New materials from the digital material laboratory

Andreas Wiegmann
CEO, Math2Market GmbH
Hannover Messe, April 26th, 2017
Math2Market GmbH and its GeoDict software
Some background information

- Math2Market creates & markets software to analyze/design porous & composite materials based on the material’s geometric inhomogeneity
- M2Ms software is called GeoDict, the Digital Material Laboratory
- GeoDict works on µCT-based, FIB-SEM-based and intrinsic models - in all cases, the computer representation consists of 3-D images
- M2M was spun off in 2011 from Fraunhofer Institute for Industrial Mathematics
- M2M is based in Kaiserslautern, Germany, and privately owned
- M2M has more than 100 clients from around the world
Mission & Vision

- Our vision is to help our clients profitably engineer better materials and processes through digital solutions.

- Our mission is to simplify material engineering and to create new standards using digital material models.
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Location and Contact

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www.geodict.com
Our focus is on the client

Software

Support & Training

User Guide

Consulting & Projects
An earlier version of the GeoDict logo was created in 2001 at ITWM. Since 2012 GeoDict is a registered trademark of Math2Market GmbH.

We not only develop the GeoDict Software but also:

- Do Projects with you to fit our GeoDict to your needs
- Offer Training sessions to improve your productivity with GeoDict
- Support you to reach your goals with GeoDict
"If our research and technology was turned into commercial software at all, it could take 10 or more years to do so. With M2M, the transfer can be achieved in as little as 2-3 years!"

Dr. Konrad Steiner

Head of department “Flow and Material Simulation”
1998  BMBF funded two-phase flow simulations in fibrous filters
1999  W. as user of fiber generator and flow solver
2000  First visualizations of materials and flow processes
2001  Fraunhofer Prize “Virtual Material Design”
2001  Invention of product name “GeoDict”, Logo by ITWM PR
2001  FhG Workshop identified filtration & mechanical properties
       simulation as major industrial needs
2001  Stiftung Innovation Rheinland Pfalz funded particle tracking
2003  Addition of DDFEM Mechanics Solver
2003  First Filtech presentation and exhibit
2003  First GeoDict workshop, 4 sales – all clients of M2M today!
2004  First filtration clients, MANN+HUMMEL and BOSCH
2005  Becker joined W.’s group
2005  First fuel cell projects, client requested scripting
2006  BMBF funded DPF simulation project with BOSCH
2007  First Pore Size Analysis at Filtech
2008  W. attended Fraunhofer Venture seminar
       Glatt joins W.’s group
       Exhibit at World Filtration Congress in Leipzig, meet GKD
2009  Began contract work for spin-off
2011  Wiegmann, Becker & Glatt founded M2M
       Last minute name changed from TGC (The GeoDict Company)
       Japanese distributor SCSK scouted ITWM
Difficulties associated with new high-tech ventures spun off from universities and research institutes

- Novelty of the venture and inexperience of the entrepreneur, give rise to a “liability of newness”

- Evolution from an initial idea in a non-commercial environment to becoming established as a competitive revenue-generating firm.

- Conflicting objectives of key stakeholders such as the university / institute, the academic entrepreneur, the venture’s management team and suppliers of finance
Difficulties associated with new high-tech ventures spun off from universities and research institutes

Novelty of the venture and inexperience of the entrepreneur give rise to a “liability of newness”

- 12, 6 and 3 years experience before founding
- Partners knew each other 6 and 3 years before founding
- Learn software engineering, learn managing a team
  - (as deputy head of department)
- Meet clients, learn their needs, keep them also at Math2Market
- Become known to several communities, such as
  - Paper Making
  - Filtration
  - Fuel Cell Materials
  - Metal Wire Mesh
Evolution from an initial idea in a non-commercial environment to becoming established as a competitive revenue-generating firm.

Many colleagues at Fraunhofer behave like researchers at universities – but this is also true of many researchers in companies. We got lucky that our clients, at least the engineers, think not so differently from ourselves.

For managers at our clients, it is a different story and to create materials for them required hiring people with a different background than the original founders.
Conflicting objectives of key stakeholders such as the research institute, the academic entrepreneur, the venture’s management team and suppliers of finance

- No external management team, no external supplier of funds
- Biggest issue money: unpaid overtime vs IP belonging to FhG
  - Complex payment involving fixed amount, project work and participation in M2Ms success as well as different numbers of shares
- Even more important than IP
  - M2M were allowed to continue with clients, now even some three-way collaborations Fraunhofer ITWM – M2M – Client
  - FhG provided fall-back solutions, in case of accidents to founders, for example escrow service

Difficulties associated with new high-tech ventures spun off from universities and research institutes
Selected Clients of Math2Market GmbH
Selected Clients
Selected Clients

- Opel
- The University of Texas at Austin
- Kyushu University
- Haver & Boecker
- Uppsala Universitet
- Johannes Gutenberg Universität Mainz
- Technische Universität Kaiserslautern
- Zeiss
- RWTH Aachen University
- CEA
- Bulgarian Academy of Sciences
- Paul Scherrer Institut
About the need for material modelling and simulation

