Atmospheric Pressure Plasma
A New Technology for Modifying Technical Textiles

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Freudenberg New Technologies KG

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We are Part of the Freudenberg Group

Corporate Headquarters:

Freudenberg und Co.
Kommanditgesellschaft
69465 Weinheim
Deutschland

www.freudenberg.de

Employees 2006: 33.526
Turnover 2006: 5.053 Mio €

Organisation of the Freudenberg Group / Turn Over 2006

Parent Company: Freudenberg & Co.

Seals and Vibration Control Technology Business Area	Nonwovens Business Area	Household Products Business Area	Specialities and Others Business Area
Business Groups	**Business Groups**	**Business Group**	**Business groups**
Seals and Vibration Control Technology Europe 1075 Mio €	Nonwovens 801 Mio €	Household Products 627 Mio €	Chemical Specialities 470 Mio €
Seals and Vibration Control Technology America 986 Mio €	Freudenberg Politex Nonwovens 216 Mio €		Building Systems 158 Mio €
Seals and Vibration Control Technology China 96 Mio €			Mechatronics 14 Mio €
Vibracoustic Europe 451 Mio €			IT-Services 51 Mio €
Burgmann Industries 359 Mio €			New Technologies 26 Mio €
			Division Service Support 111 Mio €

Organisational Structure of Freudenberg New Technologies

Freudenberg New Technologies KG (FNT)

FNT
Management Support
New Business Ideas
Networking with Universities, Associations etc

Corporate Tasks
EU-, Berlin- Presence/Funding
Cooperation Japan/USA/China …

Freudenberg Forschungsdienste KG

Materials and Processing

Testing and Calculation

Patents and Brands

New Business Development

Internal Venturing

- New Business Projects
- Start Ups
  - FFCCT

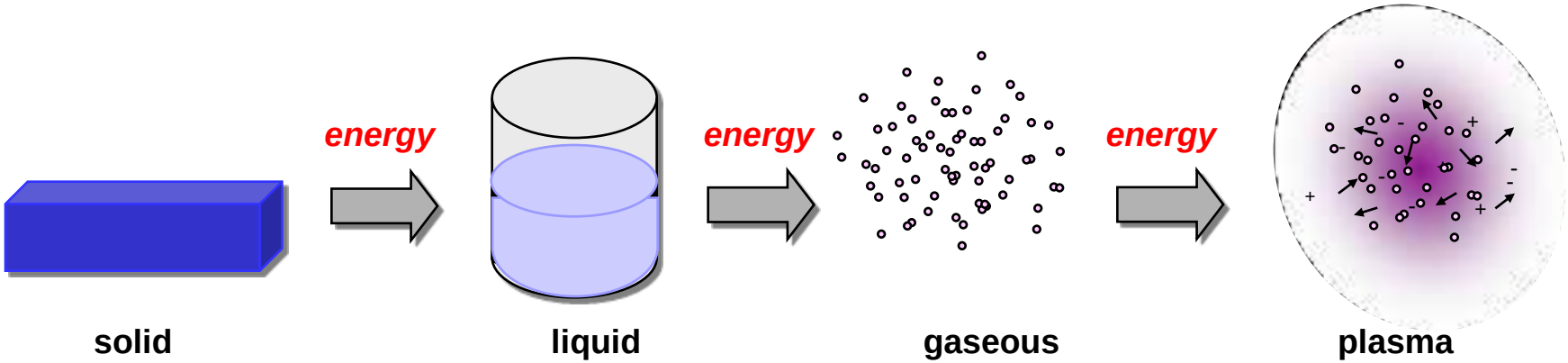
External Venturing

- Fraunhofer VC
- Condias

Agenda

- Introduction
- Technical solution
- Application examples
- Summary

Plasma - The 4th Physical State of Matter



- Plasma is an ionized gas - generated by applying energy to a volume of gas
- "Low temperature" plasma
  - energy is delivered by a high electric field
  - uniquely combines high chemical reactivity with ambient gas temperature operation

