Power of Effective University-Industry Cooperation
Personal View from both sides of the Table
as an Academician and VPRD
and
Development of Novel Polymeric Materials
From University Lab Bench to Commercial Success

İskender Yılgör and Emel Yılgör
Koç University

Summary

- Personal background in Academia and Industry
- Power of generation and utilization of new knowledge
- An example of successful University-Industry Cooperation
  Virginia Tech Polymeric Materials and Interfaces Laboratory (PMIL)
- Possible Routes for University-Industry Cooperation
- Problems in establishing successful University-Industry Cooperation
- Understanding Structure-Morphology-Property Relations in Polymeric Materials
- Personal examples in development of successful commercial products through University-Industry Cooperation.

The source of wealth is KNOWLEDGE

Peter Drucker

KNOWLEDGE is personal power.

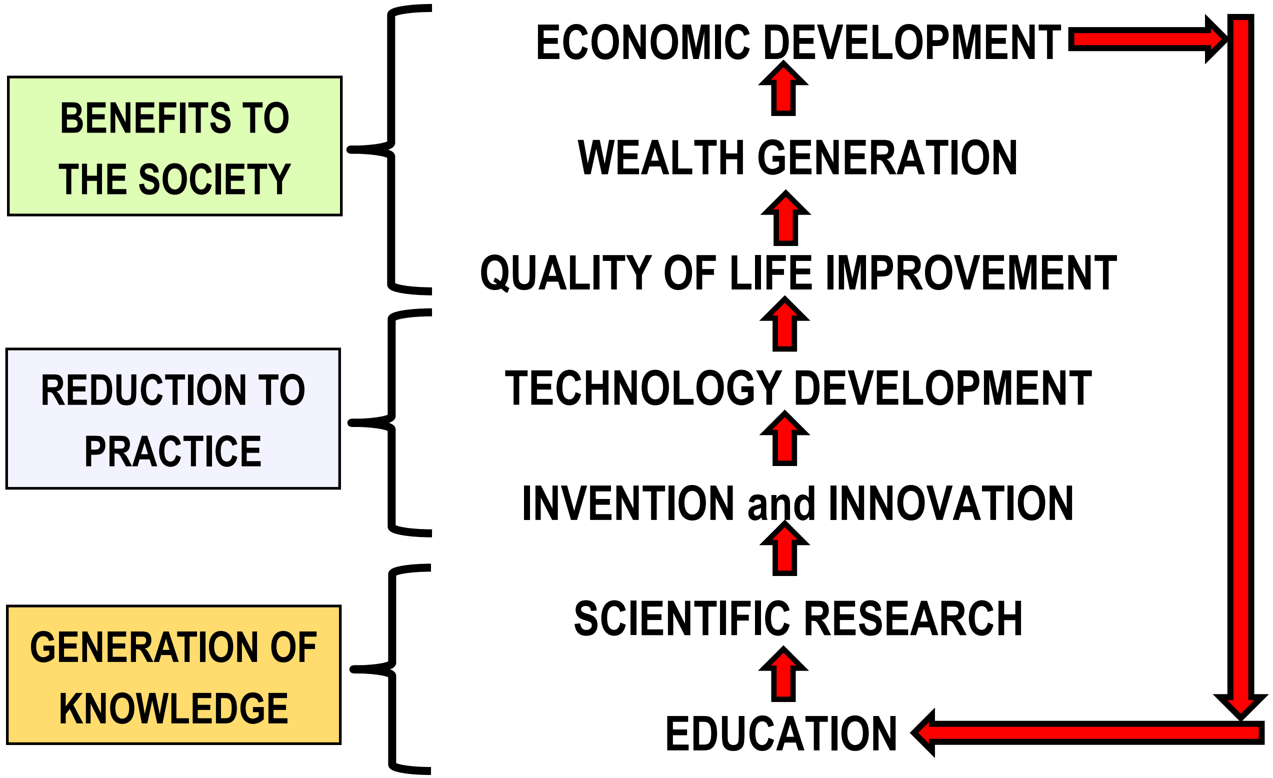
Whereas money and power may be redistributed, KNOWLEDGE must be acquired through one's own efforts.

Whereas money and power may be temporary, KNOWLEDGE is permanent.

NEW KNOWLEDGE can be GENERATED in-house or ACQUIRED.

Inability to generate/acquire and utilize NEW KNOWLEDGE
leads to huge gaps in wealth and income between knowledge-based societies (companies or individuals) and others.

THE CYCLE OF SUCCESS



Why University-Industry Cooperation?

For industry the pressures include rapid technological change that is radically transforming the current business environment, including shorter product life cycles and intense global competition.

For the university the pressures include to catch-up with the incredible growth in new knowledge and increasing costs and difficulties in getting sufficient funding for research.

Increasing pressures to contribute to the economic development by providing better education and generating new knowledge.

University-Industry collaboration plays a key role in providing economic development through commercialization of the knowledge in terms of reciprocal knowledge transfer.

It has been shown that approximately 10% of new products and technologies developed lately, would not have emerged without University-Industry Collaboration.

Some critical requirements for successful University-Industry Cooperation

University

- Qualified faculty members or preferably teams, with industrial experience/connection
- Well-established and well-functioning research infrastructure
- Timely and effective communication and dissemination of information
- Secrecy

Industry

- Project leadership, effective project management and communication
- Successful diffusion of research results within the company
- Experienced R&D personnel to utilize new knowledge for product/process development

Personal Experience in Academia and Industry

- Establishing a strong foundation in Chemistry and Polymer Chemistry
  METU (ODTÜ) (1968 – 1980)

- Getting into the fascinating Structure-Morphology-Property Behavior of Multiphase Polymers and Understanding the Critical Parameters in Structural Design of Polymers towards specific applications
  VIRGINIA TECH (1980 – 1985)

- Trying to solve Real-Life Problems in Polymer Science and Technology through Innovative Research
  MERCOR Inc., and THORATEC Laboratories, Berkeley, CA (1985 – 1989)
  GOLDSCHMIDT Chemical Corporation, Hopewell, VA (1989 – 1994)

- Touching the lives of many brilliant students
  KOÇ UNIVERSITY (1994 – Current)

METU (ODTÜ) YEARS (1968 – 1980)

- BS (1968–1972), MS (1974) and PhD in POLYMER CHEMISTRY (1977)
- Teaching Assistant (1972 – 1977)
- Assistant Professor (1977 – 1980)

<u>M. S. Thesis</u>
Synthesis and Characterization of Block Copolymers of Propylene Glycol and Methyl Methacrylate
<u>Ph. D. Thesis</u>
Kinetic Studies on Polymeric Peroxycarbamates, Their Use in the Synthesis of Block Copolymers of Styrene and Characterization of Products

METU POLYMER RESEARCH INSTITUTE
Established and led by Prof. Dr. Bahattin BAYSAL and partially supported by TUBITAK

One of the best POLYMER PROGAMS in the WORLD in 1970s, with research on:
Polymer Synthesis (Radical, Anionic, Cationic, Step-Growth,
Polymer Characterization (Structural, Thermal, Mechanical, Morphological),
Polymer Crystallization,
Solution Properties,
Polymer Rheology and Processing

VIRGINIA TECH YEARS
(1980 – 1985 and 2003 – 2004)

