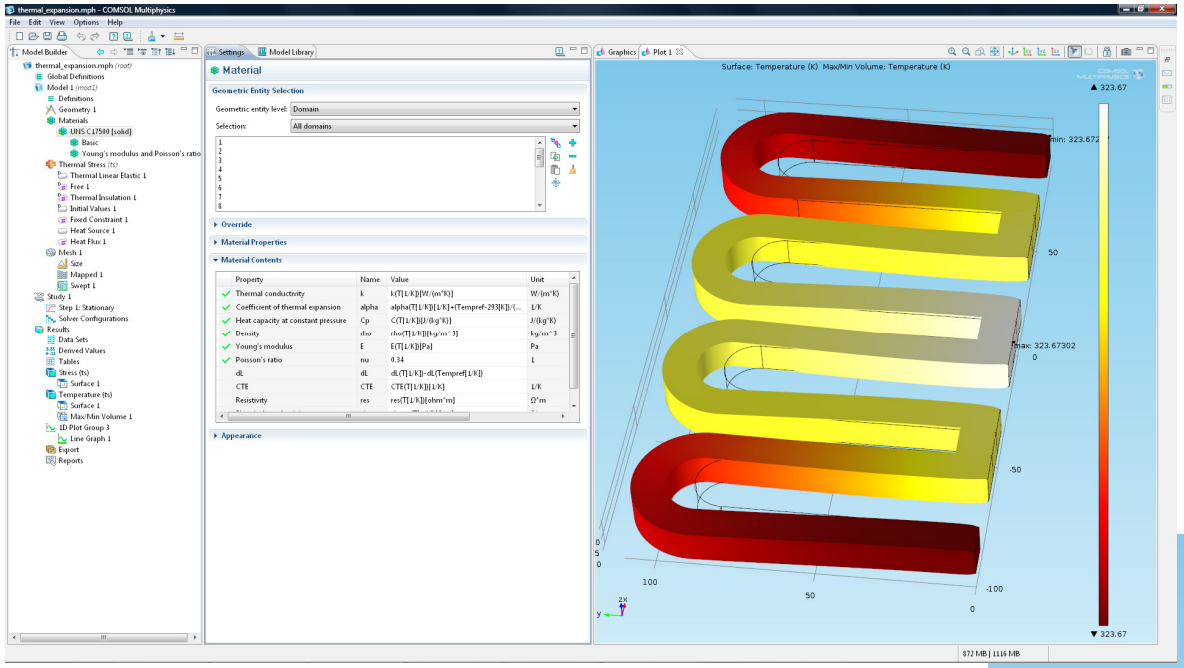
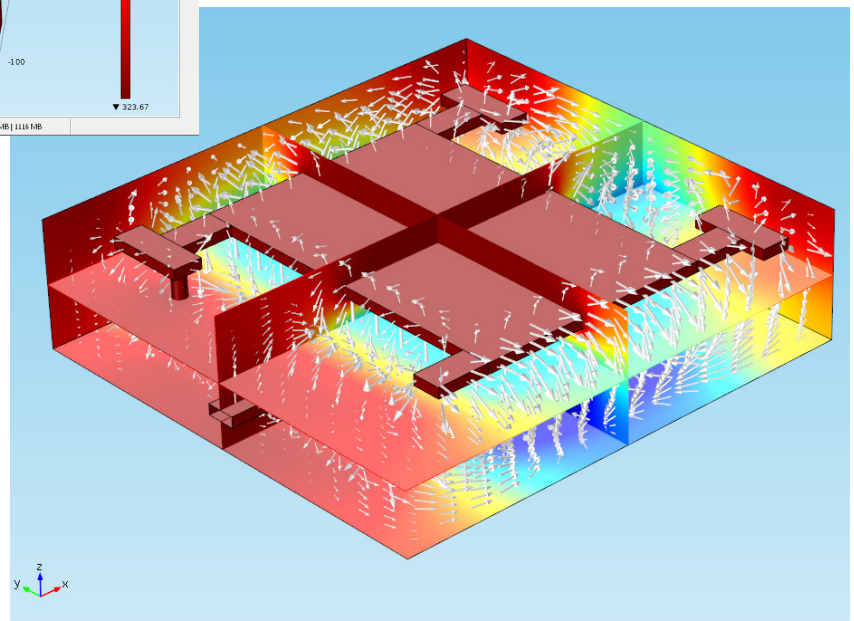
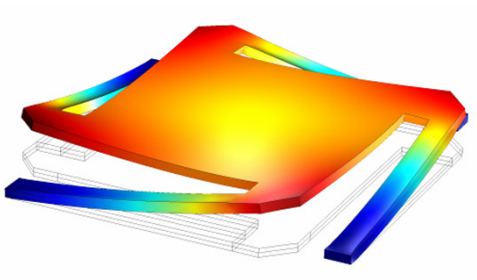




