WORKSHOP “INNOVATIVE MATERIALS”

Istanbul; Sept. 25, 2014
Profile of the Fraunhofer-Gesellschaft

7 Divisions:
• Information and Communication Technology
• Life Sciences
• Microelectronics
• Light & Surfaces
• Production
• Materials and Components - MATERIALS
• Defense and Security
Fraunhofer Division MATERIALS

MATERIALS RESEARCH ACROSS ENTIRE VALUE CHAINS

from developing new materials through quasi-industrial scale manufacturing technology to the characterization of properties and assessment of service behavior; covering components their functions, as well
MATERIALS - Business Segments

- Energy & Environment
- Mobility
- Health
- Machinery & Plant engineering
- Construction & Living
- Microsystems technology
- Safety
## Fraunhofer MATERIALS – Contribution

| Expertise in Material Science | - focus on entire processes and value chains  
|                              | - cross-institute teams and co-operation  
|                              | - neutral and independent |
| Partnership with Industry    | - know-how across industry segments  
|                              | - working with small, medium-sized and large companies worldwide |
| Integration in Scientific Community | - close link to local universities  
|                                  | - scientific publications |
| Co-operation Networks         | - local, regional and international networks  
|                              | - public-private partnerships |
The Fraunhofer IFAM

Fraunhofer Institute for Manufacturing Technology and Applied Materials Research

- established in 1968; part of FhG since 1974
- headquarter in Bremen
  - locations in Dresden, Stade, Oldenburg
- approx. 580 employees; research budget in 2013 ca. 46 Mio. €
- two divisions:
  - shaping and functional materials
  - adhesive bonding and surface technology
- close co-operation with the Universities of Bremen and Dresden
Material Science at University of Bremen

“ambitious and agile“
“ambitioniert und agil“
Fraunhofer IFAM – Further Locations

**Dresden Site**
Institute branch within the institute center Dresden (IZD) of the Fraunhofer-Gesellschaft

**Oldenburg Site**
Project team “Electrical Energy Storage” at the technology and founding center Oldenburg (TGO)

**Stade Site**
Joining and Assembly at the research center CFK Nord
Certification / Accreditation

- GL - quality management certification acc. to ISO 9001
- DAkkS - accredited testing laboratories acc. to ISO/IEC 17025
- DAkkS - accredited employee qualification acc. to ISO/IEC 17024
- DAkkS - accreditation acc. to ISO/IEC 17065 (product certification) planned
Fraunhofer IFAM – Core Competencies

**Surface Technology**

**Adhesive Bonding**

**Fiber Reinforced Materials**

**Casting Technology**

**Electrical Components and Systems**

**Powder Technology Sintering Processes**
contributions to the value chain from materials all the way to robust applications in industrial processes

- design and manufacturing semifinished parts
- surface modification
- assembly and joining techniques
- repair processes
- quality assurance
Adhesive Bonding Technology and Surfaces

manufacturing technology and applied material science scoping

Adhesive Bonding, Surface Technology and Composite Materials …

development focus:
• materials
• manufacturing integration
• fast processes
• reliability and quality
Surface Treatment

• **Process Engineering**
  - pilot-plant for plasma processes
  - paint application, drying
  - surface pretreatment
  - plasma processes and equipment

• **Material Screening / Qualification**
  - paint and coating accessories
  - raw material characterization
  - cleaning agents

• **Surface Analysis**
  - chemical, electrochemical and micro-structural analyses
  - optical / mechanical properties, wetting
  - production-integrated quality assurance
  - failure analysis
Inline Surface Treatment of Light Metals by Laser

**treatment effect**

- untreated
- laser treated

**laser system**

Q-switched Nd:YAG (λ = 1064 nm)  
250W; 10-40 kHz

example Ti6Al4V
Formation of Nano-structure

*pulsed laser plasma chemistry*  
*evaporation and condensation*

laser beam  
shock wave  
vapor/plasma - plume  
particles  
molten surface  
titanium substrate

Air (O₂, N₂, ...)

laser surface scan creates nano-structured, laterally homogeneous TiO₂-layer
Mechanism of Durable Adhesion

nano-porous titanium-oxide layer

TiO$_2$-adhesive hybrid interphase on nano-scale
Lap Shear Tests (Ti / 1C-EP, DIN EN 1465)

Objective: Adhesive Tape with Pickling Function

Requirements:
- All pickling agents integrated in the tape
- Pickling action on aluminum comparable to conventional pickling baths or pastes
- Sufficient adhesive strength to substrate
- Leaves no residues on the treated surface

Advantages:
- Local pre-treatment of complex shaped aluminum parts
- Easy to handle: no liquids used
- No additional rinsing step after pre-treatment needed

apply pickling tape to aluminum part for pre-treatment

removing of the pickling tape leaves a clean surface ready for coating or bonding.
Adhesive Tape with Pickling Function

**Pickling Agent**
Phosphoric acid (50 wt.% in dry mass)

**Adhesive**
- Water based / Retains its water content
- Resistant against strong mineral acids
- Polyvinylalcohol (base polymer)
- Polyacrylic acid (adjustment of film strength)
- Lactic acid (adjustment of tack)