Total academic freedom

Well-established scientific environment (people and laboratories) for multidisciplinary research

Weekly group meetings resulting in cross-fertilization of ideas and novel projects

Weekly contacts with leading academic and industrial scientists through seminars and meetings

Understanding real-life problems and trying to find solutions through scientific research

Three Pillars of Virginia Tech Polymer Activities

The main pillar was Jim McGRATH, who has joined VaTech in 1975 after 17 years of industrial experience

Tom WARD | Jim McGRATH | Garth WILKES

PHYSICAL POLYMER CHEMISTRY
Thermal, Mechanical and Surface Properties, Adhesion

SYNTHETIC POLYMER CHEMISTRY
Polymer Design, Synthesis, Structural Characterization

POLYMER ENGINEERING
Morphology, Processing Structure-Property Relations

Routes for University-Industry Cooperation at VA TECH

- Consulting
- Industry sponsored research projects
- Industrial support to polymer research through a Consortium
- Establishment of company funded research center
- Exchange of industrial scientists and graduate students
- Continuing Education – Short Courses (On-site or Off-site)
- Technology licensing

Polymeric Materials and Interfaces Laboratory (PMIL)

- 3 Faculty Members (McGrath, Ward and Wilkes)
- 10-15 Industrial Companies as members of the Consortium
- $25,000 each annually for a total of $250,000 - $375,000 per year
- In some cases matching funds from State or University

Benefits of Being a Member of PMIL

- Annual meetings, technical presentations (oral and poster) and discussions
- Annual reports
- Access to research activities by post-docs and graduate students on:
  - Block copolymer synthesis by anionic and step-growth polymerization
  - Synthesis and characterization of engineering thermoplastics
  - Reactive silicone oligomers and silicone copolymers
  - Toughening of epoxy resins
- Discussions with post-docs and graduate students. Opportunity of hiring top notch graduate students and post-docs
- Opportunity to initiate new projects and generate new technologies

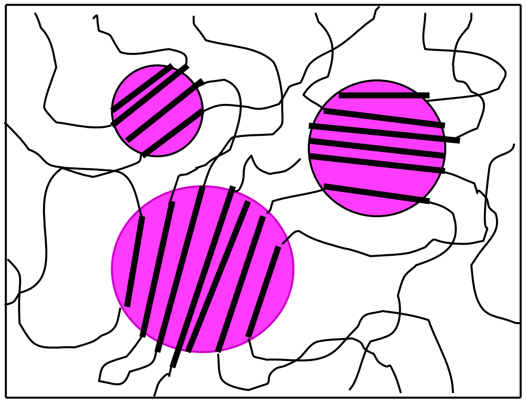
The most fundamental and lasting objective of the synthesis is not the production of new structures, but the production of properties

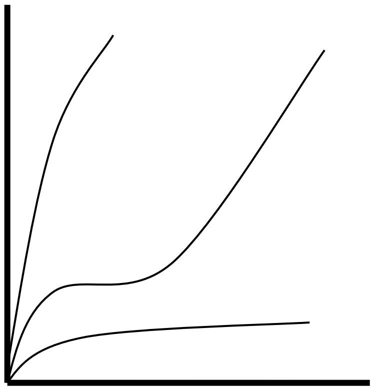
George S. Hammond (1921 – 2005)
Norris Lecture Award, 1968

Synthesize a new molecule Characterize the product Publish the results	Design and synthesize a new molecule Characterize and test for applications, optimize performance Patent and publish the results

Structure-morphology-property relations in TPUs

Chemical structure ⟷ **Morphology** ⟷ **Properties**





(Chemistry) (Physics) (Engineering)

Development of a Polymeric Engine Oil Additive as Viscosity Modifier

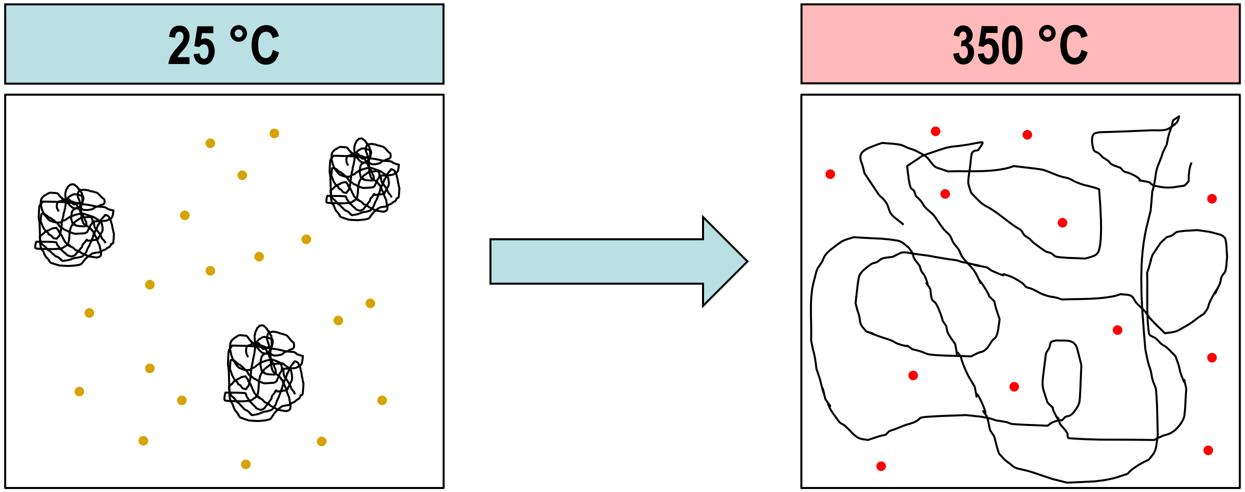
Funded by EXXON Chemicals

GOAL

To develop novel polymeric oil additives that will prevent the drop in the viscosity of the engine oil at high temperatures and improve the engine performance

PROBLEM: Significant reduction in the viscosity of the engine oil at high temperatures leading to performance loss

SOLUTION: Design and synthesis of linear polymers with strong intermolecular interactions that break-up at high temperatures



2 US Patents and 2 Articles

PROTECTIVE COATINGS FOR SPACE STATION AND SPACE VEHICLES

Funded by NASA Langley

Problem

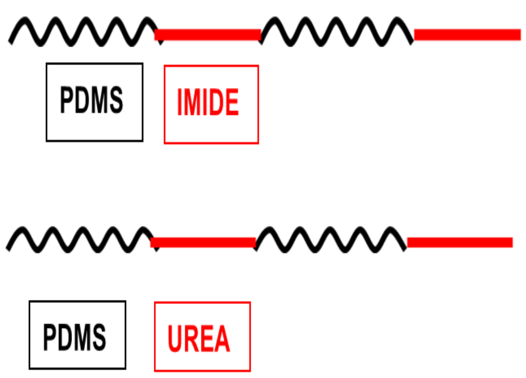
Lightweight and strong polymers are widely used as structural materials in space applications.

