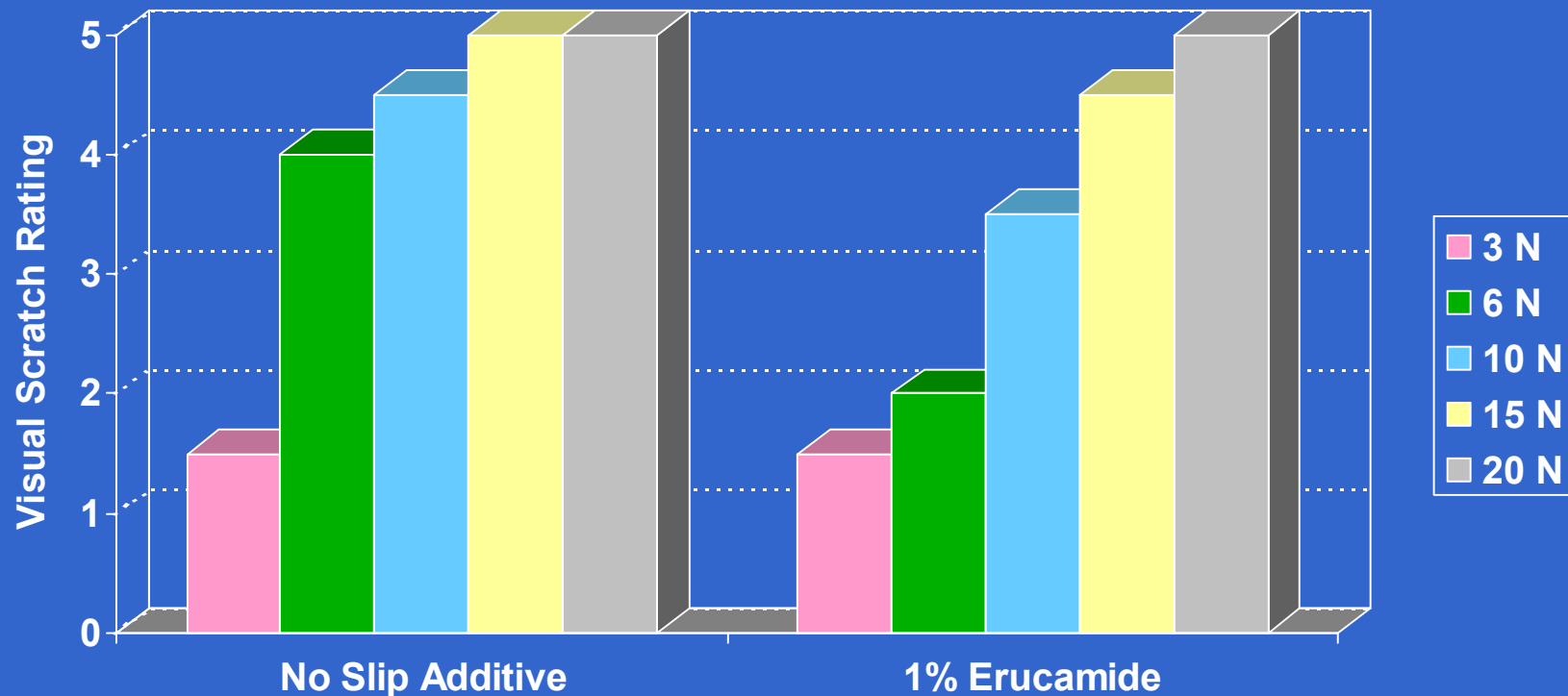
Unfilled TPO Compound

Slip Additive	Force to Give Visible Scratch
None	0.6 N
0.3% Erucamide	>7 N
0.3% Oleamide	>7 N

50% PP homopolymer, 50% ethylene/butene copolymer/PP blend, 4 phr carbon black
Scratch testing: Ford Test Method BN 108-13