- The function of porous and composite materials results from the choice of raw materials and their micro structure, i.e. the distribution of the constituents, e.g. fibers, in space.
- The power of simple models to predict the effects of the micro structure is limited.
- μCT and FIB-SEM provide 3D images of existing materials with unprecedented resolution.
- From these, one can compute the material's properties to match measured properties.
- Models also convert into 3D images. From these, material properties can be determined without the need to manufacture the new materials first.
- Instead of letting universities or institutes develop next generation materials, companies keep this knowledge in-house, by letting their own employees run the digital experiments.
- The Difficulty of the Math & Software Know-How is such that even the largest companies cannot do it all by themselves.
- 10 of the top 100 market capitalized companies are M2M clients, including Shell and P&G, who introduced the concept of open innovation about 2 decades ago.
- In the future, companies will need to be on top of their materials. The days of trial and error are coming to an end as powerful research tools deliver scientific data of unprecedented depth. [http://www.economist.com/technology-quarterly/2015-12-05/new-materials-for-manufacturing]
- At M2M, we believe this is true for our business areas – the future has already begun!
# Math2Market GmbH

## Promoted Industries

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<th>Industry</th>
<th>Description</th>
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<td>Filtration</td>
<td>Mostly automotive, filter media &amp; filters for water, sludge, oil, air and fuel</td>
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<tr>
<td>Electrochemistry</td>
<td>Fuel cell media &amp; battery materials, catalyst materials</td>
</tr>
<tr>
<td>Composites</td>
<td>CFRP, GFRP, mostly automotive, lightweight materials</td>
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<tr>
<td>Oil and Gas</td>
<td>Digital rock physics, digital sand control</td>
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</table>
Digital Rock Physics
Basic Workflow

1. Receive image of core, plug or cutting
2. Segment pores & minerals in image
3. Compute rock properties
**Math2Market GmbH, GeoDict for Oil and Gas: Digital Rock Physics Portfolio**

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Math2Market GmbH, GeoDict for Oil and Gas: Digital Rock Physics Portfolio

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- Geometrical parameters
- Flow parameters
- Electrical parameters
- Mechanical parameters
- NMR in preparation
### Math2Market GmbH, GeoDict for Oil and Gas: Digital Rock Physics Portfolio

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**Math2Market GmbH, GeoDict for Composites: Digital Experiments on CT-Scans**

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<th>Mechanical Parameters</th>
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<td>• Absolute permeability</td>
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<td>• Hyperelastic materials</td>
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<td>• Fiber diameters</td>
<td>• Thermal conductivity</td>
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<td>• Fiber orientation</td>
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<td>• Stress-Strain curves</td>
<td>• Structure change</td>
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- Flow & Conduction Parameters:
  - Absolute permeability
  - Thermal conductivity
  - Electrical conductivity
  - Tortuosity
  - Diffusivity

- Mechanical Parameters:
  - Elastic moduli
  - Stiffness tensor
  - Full anisotropy
  - Thermal expansion
  - Stress-Strain curves

- Large Deformation, Damage & Failure:
  - Hyperelastic materials
  - Plastic deformations
  - Viscous effects
  - Failure and damage
  - Structure change
**Math2Market GmbH, GeoDict for Electrochemistry: Electrode Portfolio**

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<td>Path of single particle</td>
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<td>Electrical Flux</td>
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Math2Market GmbH, GeoDict for Filtration: Gas Filtration Portfolio

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<td>Most penetrating particle size</td>
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## Math2Market GmbH, GeoDict for Filtration: Liquid Filtration Portfolio

### Filter Media
- Nonwoven fabrics
- Woven fabrics
- Foams
- Membranes
- Metal wire meshes
- Pleats & support meshes

### Clean Filter Parameters
- Media thickness
- Fiber diameters
- Fiber orientation
- Grammage
- Pore size distribution
- Bubble point
- Percolation path

### Liquid Filtration Experiments
- Multi pass tests
- Standard test dusts

### Liquid Filtration Results
- Initial pressure drop
- Pressure drop evolution
- Initial filter efficiency
- Fractional efficiencies
- Filter capacity
- Filter class
- Filter clogging behavior
Creating 3D Structure Models

Input parameters needed (straight fibers):

- Porosity
- Fiber type: cross sectional shape, diameter, length
- Fiber orientation tensor
- Thickness (height) of the filter media

Parameters might be

- known from manufacturing process
- measured experimentally
- measured from CT image
Oil Filter model

- Ellipsoidal cross section, diameter distribution
- Curved fibers
- Fibers oriented in xy-plane
- 500 x 500 x 650 grid cells, 1 µm voxel length
Create cellulose and layered media scale models

Cellulose nonwoven

Layered filter medium
Create woven, foam and sintered media scale models

- Metal wire mesh
- Open-cell foam
- Sintered ceramics
model a desalination membrane from a SEM image

http://www.geodict.com/Showroom/structures.php
Tomography and Models of Felts

Paper machine

Forming fabric and dewatering felt

10m

1mm

Tomography
Woven Metal Wire Meshes: Complex weave models

Left: Model of a two-layer weave based on a CT-scan.
Right: Model of a complex one-layer twill Dutch-weave.
Glass fiber nonwoven

SEM visualization of 8 volume percent 5 micron fibers

anisotropy 100

anisotropy 7
Curled & inhomogeneous nonwoven

homogeneous model  μCT scan  inhomogeneous model
Simulation provides deposition location details over time. Distinguishes depth filtration and cake filtration phases.
Thank you and come visit us at Booth D03 of young tech enterprises

Visit us @ www.geodict.com