Idea


© Dow Corning

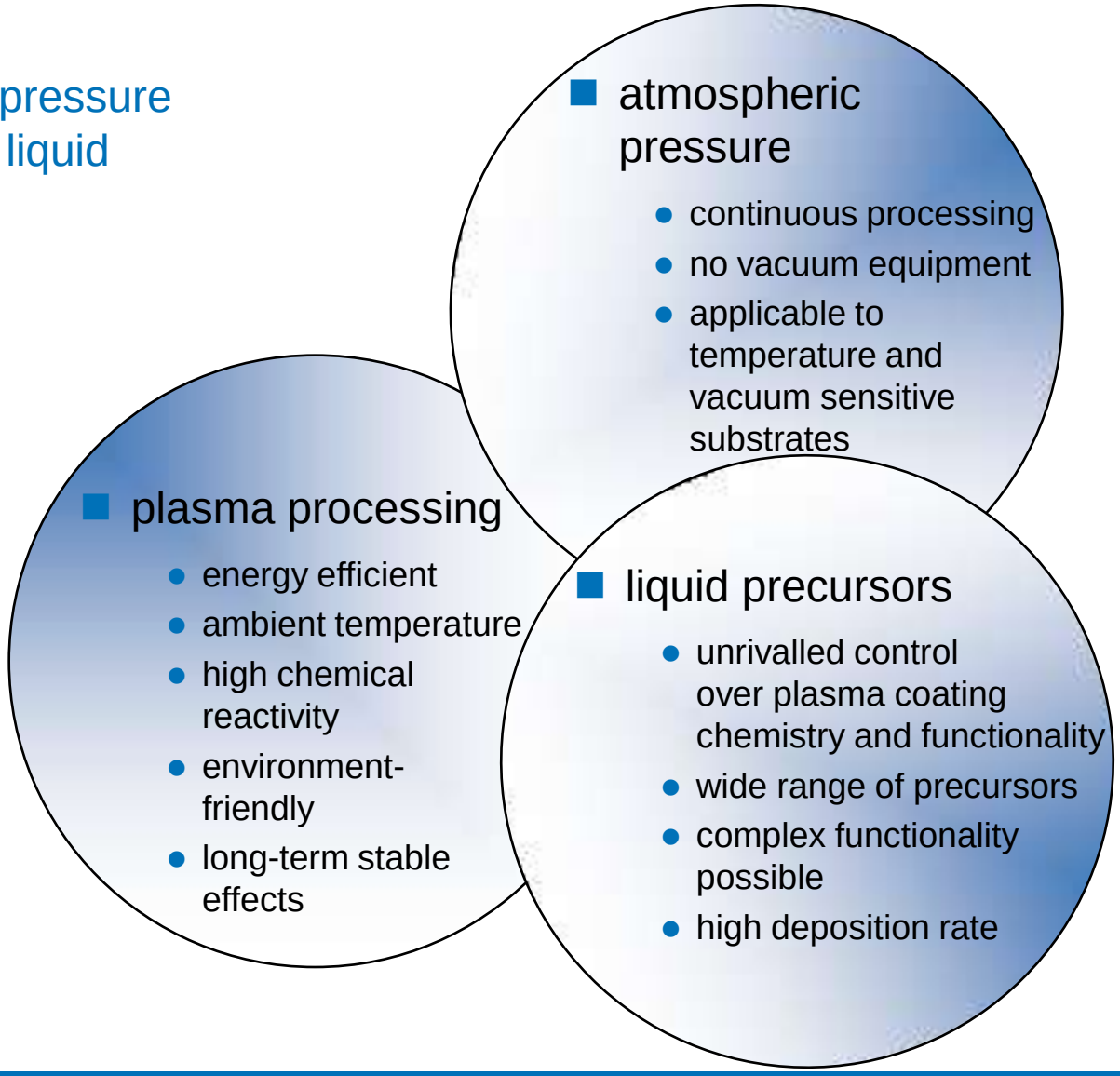
- Establish and commercialize the plasma technology for roll-goods in an industrialized, continuous, non-vacuum process
- Customize the surface characteristics of
  - nonwovens
  - technical textiles
  - polymer films and
  - membranes

  while the bulk properties are left unaffected by the process

Atmospheric Pressure Plasma Advantages

➔ Combines atmospheric pressure plasma processing with liquid precursors

- customized surfaces, bulk properties left unaffected
- control over surface functionality
- eco-friendly, continuous processing



Customer Value

- Create novel products, or enhance the performance of existing products → enter new markets, technology leadership
- Replace high-priced specialties by cost-saving modified commodities → enhanced market penetration, increased margins leveraged by premium products
- Replace polluting wet-chemical processing → process cost saving (less energy, water, waste, raw materials)
  environment, health and safety benefits

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The Processes

- Plasma activation

  long-term stable hydrophilization and/or activation as a pretreatment of polymer and natural substrates prior to coating, dying, lamination and other adhesion processes