C. K. Buehler, S. M. Dwyer, D. Mosier, M. L. Paschick, U.S. Patent No. 6,048,942, April 11, 2000

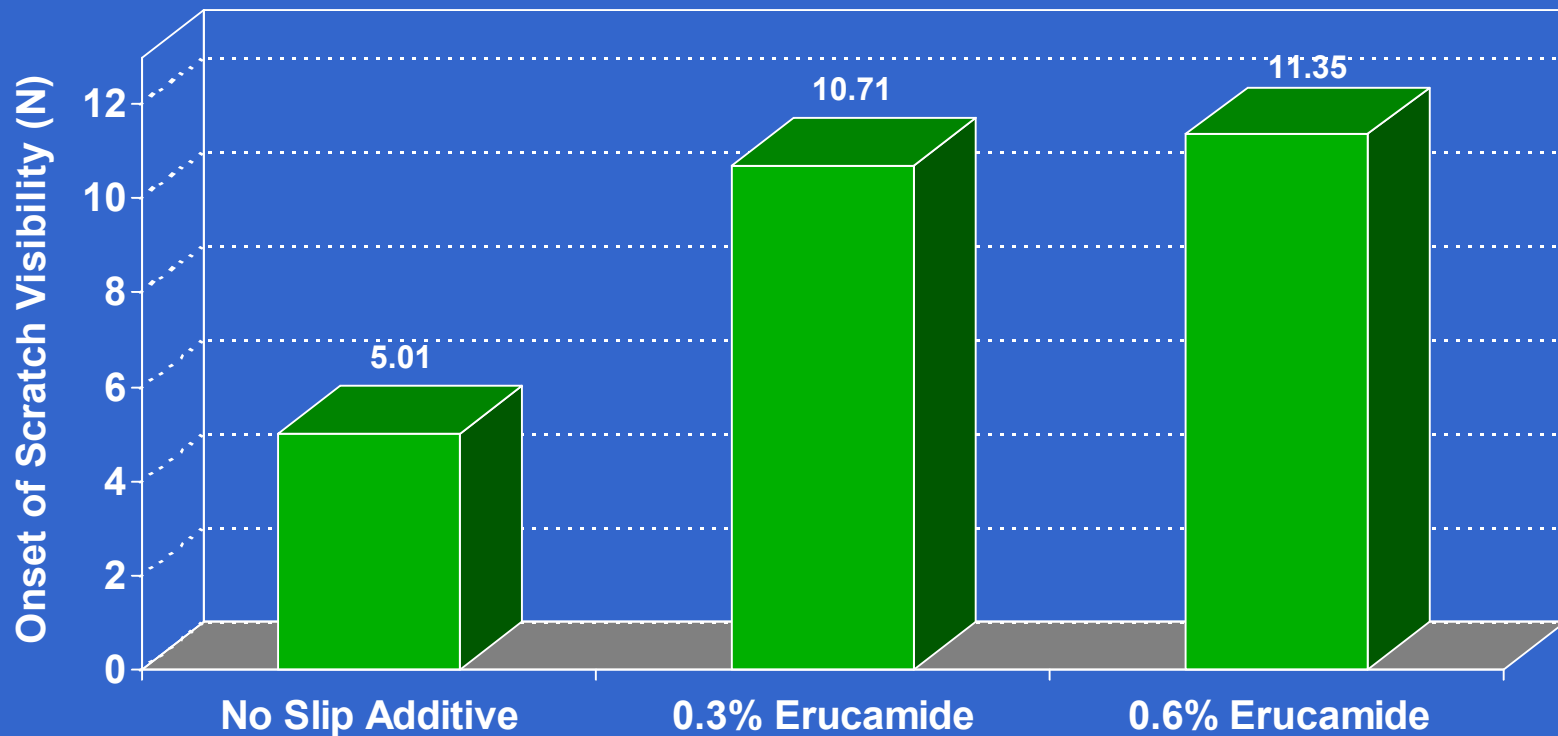
Antiscratch Performance Talc-Filled PP Compound



20% talc-filled PP copolymer containing carbon black
Scratch testing: Ford Five Finger Scratch Test

A. H. Sharma, J. H. Botkin, L. Simonpietri, L. Brunner, A. Zedda, "Additive Approaches to Improving Scratch and Mar Resistance in Automotive Polyolefins", 2004 SPE Automotive TPO Global Conference

Antiscratch Performance Talc-Filled TPO Compound



20% talc (untreated) filled PP/EPR copolymer containing carbon black
Scratch testing: ASTM D 7027-05

R. Browning, G. T. Lim, A. Moyse, L. Sun, H.-J. Sue, *Polym. Eng. Sci.*, 2006, 46, 601-608

Coadditives for Migratory Slip Additives

Role of Coadditives

- Problems associated with uncontrolled slip additive migration
 - Exudation or “blooming”
 - Temporary nature of the effect
 - Uneven distribution on textured surfaces
 - Role in automotive fogging
 - Part stickiness after weathering
- Polar coadditives can increase solubility and reduce the migration rate of slip additives

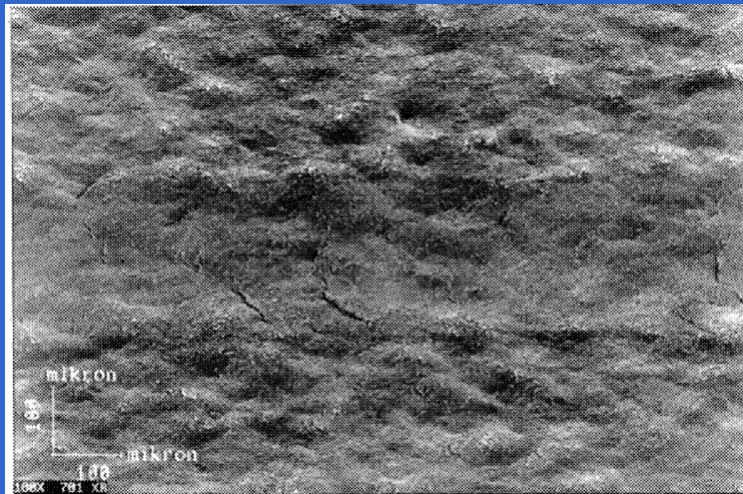
Other Possible Coadditive Effects

- Surface segregation during molding
 - Provide polar functionality to enable a more durable bond between slip additive and part surface
 - Effect on surface hardness?
- Effect on mechanical properties (modulus, impact, etc.)
 - May be positive or negative