*PP-film and polyester non-woven*
- application weight: 0.5 g/cm²
- drying at ambient temperature
Structure of Pickled Aluminum Surfaces (SEM)

technical surface as received (top view)

after 2h application of pickling tape (top view)

after 2h application of pickling tape (cross section)
## Adhesion and Interface Research

<table>
<thead>
<tr>
<th>development of materials and processes</th>
<th>development of tests and techniques</th>
<th>production</th>
<th>in-service</th>
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</thead>
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<tr>
<td>adhesives</td>
<td>techniques for material and surface evaluation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>surface treatment</td>
<td>computational chemistry</td>
<td>quality assurance of surfaces</td>
<td>failure analysis development of sensor devices</td>
</tr>
</tbody>
</table>

🛠 → development of analytical strategies, materials, processes, techniques

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Quality Controlled Adhesive Bonding

**Pre-Process:**
- integrity of substrates, internal stresses, surface condition, adhesive rheology, storage condition

**In-Process:**
- rheological performance, change in viscosity, adhesive application (geometry, position), pores, inclusions, wetting, curing

**Post-Process:**
- cohesive / adhesive failure, “defects“ (delamination, pores, “kissing bonds“)
- thickness and geometry of bond line, filling degree

**Initial Materials:**
- substrates, surfaces, adhesive

**Bonding Process:**
- adhesive application, joining, curing

**‘Final’ Bond:**
- (before supply)
- cured bond line
Inline Monitoring of Surface Quality

AEROSOL WETTING TEST

- surface pre-treatment
- aerosol application
- image acquisition and processing
- application of coating
Plasma Treatment of CFRP Before Painting

- Monitoring of plasma cleaning and activation of release agent contaminated CFRP

- Activated areas (left side):
  - large water droplets
  - good wetting behavior
  - good paint adhesion (GT0)

- Non-activated areas (right side):
  - small water droplets
  - poor wetting behavior
  - poor paint adhesion (GT5)

Good correlation between droplet-size and paint adhesion
From Raw Materials to Functional Coatings

- raw materials
- paint systems
- formulations

- smart coatings:
  - anti-ice
  - anti-drag
  - micro- and nano-structuring
  - self healing
  - anti-fouling
  - insulation

- treatment / cleaning
- process optimization
- qualification and characterization of coatings
- application, mixing and drying

- developing specific test devices

- corrosion test
- weathering test
- outdoor exposure
Influence on Aging Behavior

- UV-light
- variation of temperature
- humidity
- diffusion of water
- chemicals (hydraulic fluid, cleaner…)
- mechanical load
- surface preparation
- coating selection
Cracking: New Test Chamber

QUV – chamber + liquid nitrogen to generate temperature gradients within the sample

cold gas corresponding to cold and dry conditions during aircraft cruise phase

additional chemical impact due to operating liquids (deicing fluids, cleaning agents, atmospheric sulphur species) → where appropriate

alternating cold gas exposure will be used to simulate flight phases of an aircraft

H₂O diffusion in the case of CFRP; other fluids might be used if necessary

temperature range / humidity corresponding to conditions of aircraft interior
Specialty Adhesives and Sealing

- Develop / select formulations
  - material data

- Control substrate surfaces
  - validate methods for surface characterization
  - benefits in production, maintenance and repair

- Adhesive application
  - control geometry (position, volume) of dispensed adhesives
  - mixing ratio of 2K adhesives

- Bonded components
  - FEM simulation
  - destructive / non-destructive testing of bonded joints
  - durability and aging
  - structural health monitoring
Adhesive Bonding - Competencies

**Material Development**
- adhesives, potting materials, coating materials
- modification of polymer systems
- biomimetic adhesives
- adhesion promotion
- aging protection

**Characterization**
- thermo-analytics
- chemical analysis (IR, chromatography)
- describing material behavior
- rheology
- adhesion
- aging of bonded structures

**Structures**
- measuring and calculation of manufacturing effects
- modeling, simulation, dimensioning of adhesive bonds
- hybrid structures
- aging of bonded structures

**Application Processes**
- adhesive selection and qualification
- surface treatment
- dosing and mixing techniques
- simulation of flow behavior
- automation
- tolerance adjusted manufacturing
- potting

**Quality Assurance**
- Optical measuring technique
- inline-analytics
- Destructive and non-destructive testing and qualification
- certification body of German EBA
- workforce qualification

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Pre-applicable Structural Adhesives (“PASA”)

<table>
<thead>
<tr>
<th>pre-applied structural adhesives</th>
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</thead>
</table>

### Technical concepts for structural applications

- **dual cure systems**
  - blend of acrylic and epoxy resins
  - 1\(^{\text{st}}\) stage: polymerizing acrylic part by UV radiation
  - 2\(^{\text{nd}}\) stage: thermal cross-linking of epoxy resins

- **dispersions of solid resins**
  - thermal cross-linking of epoxy resins

- **hot melt adhesives**
  - melt or powder application (sinter process)
  - thermal cross-linking of epoxy resins