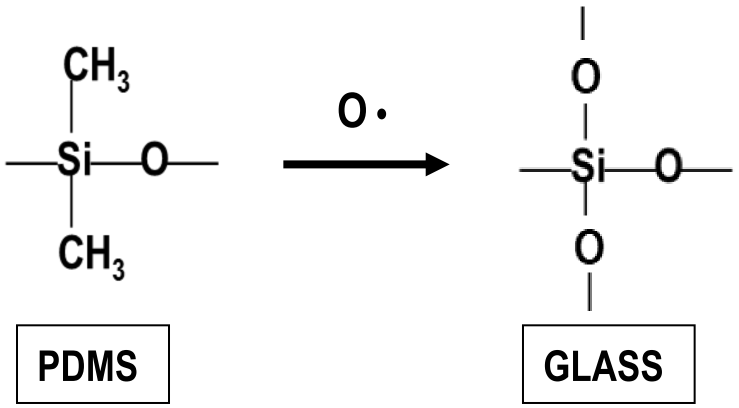
Atomic oxygen present at low earth orbit (LEO) results in significant degradation of polymers.

Protective polymeric coatings against atomic oxygen are needed.

Solution

Development of polydimethylsiloxane based polyurea and polyimide coatings that form a glass-like protective coating upon reaction with atomic oxygen.





S. Bilgin, M. Isik, E. Yilgor, I. Yilgor
Polymer, 54(25), 6665-6675 (2013)

E. Yilgor, O. Kaymakci, M. Isik, S. Bilgin and I. Yilgor
Applied Surface Science, 258(10), 4246-4253, (2012)

Toughening of Epoxy Resins with Reactive Polysulfone Oligomers

Funded by PMIL CONSORTIUM

Polymer Bulletin 13, 201–208 (1985)

Polymer Bulletin
© Springer-Verlag 1985

Engineering

Chemical Modification of Matrix Resin Networks with Engineering Thermoplastics

1. Phenolic Hydroxyl Terminated Poly(Aryl Ether Sulfone)-Epoxy Systems

James L. Hedrick, I. Yilgör, Garth L. Wilkes, and James E. McGrath*

Departments of Chemistry and Chemical Engineering, Polymer Materials and Interfaces Laboratory, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061, USA

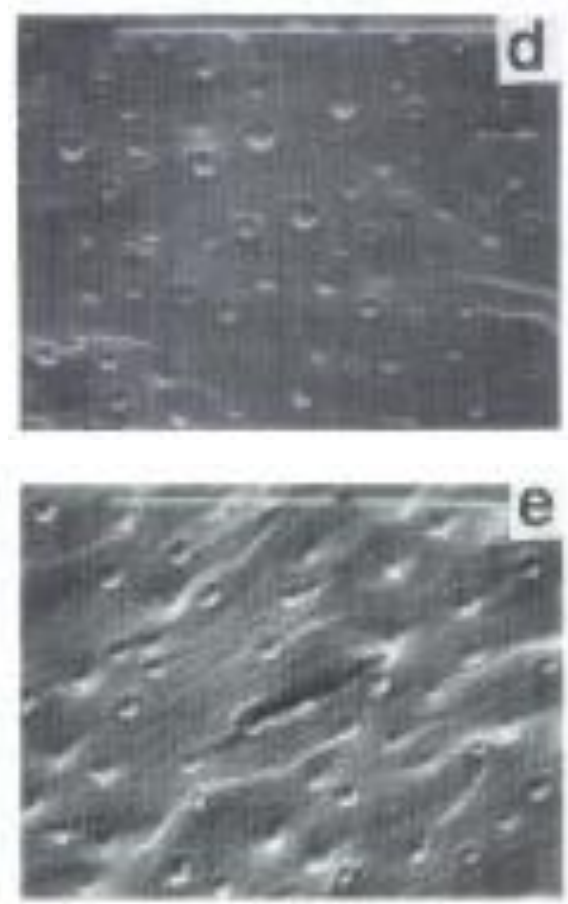
TABLE II

Mechanical Properties of Modified Epoxy Networks

No.	PSF $\overline{M}_n$ (g/mole)	PSF (wt. %)	Flex. Mod. (N/M^2)	Fract. Tough. K_{IC} ($N/M^{3/2}$)
1	Epon Resin 828/DDS Control		2.5×10^9	0.6×10^6
2	5300	10	2.0×10^9	0.9×10^6
3	5300	15	2.0×10^9	0.9×10^6
4	8200	10	---	1.0×10^6
5	8200	15	2.2×10^9	1.3×10^6
6	UDEL P-1700 Polysulfone Control		---	2.4×10^6

0032–3861/91/112020–13

2020 POLYMER, 1991, Volume 32, Number 11



SEM images of 15% by weight amine terminated PSF containing epoxy resins
(d) Mn=8,200 g/mol,
(e) Mn=14,600 g/mol

University-Industry Cooperation in Turkey

- Consulting
- University providing analytical services to companies
- Sponsored research projects
- Sponsored PhD students

Problematic areas

- Support for general research through a Consortium
- Establishment of company funded research centers at the universities
- Continuing Education – Short Courses
- Technology licensing

A selection of sponsored research projects performed at Koç University Polymer Research Laboratories