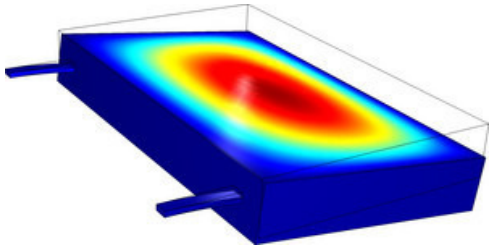
COMSOL Multiphysics for Hi-tech Industry

COMSOL

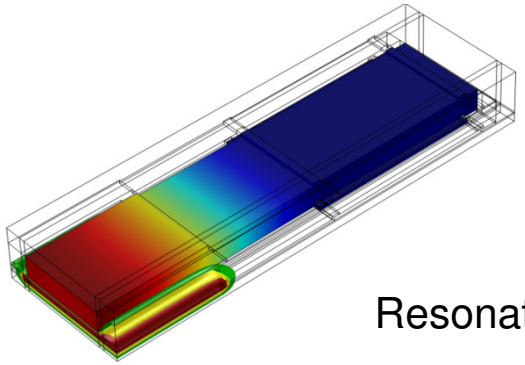
MEMS Application Areas



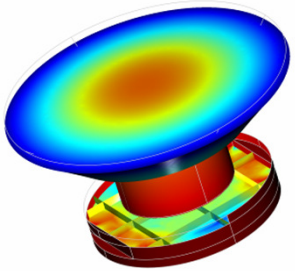
Actuators and Sensors



Gyros and Accelerometers



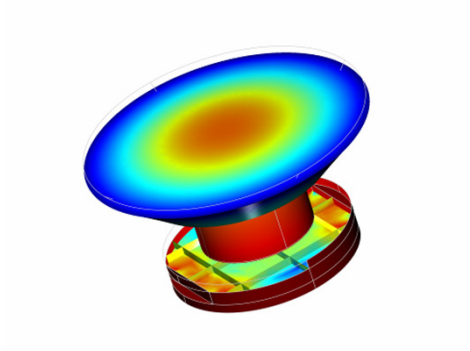
Resonators



Piezoelectric and
Piezoresistive Devices

MEMS Module Highlights

- User interfaces for
  - electrostatics
  - solid mechanics
  - electromagnetic-structure interactions
  - thermal-structure interactions
  - fluid-structure interactions
  - piezoelectricity
  - combinations of the above
- Advanced damping mechanisms
  - thin-film gas damping
  - anisotropic loss-factors for solid and piezo materials
  - anchor damping where perfectly matched layers (PMLs) provide state-of-the-art absorption of outgoing elastic energy
- Stationary and transient analysis, fully-coupled eigenfrequency, parametric, quasi-static, and frequency response analyses
- Lumped parameter extraction of capacitance, impedance, and admittance and connections to external electrical circuits via SPICE netlists