- Plasma functionalization

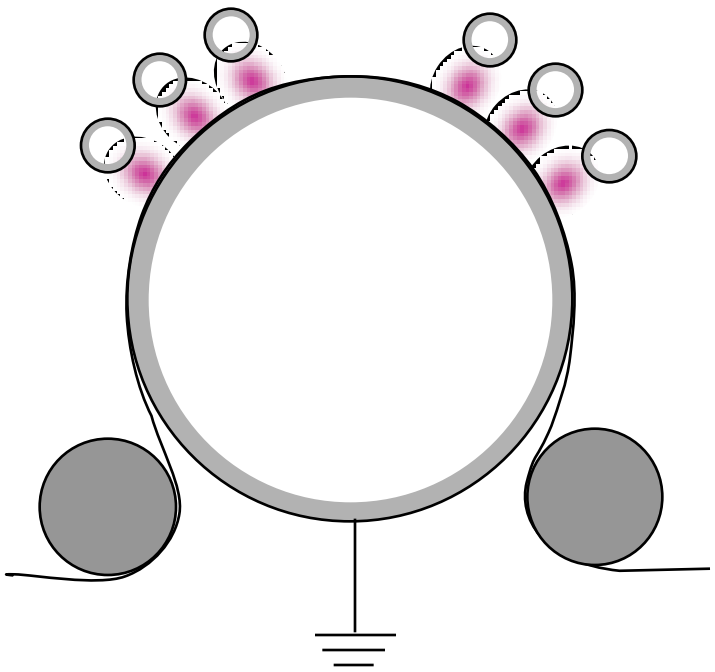
  preparation of polymer and natural surfaces for specific reactions (chemical affinity) by generation of functional chemical groups

- Plasma polymerization

  sub-micron highly functional layer deposition to get new performance coatings and finishing

The Technical Solution – I

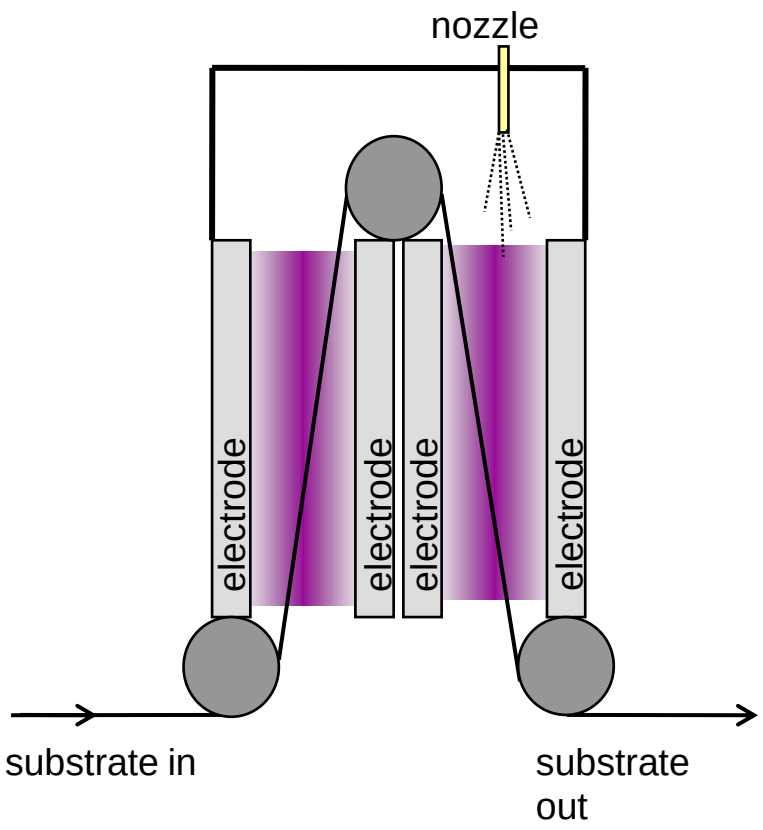
Activation / Hydrophilization



- Dielectric Barrier Discharge (DBD)
  - configuration: rod electrodes, grounded drum
  - pressure: open perimeter - atmospheric pressure
  - process gas: air
  - temperature: ambient temperature - air cooled system
  - substrate: roll-goods - up to 3 mm thickness
  - pilot line with 1000 mm width and 5-20 m/min