From Laboratory bench to commercial application

Sponsors

Turkish Ministry of Defense
Roketsan AŞ
Tübitak
DowAksa

Procter and Gamble Company
Wacker Chemie
Nylstar SA
Lubrizol Corporation

Development of Moisture Permeable, Waterproof Textile Coatings

Funded by Turkish Ministry of Defense

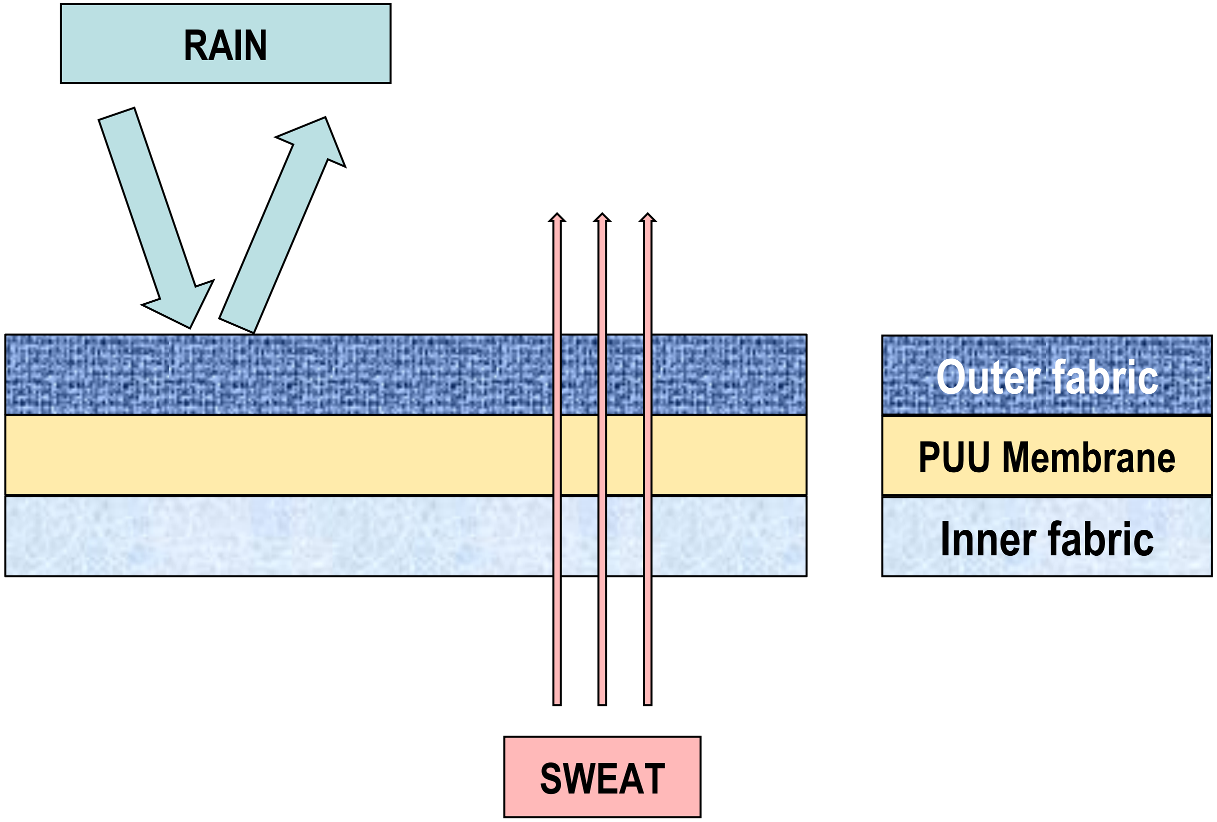
WATER VAPOR PERMEABLE, WATERPROOF (BREATHABLE) TEXTILE COATINGS







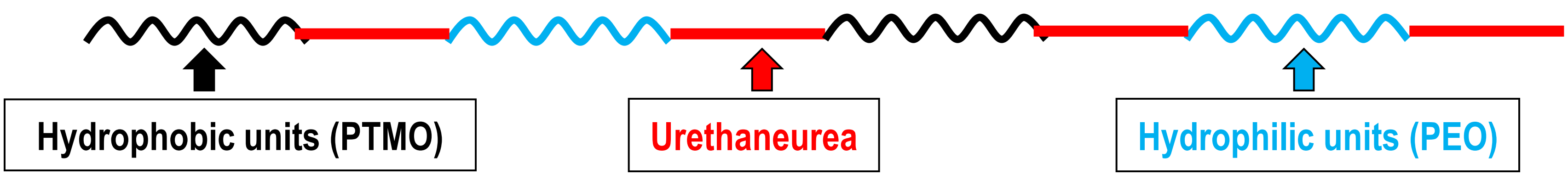
Water vapor permeable, waterproof (breathable) textile coatings

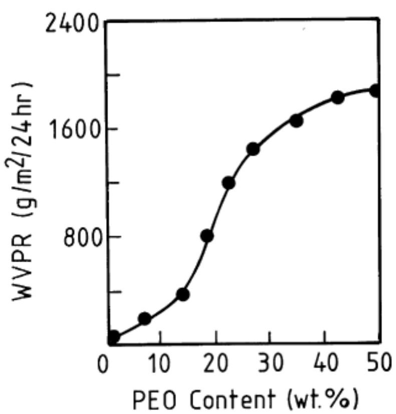


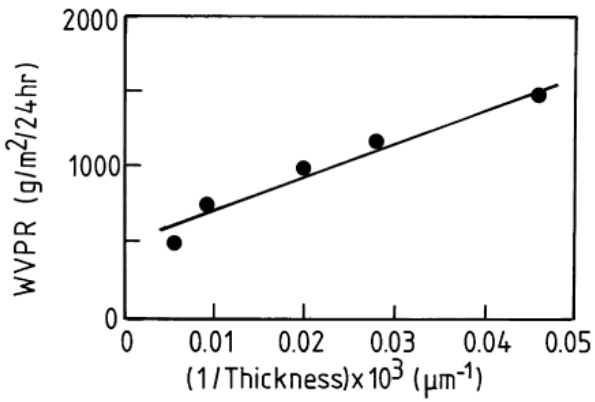
POLYURETHANEUREA MEMBRANES FOR
Water vapor permeable, waterproof (breathable) textile coatings

Solution

Microphase separated polyurethaneureas containing hydrophilic and hydrophobic soft segments with co-continuous soft segment morphology







E. and İ. YILGÖR

US PATENTS

5,389,430

5,461,122

5,521,273

TURKISH PATENT

TPE 2000/00998

E. Yılgör, I. Yılgör, Polymer 40 (1999) 5575–5581

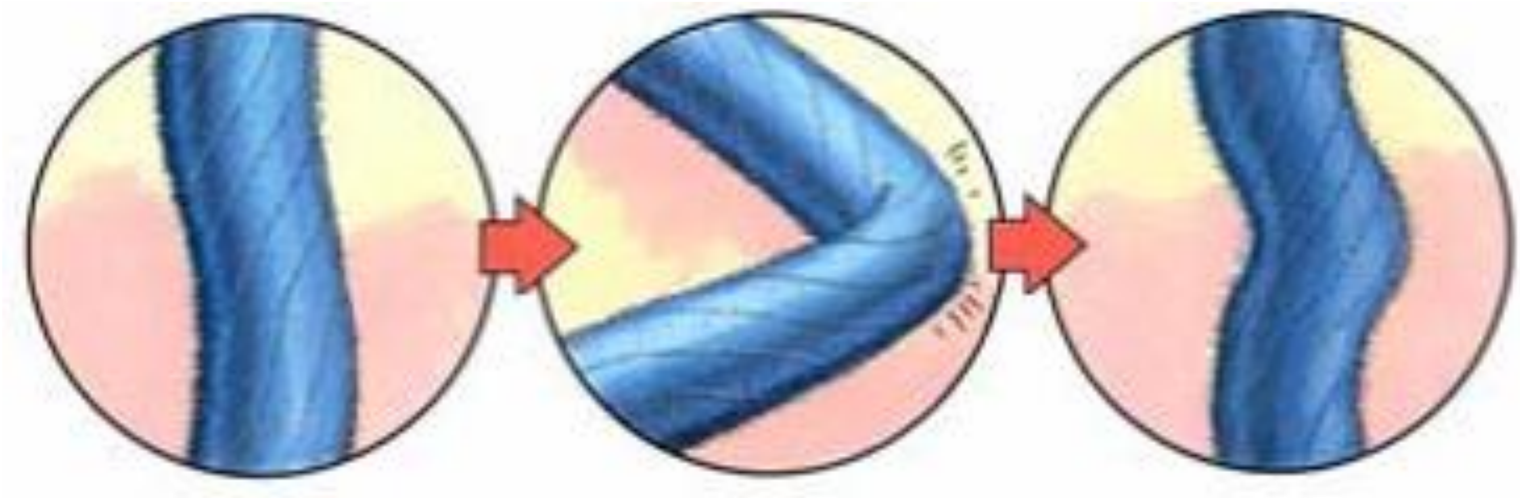
Polyurethaneurea additives to prevent wrinkling of fabrics

Funded by Procter and Gamble

Polyurethane coatings for prevention of wrinkling of fabrics

Problem
Wrinkle formation is a result of the deformation of non-elastic fibers which cannot recover

Solution
Development of polyurethane coatings that will improve the elasticity of textile fibers through hydrogen bonding.