Green Energy Examples – Energy Harvesting

<u>Mechanical Energy Harvesting</u>

- Waves into Electrical Power
- Generate milliWatts to Watts

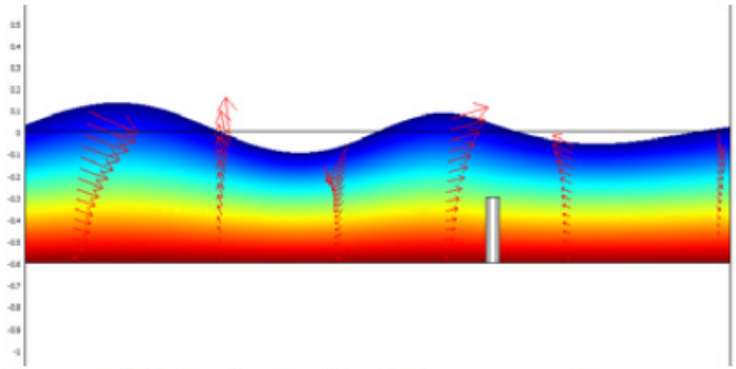


Figure 7 Partical velocity of the wave motion

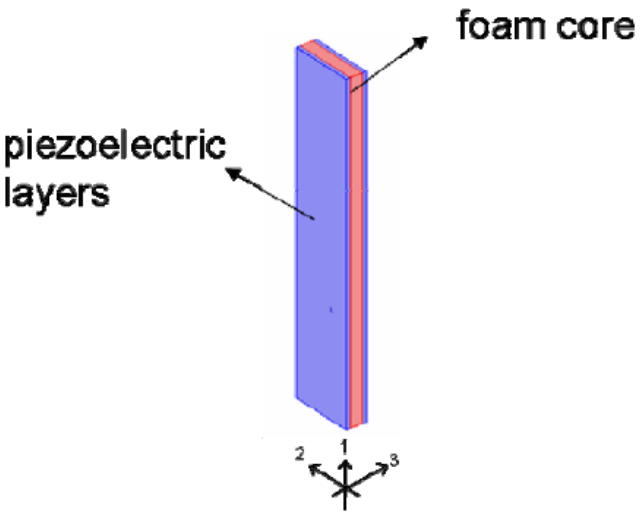


Figure 3 Piezoelectric generator: blue PVDF, red foam core.

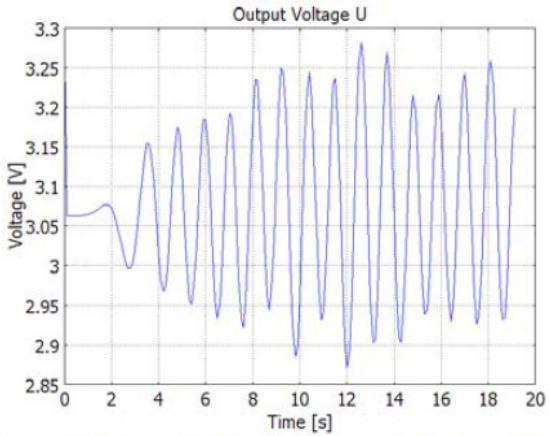
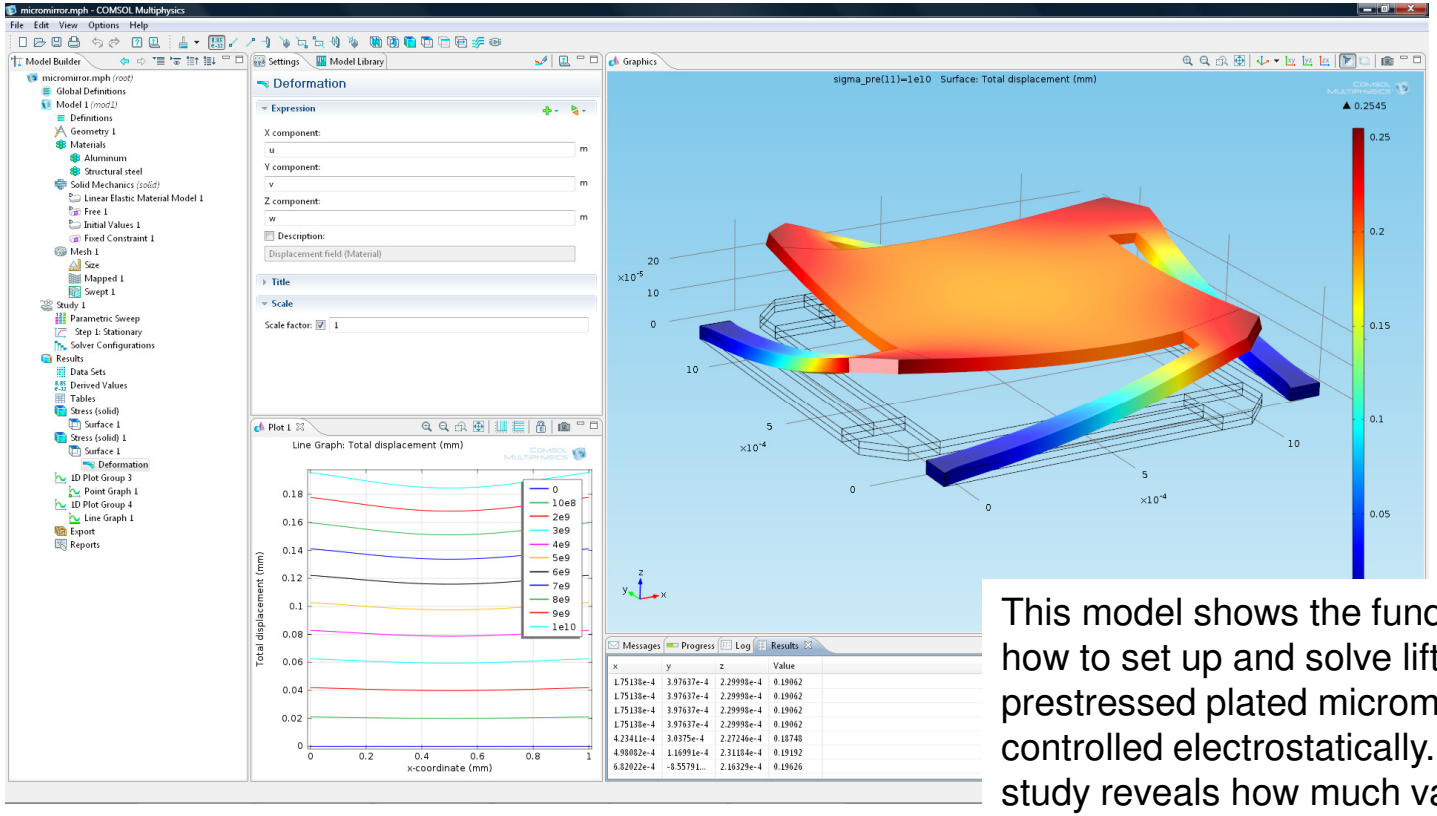