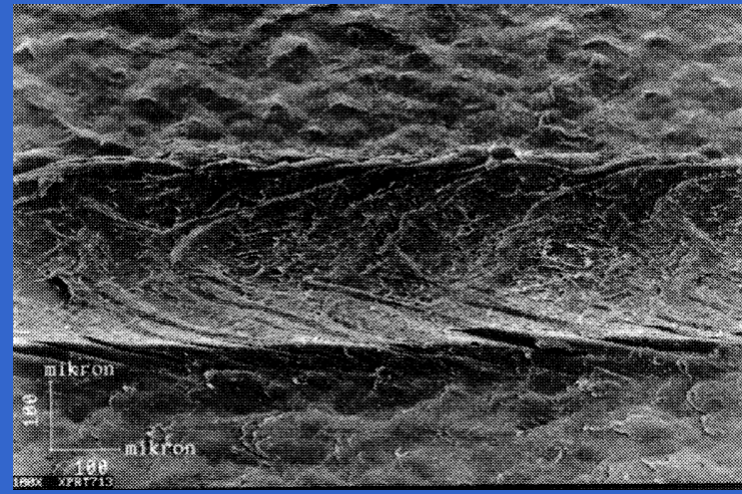
Examples of Coadditives

- Ethylene-vinyl acetate copolymers (EVA)
- Polyolefin - acrylate graft copolymers
 - *Eliminates blooming while maintaining scratch resistance*
- Functionalized long-chain α -olefin / maleic anhydride copolymers
 - *Avoids stickiness after weathering*
- Synthetic silica
 - *Immediate reduction in CoF (PP films)*
 - *Enhanced oxidation stability of slip additives*

Antiscratch Performance Talc-Filled TPO Compound



70% PP copolymer
10% EPDM rubber
10% talc (aminosilane treated)
5% PP-g-MA copolymer
5% erucamide/silica concentrate



80% PP copolymer
10% EPDM rubber
10% talc (aminosilane treated)

Scratch testing: Ericsson pen according to ISO 1518

H. Baann, U.S. Patent No. 5,973,070, October 26, 1999

Nonmigratory Slip Additives

Nonmigratory Slip Additives

- Polysiloxanes are the most common type
- Advantages vs. migratory slip additives
 - Immediate and more durable antiscratch effect
 - More stable to oxidation
- Disadvantages vs. migratory slip additives
 - Cost performance (higher price and use levels)
 - Prone to adsorption on untreated talc filler
- Combinations with migratory slip additives have been employed for improved cost performance

Antiscratch Performance

Unfilled TPO Compound

Slip Additive	Force to Give Visible Scratch	
	Before Washing	After Washing
None	0.6 N	0.6 N
0.2% Erucamide 0.2% Oleamide	>7 N	2 N
2% Siloxane MB	6 N	6 N
2% Siloxane MB 0.2% Erucamide 0.2% Oleamide	>7 N	>7 N

50% PP homopolymer, 50% ethylene/butene copolymer/PP blend, 4 phr carbon black
Scratch testing: Ford Test Method BN 108-13

C. K. Buehler, S. M. Dwyer, D. Mosier, M. L. Paschick, U.S. Patent No. 6,048,942, April 11, 2000

Antiscratch Performance Talc-Filled PP Compound

Slip Additive	Scratch Ranking
None	12
2% PDMS	1
2% PDMS (w/o talc pretreatment)	7
1.5% PDMS	9
1.5% PDMS + 0.5% erucamide	1

22% talc-filled PP medium impact copolymer

Talc pretreatment: 0.5% epoxy resin added prior to PDMS

Scratch testing: Hand-operated scratch tester, up to 1 kg weight, 0.5 mm stylus, visual assessment

J. R. Grasmeyer, PCT Intl. Patent Application Publication WO 93/03095, February 18, 1993

Conclusions

- Systems based on migratory slip additives improve scratch resistance in filled and unfilled TPO's
- Coadditive technologies have the potential to overcome the adverse effects of excessive slip additive migration and may provide other effects
- Nonmigratory slip additives such as polysiloxanes overcome some of the disadvantages of migratory additives, but suffer from inferior cost performance and interaction with talc fillers

Potential for Improvements

- Migratory slip additives
 - *More efficient reduction of CoF at part surfaces*
 - *Improved oxidation stability*
- Coadditive technologies
 - *Systematic investigation is needed!*
- Nonmigratory slip additives
 - *Cost reduction*
 - *Improved technology for passivating talc surfaces*

Thank You

- Detroit Section and Automotive Division, Society of Plastics Engineers
- My clients