PATENTS ON WRINKLE FREE FABRIC FORMULATIONS

FABRIC CARE COMPOSITIONS COMPRISING ORGANOSILOXANE POLYMERS

Rajan Keshav Panandiker, Kerry Andrew Vetter, Bernard William Kluesener, Iskender Yilgor, Christian Herzig, Richard Becker, Rafael Trujillo Rosaldo, Leslie Dawn Waits, Janine A. Flood, Keith Homer Baker, Jennifer Beth Ponder, Mark Gregory Solinsky, Matthew Scott Wagner, Pradipta Sarkar, Emily Suzanne Klinker, Julie Ann O'Neil

US Patent 8,263,543 B2 (Procter and Gamble Company) (September 11, 2012)
US Patent 8,598,108 B2 (Procter and Gamble Company) (December 3, 2012)
US Patent 9,085,749 B2 (Procter and Gamble Company) (July 21, 2015)
US Patent 9,469,829 B2 (Procter and Gamble Company) (October 18, 2016)
US Patent 8,518,247 B2 (Procter and Gamble Company) (December 11, 2016)

Country	Application No	Application date
Argentina	AR 076316 A1	2011.06.01
Australia	AU 2010236527 A1	2011.11.10
Canada	CA 2756294 A1	2010.10.21
China	CN 102395667 A	2012.03.28
Europe	EP 2419498 A1	2012.02.22
Japan	JP 2012523508 A	2012.10.04
Japan	JP 5453521 B2	2014.03.26
Mexico	MX 2011010898 A	2011.11.01
World	WO 2010120863 A1	2010.10.21

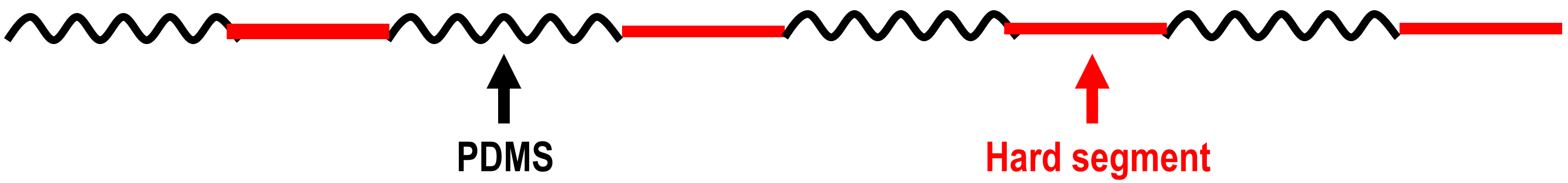
Development of Functional Thermoplastic Silicone Copolymers

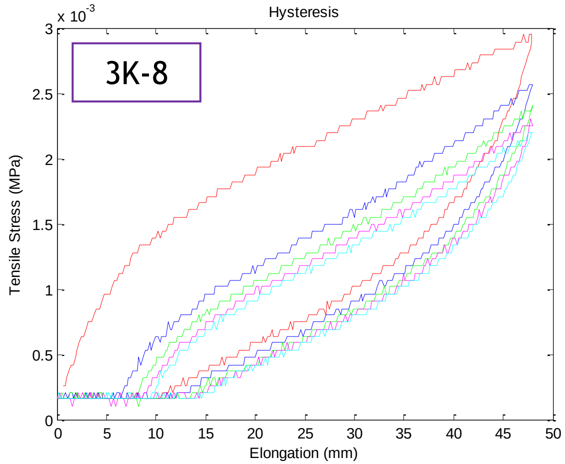
Geniomer TPSC
Genioperl ® W35

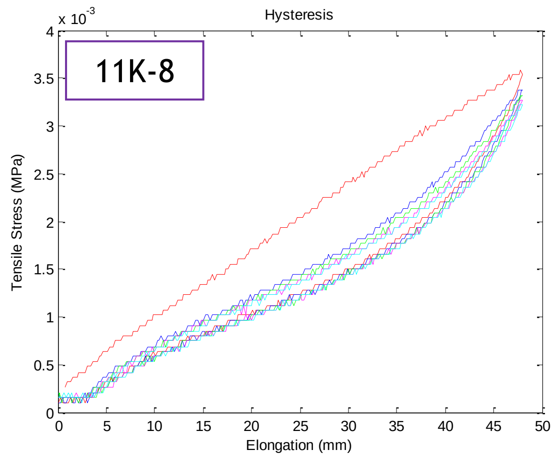
Funded by Wacker Chemie

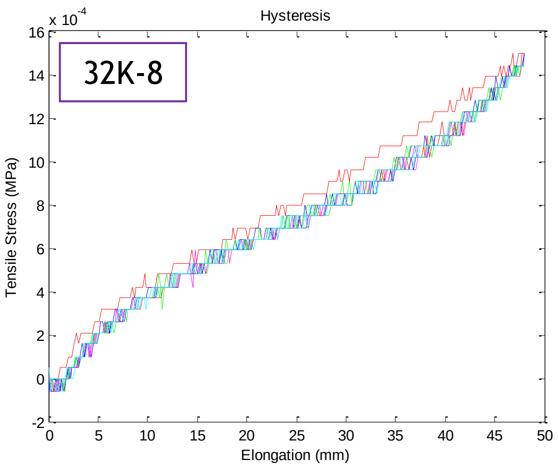
Thermoplastic Silicone-Urea Copolymers with Low Hysteresis