Figure 9 Voltage Field at the bottom right edge of the structure.

Excerpted from "Wave Energy Converter through Piezoelectric Polymers", Zurkinden, Campanile, Martinelli COMSOL Users Conference 2007 Grenoble

COMSOL

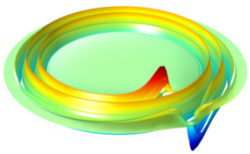
Prestressed Micromirror



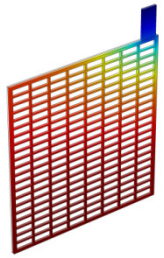
This model shows the fundamentals of how to set up and solve lift-off of a prestressed plated micromirror that is controlled electrostatically. A parametric study reveals how much variations in the prestress affect the displacements.

COMSOL

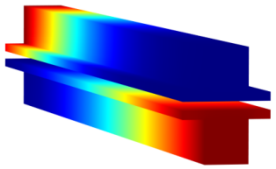
The Batteries & Fuel Cells Module



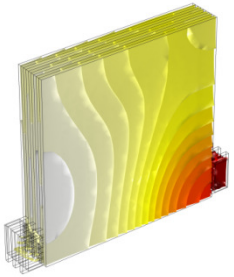
Spiral wound Li-ion battery



Lead-acid battery electrode



Planar fuel cell,
counter current flow

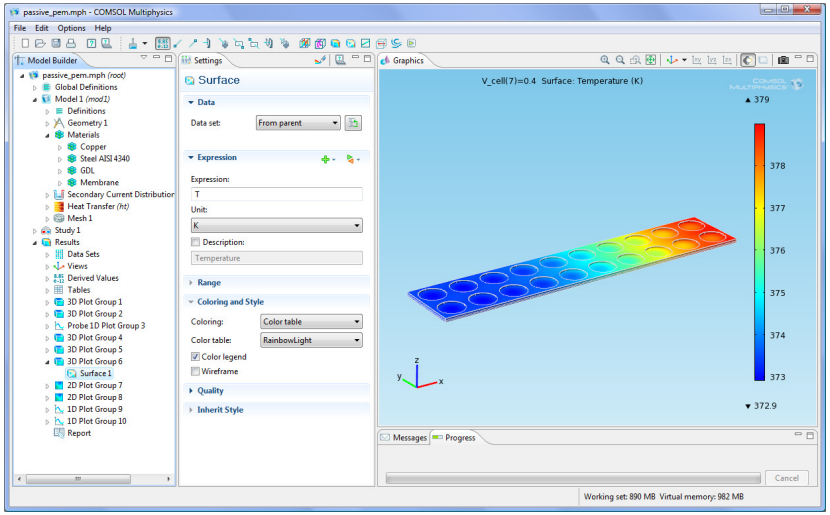


Water-cooled Li-ion
battery pack

COMSOL

The Batteries and Fuel Cells Module

- Specialized tool:
  - Models and simulates all major types of battery and fuel cell applications
- Ease-of-use
  - Tailored functionality/interfaces for:
    - Primary, secondary and tertiary current density distribution
    - Porous and gas diffusion electrodes
    - Dilute and concentrated electrolytes
- Multiphysics
  - Flow, electric fields, and heat transfer with electrochemical reactions