The Technical Solution – II

Functionalization / Coating

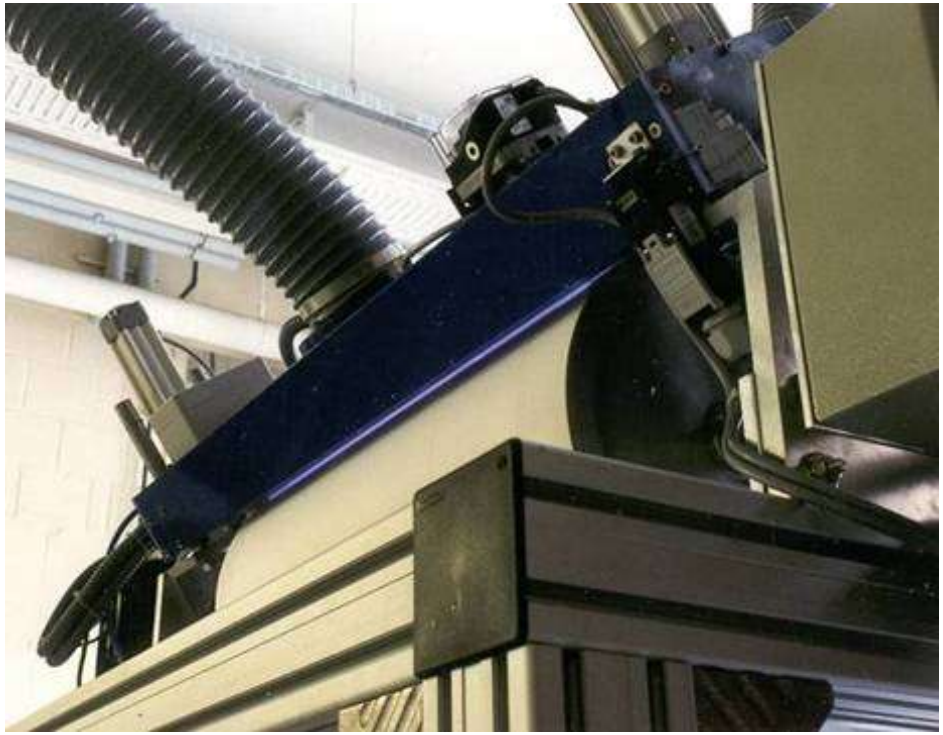


- Atmospheric Pressure Plasma Liquid Deposition (APPLD)
  - configuration: parallel plates, helium atmosphere
  - pressure: open perimeter - atmospheric pressure
  - temperature: ambient temperature - air cooled system
  - chemistry: direct introduction of liquid precursor (aerosol) into the plasma zone
  - substrate: roll-goods - up to 3 mm thickness
  - pilot line with 1000 mm width and 10-50 m/min