Influence of PDMS molecular weight on 200% hysteresis behavior of TPSU







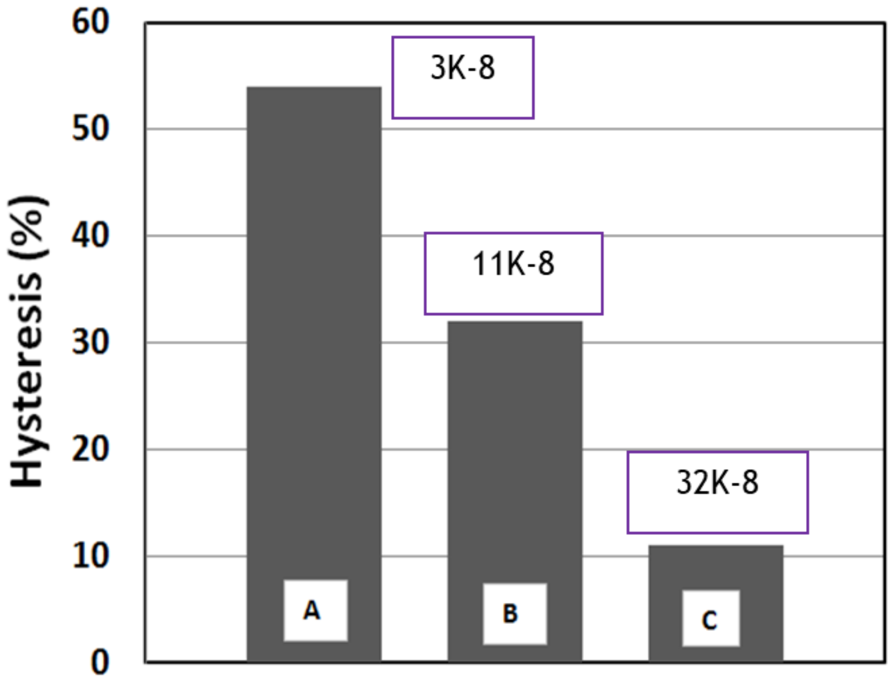


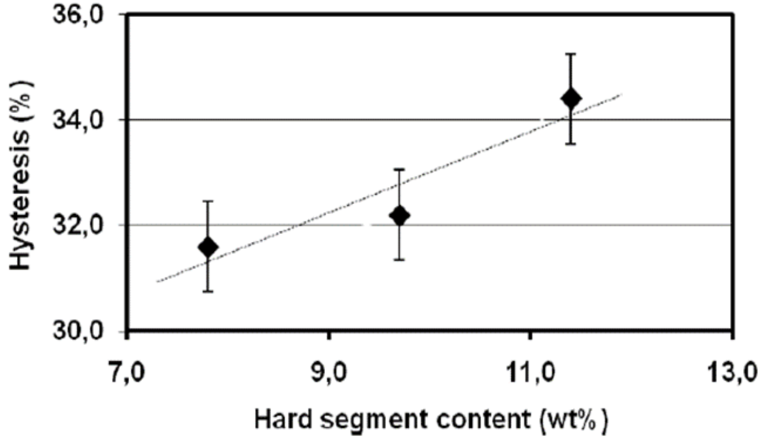
I. Yilgor, T. Eynur, E. Yilgor and G. L. Wilkes
Polymer, 50(19), 4432-4437 (2009)

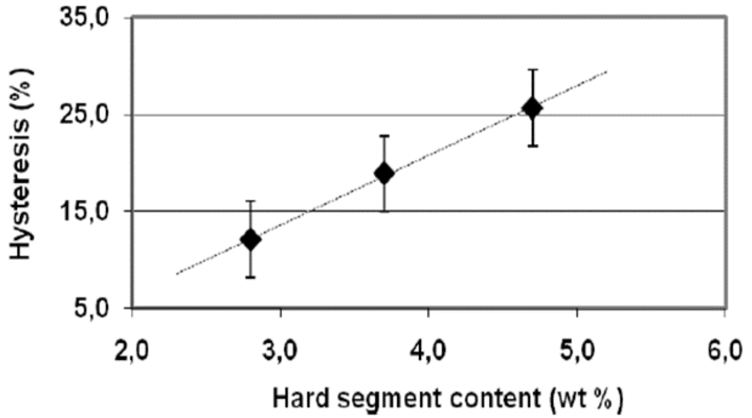
I. Yilgor, T. Eynur, S. Bilgin, E. Yilgor G. L. Wilkes
Polymer, 52(2), 266-274 (2011).

Thermoplastic Silicone-Urea Copolymers with Low Hysteresis

Influence of PDMS molecular weight and hard segment content on first cycle 200% hysteresis behavior of TPSU







Genioperl® W35

GENIOPERL® W35 is a polymer modifier with a linear structure based on a functionalized silicone.

GENIOPERL® W35 improves the impact strength of thermoset polymer systems like epoxy- or vinylester resins, especially at low temperatures. Addition of 2 - 8 wt.% is sufficient.

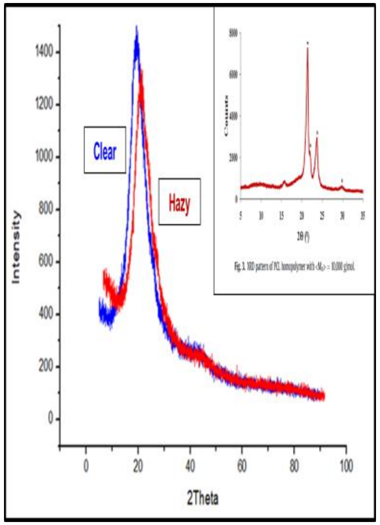
Due to low amount of GENIOPERL® W35 added, viscosity of the uncured resin as well as the glass transition temperatures of the cured resins remain almost unaffected.

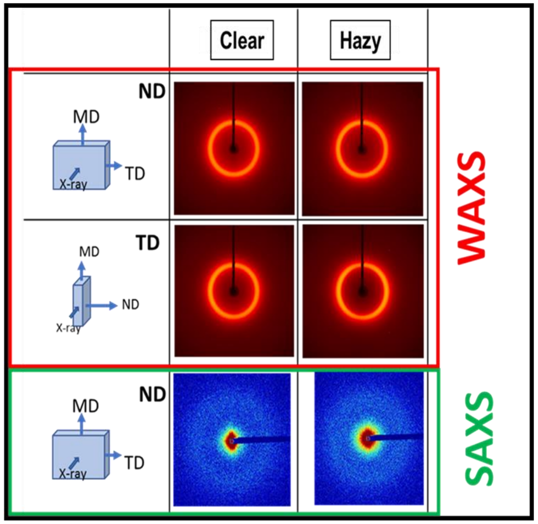
Investigation of the sources of haze formation on protective polyurethane films with similar compositions but produced by different methods

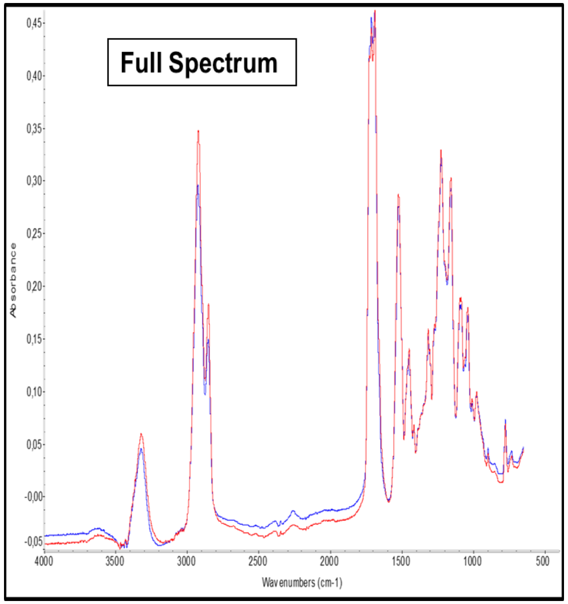
Funded by Lubrizol

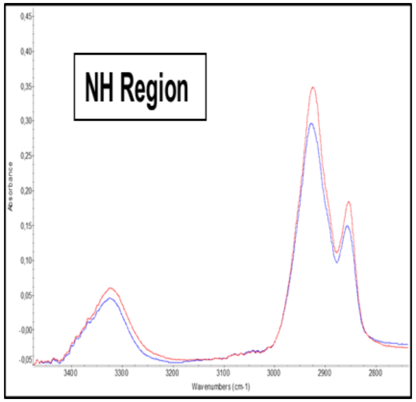
Analytical Methods

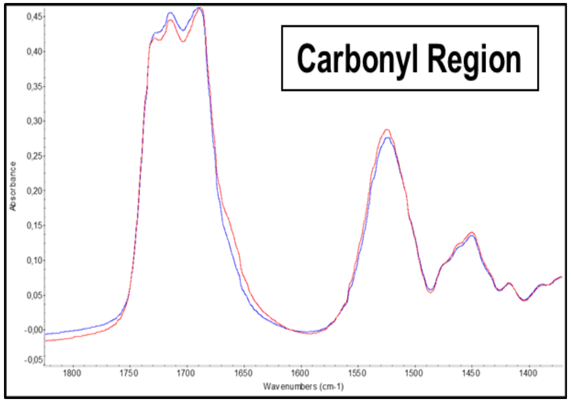
- Thickness measurements
- Differential Scanning Calorimetry (DSC)
- Infrared Spectroscopy
- X-Ray Diffraction (XRD)
- Small angle X-ray scattering (SAXS)
- Polarized Optical Microscopy
- Tensile measurements