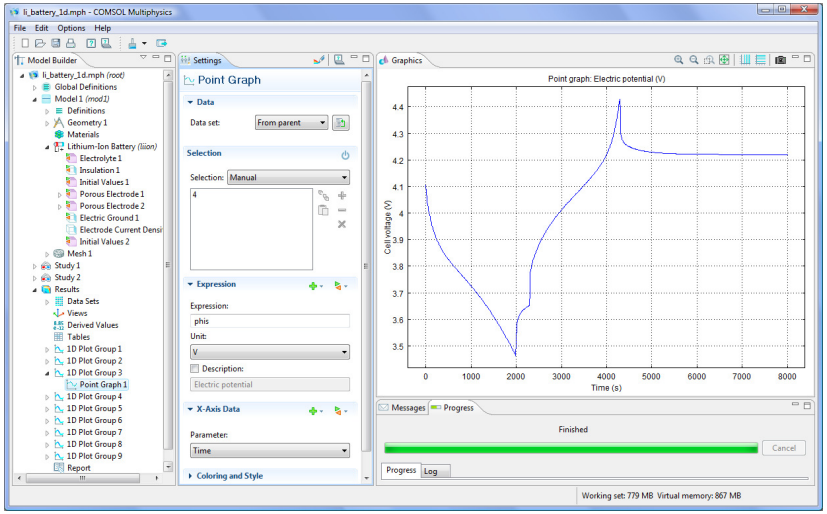


Temperature distribution in a PEMFC equipped with passive self-breathing electrodes

COMSOL

Targeted Batteries and Fuel Cell Systems

- Batteries:
  - Lithium-ion
  - Nickel-metal hydride
  - Lead-acid
  - Nickel-cadmium
- Fuel Cells:
  - Proton exchange membrane, high and low temperature
  - Solid oxide
  - Molten carbonate
  - Direct methanol



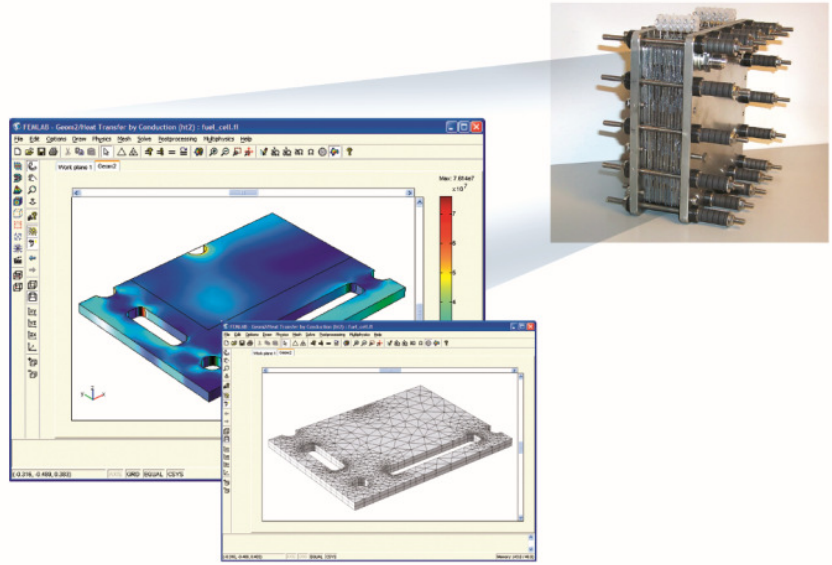
Discharge-recharge cycle for a lithium-ion battery simulated with the new Lithium-ion battery interface.