DOW CORNING Plasma Solutions

Equipment Platforms

Activation / Hydrophilization



Functionalization / Coating

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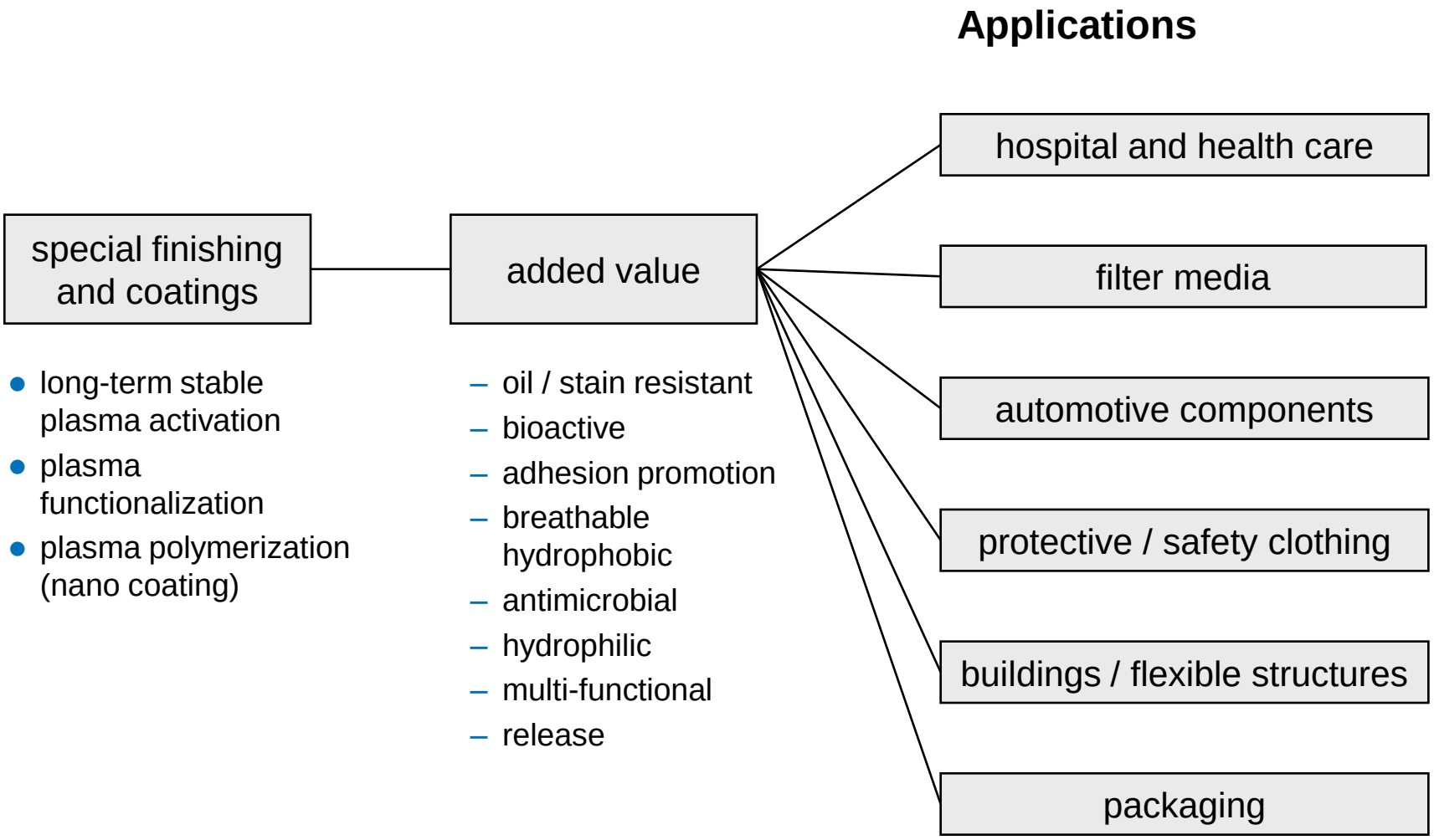
Added Value Products



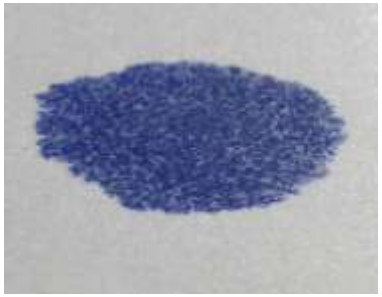
Long-term Stable Activation: Battery Separators

- In NiMH rechargeable battery separators made from nonwoven PP or PP/PE are used
- Substrate is hydrophobic by nature, insufficient wetting with water based electrolytes

➔ Activation / hydrophilization without the need of any chemistry

  - excellent initial wettability
  - long-term stability at ambient condition shown for more than 18 month
  - durability after storage in 30 % KOH (70°C)