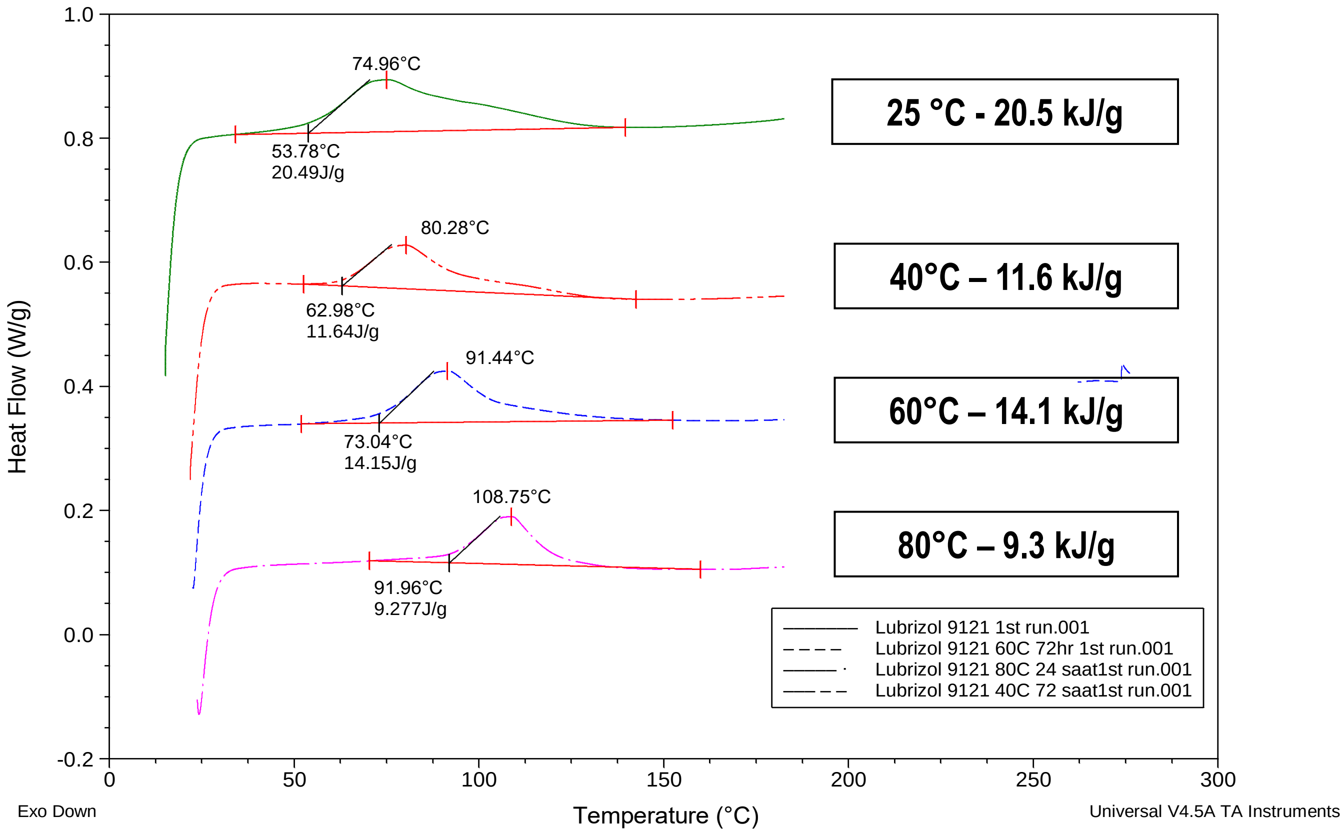


Film Thicknesses

Clear films: 120±5 µm

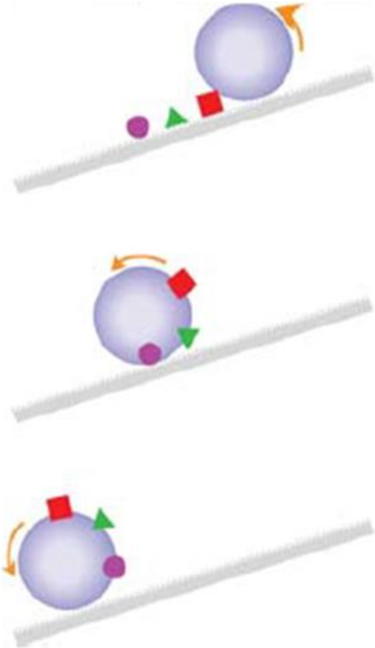
Hazy films: 150±10 µm

Comparative DSC Scans after annealing at 40, 60 and 80 °C

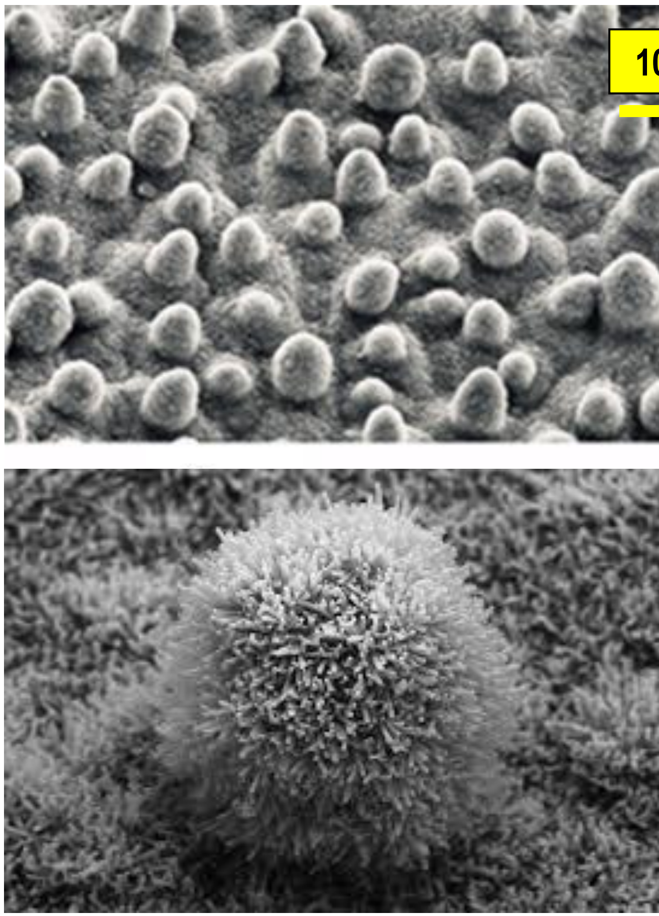


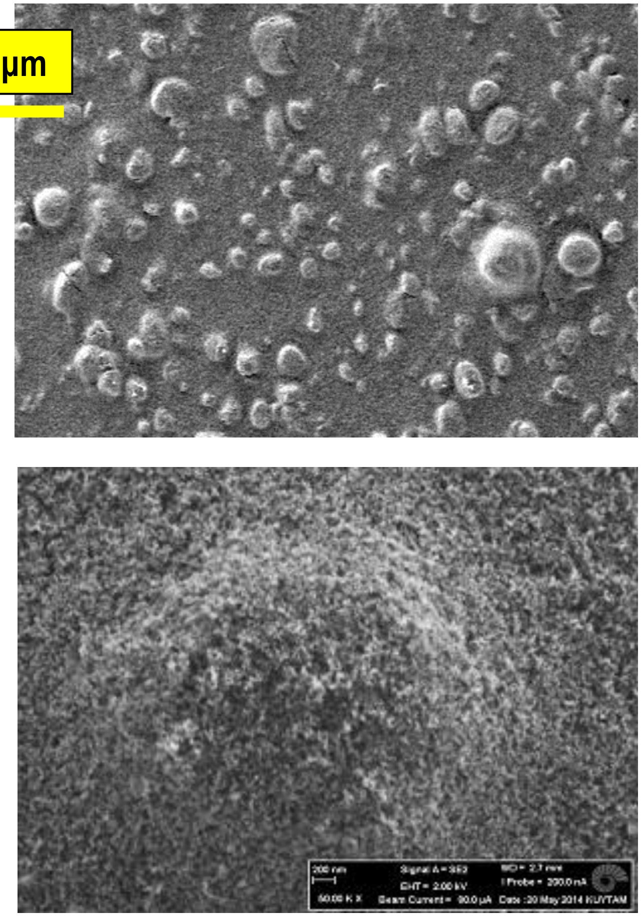
Superhydrophobic, Self-cleaning Polyurethaneurea coatings

Superhydrophobic and self-cleaning Lotus leaf



Electron microscope images of Lotus Leaf surface and hydrophobic silica filled polyurethaneurea surface

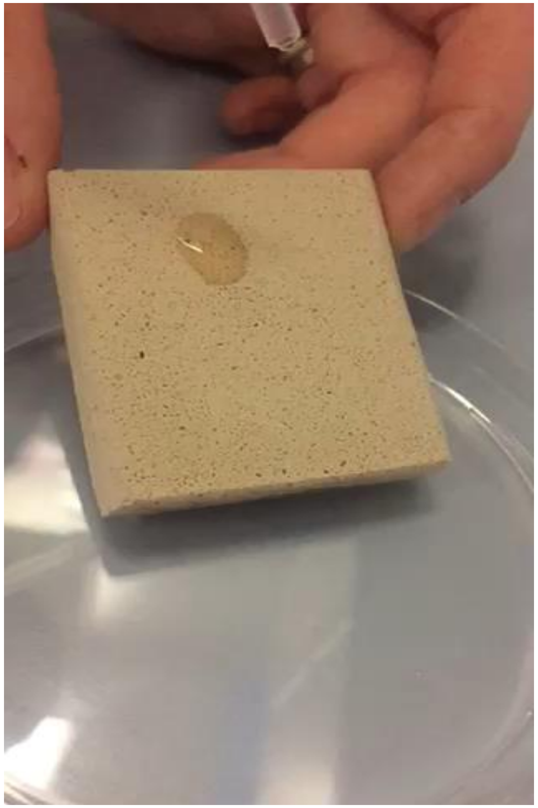


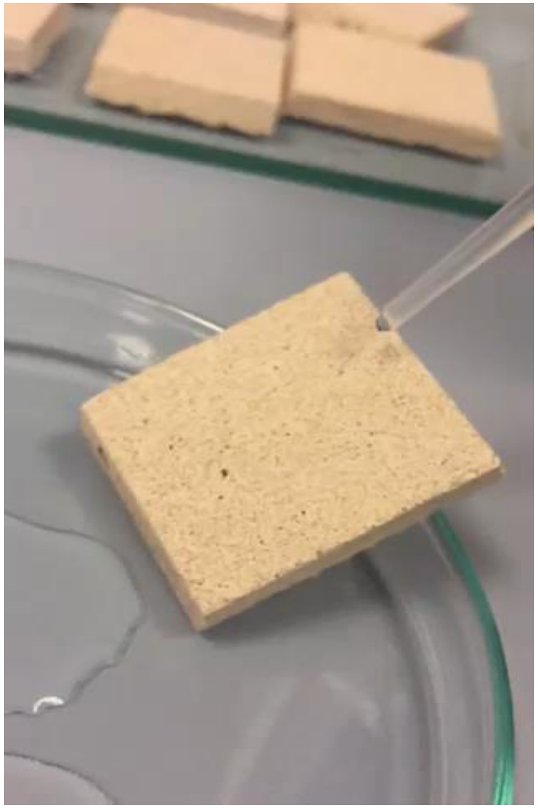


Lotus Leaf surface

Silica filled polyurethane surface

Superhydrophobic Polyurethane Coated Natural Stone Surfaces



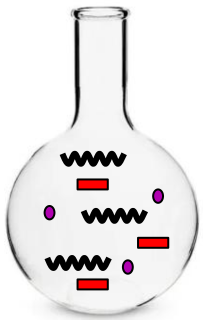
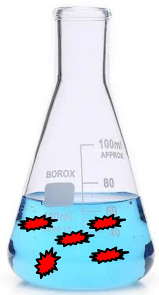
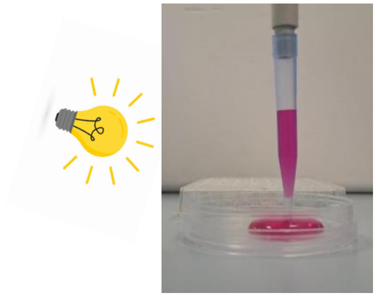
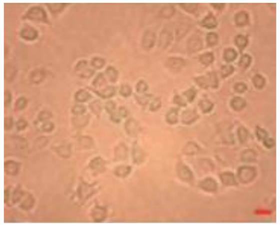


I. Yilgor, S. Bilgin, M. Isik E. Yilgor
Polymer, 53(6), 1180-1188, (2012)

C. Kosak, E. Yilgör, I. Yilgör
Polymer, 62, 118-128 (2015)

C. Kosak Söz, E. Yilgör, I. Yilgör
Prog. Org. Coat., 84, 143-152 (2015)

Water-soluble, Non-cytotoxic, Biocompatible, Biodegradable, 3D-Printable, Photocurable BIOINK Platform for Tissue Engineering Applications

BIOINK Synthesis	Cell Seeding	3D Printing and Curing	Cell Growth	Tissue Generation
				

First totally synthetic bioink

Funded by Tübitak – Joint project with Ankara University
2 PCT Patent applications

CONCLUSIONS

- Source of wealth is knowledge.
- Cost of a missed opportunity in a novel technology or process is usually far more expensive than supporting the research project.
- If you cannot generate new knowledge efficiently compared to your competitors, Industry-University cooperation may be a viable venue.
- Effective project leadership and communication on both sides are important for a successful cooperation.
- Effective transfer, diffusion and utilization of research results generated by the university, within the company is critical for a successful cooperation.
- It is possible to perform leading-edge, world-class polymer research to develop novel products and processes in select Turkish Universities.

Touching the lives of many brilliant young students

Koç University Polymer Research Group (Spring 2001)