COMSOL

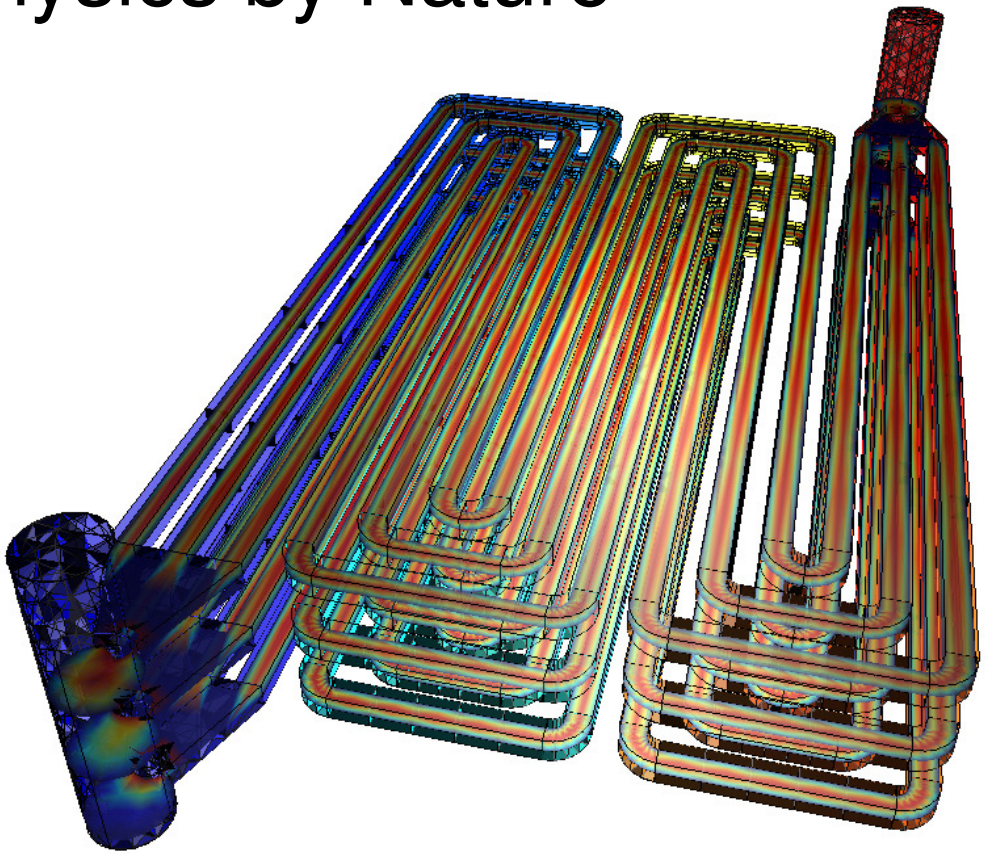
Fuel Cells – Multiphysics by Nature

<u>Fuel Cells in General</u>

- Electro Chemistry
- Heat + Flow



Stress from Thermal & External Loading



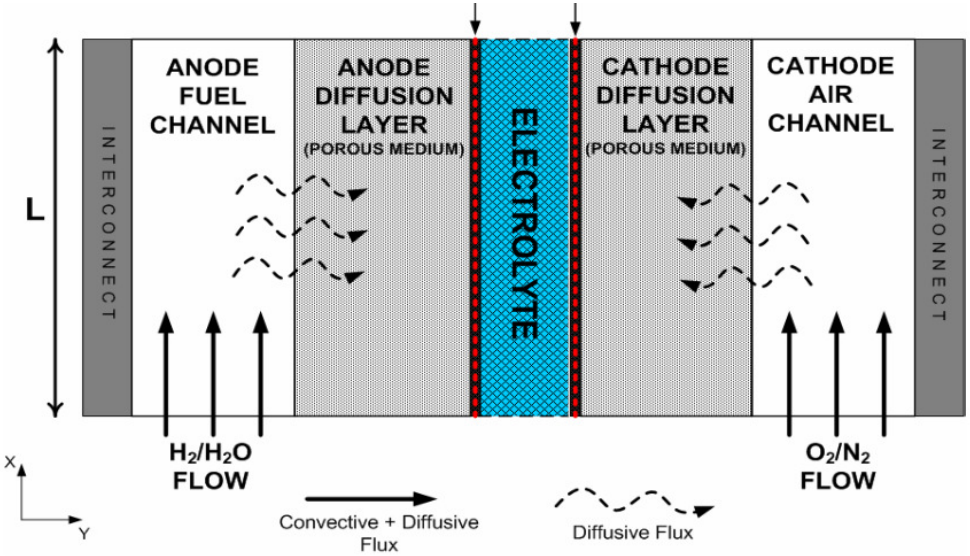
Slice Plots of Velocity through Transparent Boundary Plot of Concentration in Fuel Cell Stack