untreated

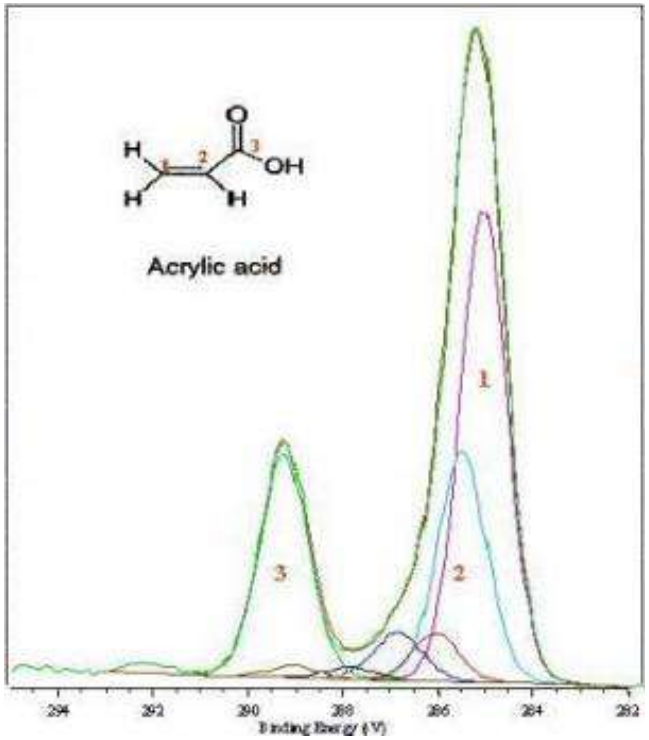


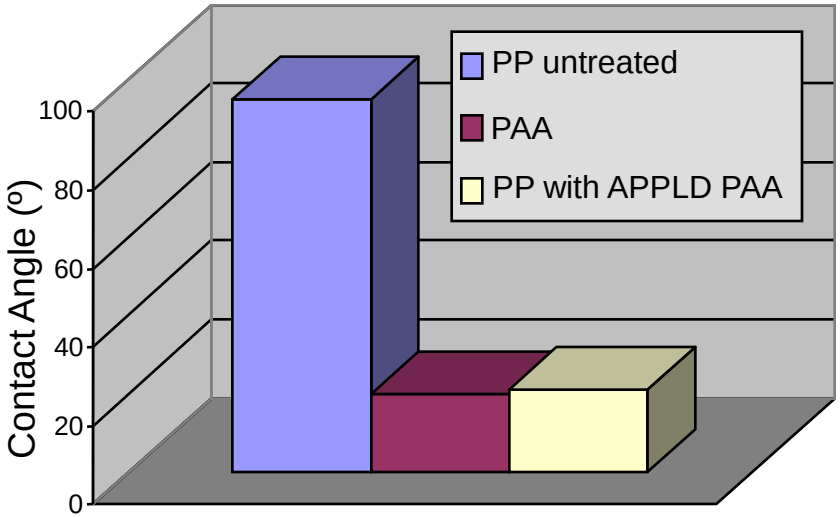
hydrophilic

	Initial wettability wickng rate after 10 min	**Durability in KOH** wicking rate after 30 min
A-Plasma	95-120 mm	40-60 mm
Fluorination	10-20 mm	40-50 mm

Hydrophilic and Reactive Coatings

- Features & results
  - retention of molecular structure in poly(acrylic acid) coating:
    –COOH rich
  - low water contact angle