- fast cure and long shelf life
- good adhesion in uncured state
- non-tacky and good wetting
Target Application: Bonding Bolts

- pre-application of epoxy-based reactive hotmelts
- tack-free up to 50 °C
- induction heating
- fast curing within seconds
- integrated development of adhesive formulations, warming process and part geometry
- development of application process necessary
Target Application: Hem Flange Bonding

Conventional process:
1. 90° bending and adhesive application
2. Closing of the flange
3. Pre-hemming to 135°
4. Final hemming to 180°

PASA process:
- PASA application
- Storage
- Hemming
- Curing

PASA application at ca. 80°C and curing at > 150°C.
Hem Flange Bonding: Testing Concepts

scenario 1:
load transmission panel outside

test coupon and fixture for scenario 1

scenario 2:
load transmission panel inside
## Hem Flange Bonding: Testing Results

<table>
<thead>
<tr>
<th></th>
<th>PASA A</th>
<th>PASA B</th>
<th>Benchmark</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>force [N]</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.1 mm</td>
<td>4.240</td>
<td>4.680</td>
<td>3.660</td>
</tr>
<tr>
<td>0.2 mm</td>
<td>5.020</td>
<td>4.900</td>
<td>4.660</td>
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<tr>
<td>0.4 mm</td>
<td>5.070</td>
<td>4.640</td>
<td>4.640</td>
</tr>
<tr>
<td><strong>energy [J]\times 10^{-3}]</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.1 mm</td>
<td>4.964</td>
<td>9.115</td>
<td>1.999</td>
</tr>
<tr>
<td>0.2 mm</td>
<td>13.062</td>
<td>12.590</td>
<td>8.983</td>
</tr>
<tr>
<td>0.4 mm</td>
<td>13.784</td>
<td>8.550</td>
<td>8.273</td>
</tr>
</tbody>
</table>

Test scenario 1
Benchmark: commercial 1K epoxy adhesive
Focus Quality

- **Processes**
  - defining process windows
  - validation of machine and process capability

- **Products**
  - test methods, in-line if needed
  - non-destructive testing
  - structural health monitoring (SHM)

- **Norms**
  - international (minimum) standards
  - best practice benchmark

- **Personnel Training**
  - technology transfer
  - certified education
Center for Adhesive Bonding Technology

Training on adhesive bonding for workers up to engineers
(languages: German and English)

• DVS®/EWF-European Adhesive Bonder - EAB
  (DVS®/EWF-Klebpraktiker/in)
  Time: 40 h
  Focus: understand and realize work instructions

• DVS®/EWF-European Adhesive Specialist - EAS
  (DVS®/EWF-Klebfachkraft)
  Time: 120 h
  Focus: establish work instructions, guide workforce

• DVS®/EWF-European Adhesive Engineer - EAE
  (Klebfachingenieur/in)
  Time: 332 h
  Focus: develop / implement adhesive bonding processes for production and repair

in-house training: according to DVS®/EWF norms or individual

⇒ certified according to AZWV (accepting and approving procedure for trainings)
⇒ covers quality requirements of DIN EN ISO/IEC 17024
Fiber Reinforced Plastics - Competencies

**Resin Development**
- interior interfaces
- resin shrinkage
- electr. conductivity, lightning protection
- dry prepreg and shape-less tape laying
- fast curing of matrix resins
- internal release agents
- toughening modification

**Design Manufacturing**
- part manufacturing (structures, plates): infusion, hand lamination, autoclave processes
- release films
- prepregs
- surface structures
- functional structures
- modeling

**Surface Modification**
- pretreatment
- cleaning / activation
- painting, coatings
- fiber surfaces
- bonded areas
- paint stripping
- functional coating

**Assembly Joining**
- bonding, shimming, sealing
  - automated
  - all part sizes
- Precision machining
  - drilling, milling
  - water jet cutting
- form- and position adjustment
- optical measuring
- robotics

**Quality Assurance**
- FRP manufacturing
- FRP repair
- adhesive bonding of FRP structures

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CFRP Research Center Stade

- joining techniques
- machining
- textile technologies
- light weight design
- components
- virtual CFRP-development
- application research (e.g. new resins)
Automated Assembly Processes

- adaptive setting of form and position of CFRP parts by hexapods
- vacuum grabs for part handling
- grabs with integrated force-displacement sensors; tension controlled assembly processes

Flexible assembly processes:
- short cycle time with reduced manual work
- tolerance adjusted assembly
- sealing of joints and rivets
- high process safety
- hard- and software solution for sensor-guided CAD/CAM-systems
Machining of Composite Materials

Objective
Developing modules and principles of robot based CFRP machining:
- robot-specific process strategies
- reliable process control concepts
- dust collecting concepts

Pilot Plant at CFK Nord, Stade
- maximum part dimension: 13 m x 5 m x 5 m
- 3 robot units with milling shafts and 4 m linear axis
- extraction unit
- rigs for part fixation
- control units for machine evaluation and milling testing
Upcoming soon …..

Conference
INNOVATIVE MATERIALS
Nov. 25-26, 2014 in Bremen

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