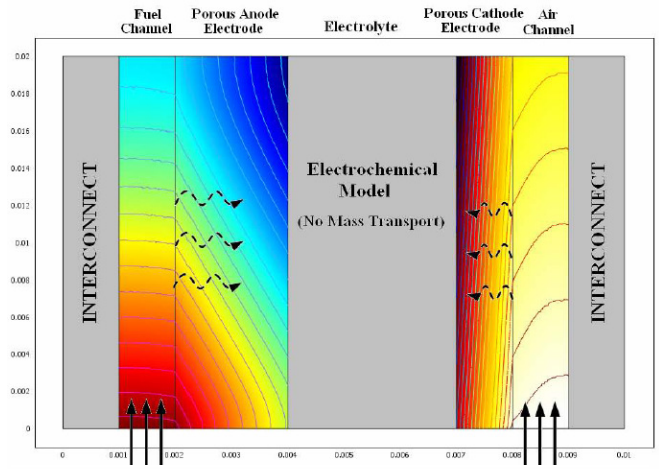
COMSOL

Fuel Cell Electrochemistry

<u>Solid Oxide Fuel Cell</u>

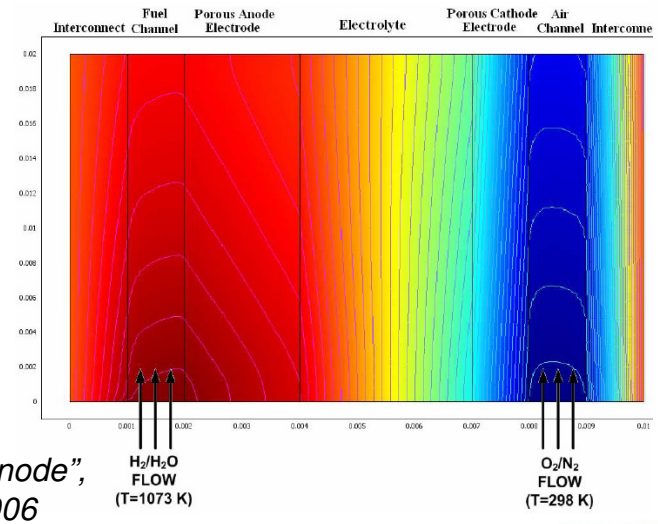
- Electro Chemistry
- Convection & Diffusion
- Heat & Flow





O2 Molar Fraction

H2 Molar Fraction



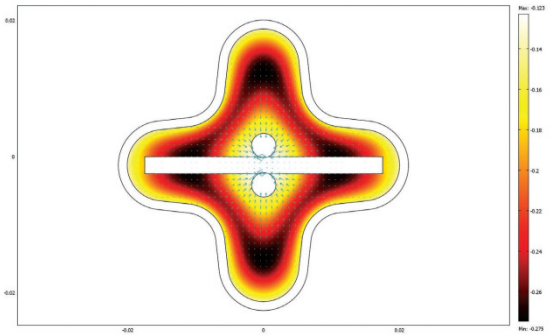
Temperature

Excerpted from "Modelling and Design of Solid Oxide Fuel Cell Anode", Tseronis, Kookos, and Theodoropouls COMSOL Conference 2006

COMSOL

Fuel savings of up to 15%.

GE plans to make use of the energy generated while dynamic breaking in their hybrid locomotives to achieve fuel savings of up to 15%. Michael Vallance of GE Global Research is simulating the sodium metal-chloride batteries that will drive GE's hybrid locomotives to enable and even increase these savings.



Company: General Electric Global R&D
Industry: Transportation
Application: Hybrid Locomotives
Simulation: Electrochemistry, ion transport, heat transfer