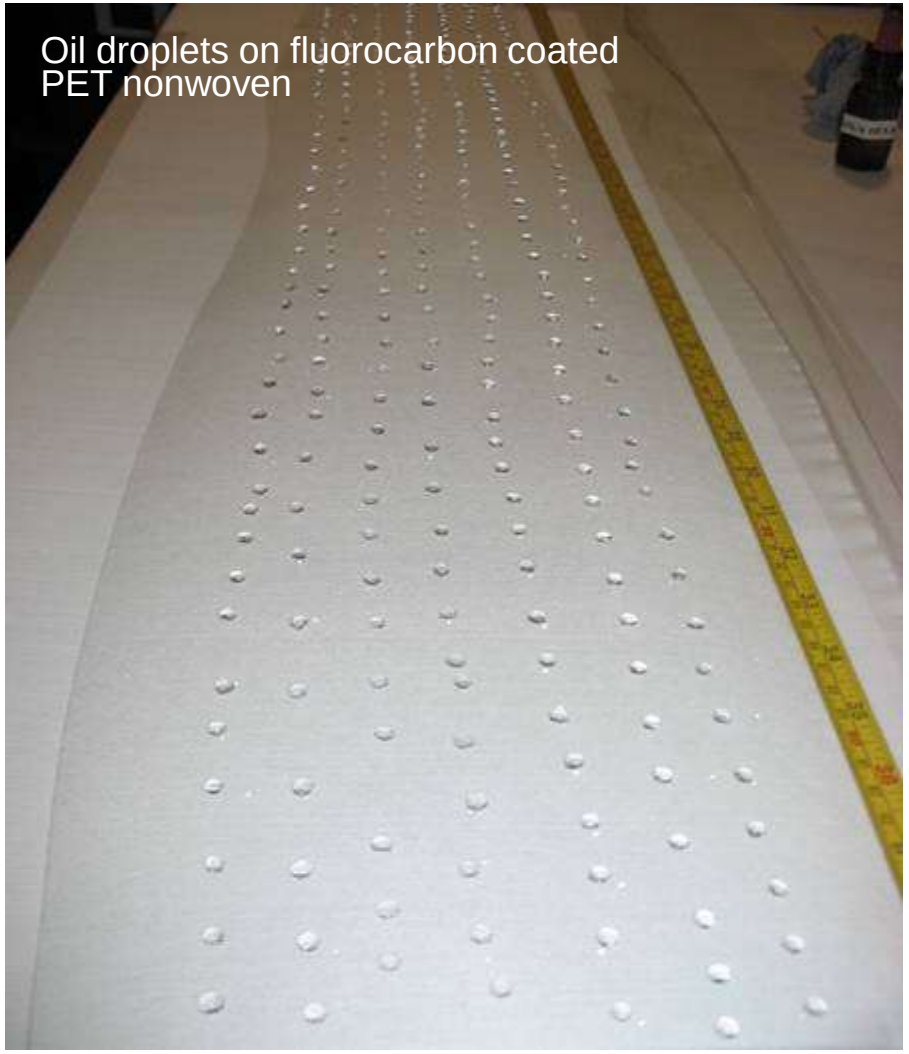




- Benefits & applications
  - high surface energy
  - acid rich & very reactive
  - water wicking, extra absorbency
  - anti-fog
  - easy take-up and good coverage for printing, coating, dyeing, etc

Oleophobic / Hydrophobic Coatings

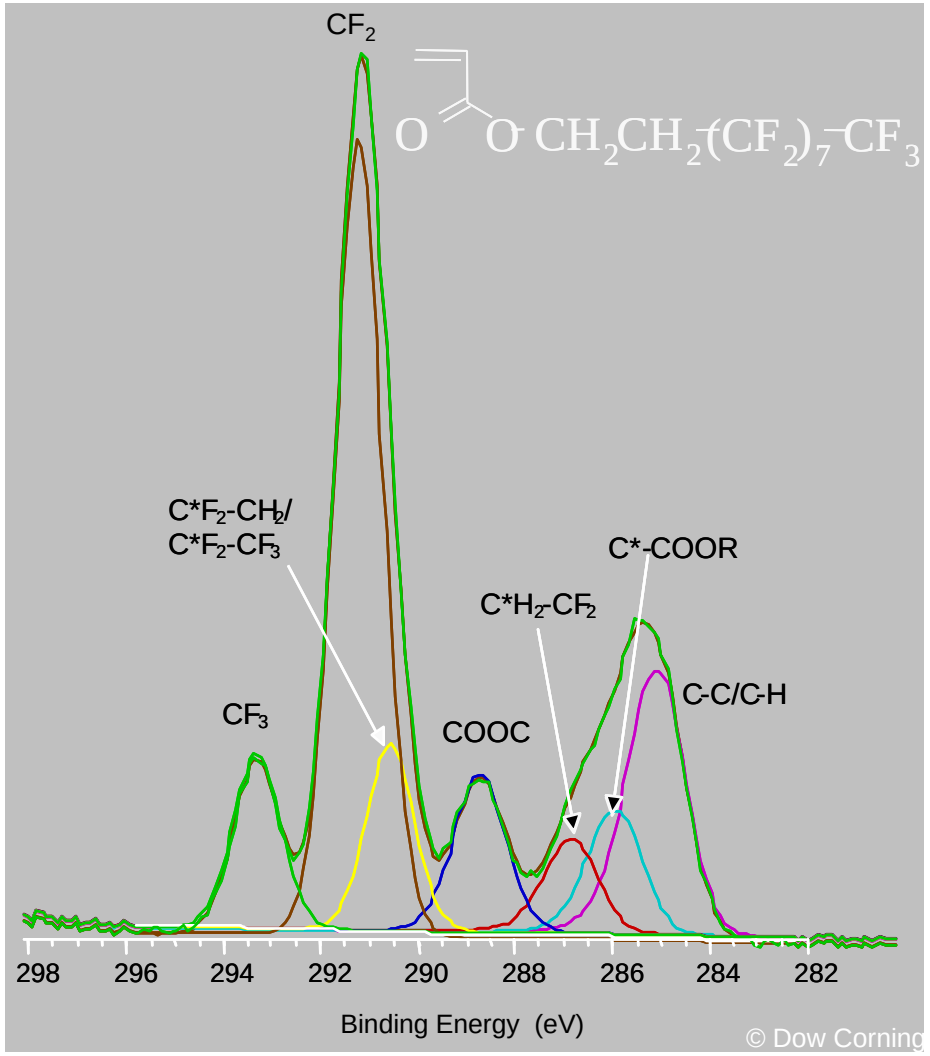
- Features & results
  - retention of molecular structure in coating: long-chain CF_x and cyclic siloxanes
  - large tetradecane and water contact angle
  - AATCC standard oil rating > 4
  - laundry durable
- Benefits & applications
  - oil & solvent repellency
  - excellent stain resistance and easy-clean performance
  - water repellent
  - friction control
  - low release force combined with high reusability



Oleophobic / Hydrophobic Coatings

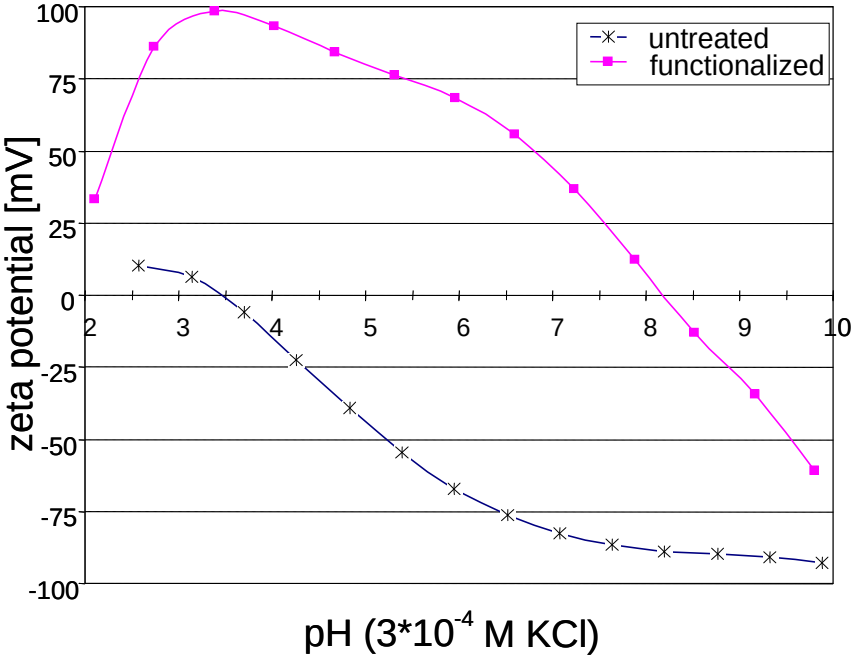
- Features & results
  - retention of molecular structure in coating: long-chain CF_x and cyclic siloxanes
  - large dodecane and water contact angle
  - AATCC standard oil rating > 6
  - laundry durable

- Benefits & applications
  - oil & solvent repellency
  - easy clean
  - water repellent
  - friction control
  - low release force combined with high reusability



Functionalized Textile Surfaces

- Polyester nonwoven with positively charged surface
  - basic functional groups, covalently bonded to the fibre surface
  - Positive Zeta Potential in aqueous media up to pH >8



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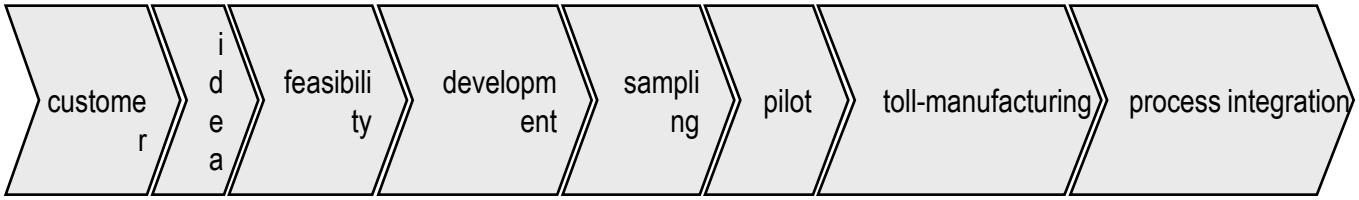
Summary

- Enables innovative products and processes
- Combines atmospheric pressure plasma processing with liquid precursors
- Delivers highly functional thin-film coatings for large area flexible substrates
- Industrialized continuous process
- Surface characteristics can be customized
- Bulk properties remain unaffected
- Process cost saving and environmental benefits

Benefits for our Customers

- Unique, customized, high value-added solutions for surface modifications



- product and process development for different customers
  incl. surface analysis expertise
- pilot production
- toll-manufacturing on smaller scale (1m width)
- scale-up and transfer to customer's production
  together with our Partner *Dow Corning Plasma Solutions*