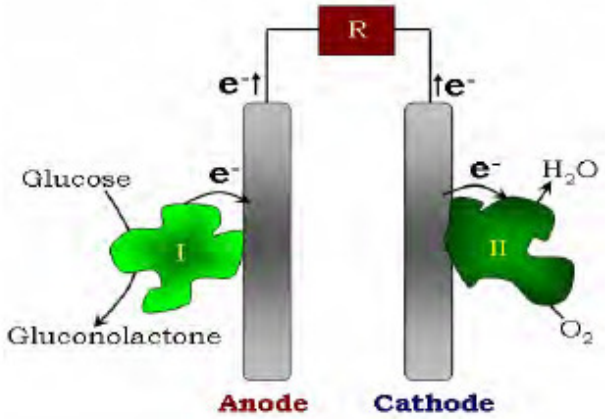
COMSOL

http://www.comsol.com/stories/general_electric_modeling_train_batteries/

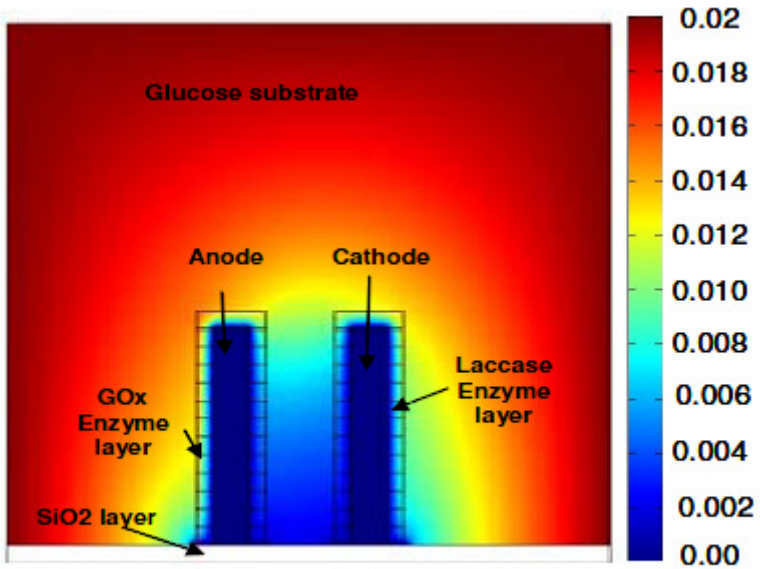
Biofuels

Enzymatic Biofuel Cell

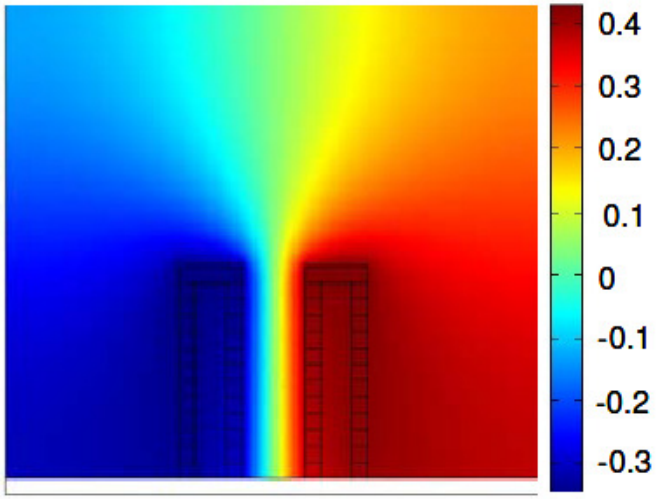
- Chemical Energy to Electricity
- Nernst-Planck Analysis



Biofuel cell configuration, with the electrons flowing from the anode to the cathode of the cell[1].



Surface plot for concentration [mol/m^3], Time 50s



Surface plot for Potential [V], Time 50s

Excerpted from "Simulation of C-MEMS Based Enzymatic Biofuel Cell", Parikh, Penmatsa, Yang, and Wang COMSOL Users Conference 2008

COMSOL

References: ENEL, Rome, Italy

- Situated on the east coast of Sicily, this innovative industrial demonstration plant uses Parabolic Trough Concentrating Solar Power (CSP) technology to generate electricity during sunny hours as well as under overcast conditions or at night
- Jointly developed by Italian utility ENEL and the Italian National Agency for New Technologies ENEA, it began operating in July 2010 and is named after the mathematician and engineer Archimedes who lived in the nearby town of Syracuse.
- Archimede incorporates 30,000 square meters of reflective parabolic mirror surface, in the shape of troughs. The sun's rays are concentrated onto long thin tubes, which together make up a receiver pipeline running along the inside of the curved surfaces and stretching for 5,400 meters.
- This pipeline contains a heat transfer fluid made of 60% sodium nitrate and 40% potassium nitrate, commonly used as fertilizer.

Around the Clock Solar Power

Thermal modeling enabled the optimization of a critical drainage system for Archimede, the first Concentrating Solar Power (CSP) plant in the world to use molten salt for heat transfer as well as storage and to be integrated with an existing combined cycle gas facility.

BY JENNIFER HAND

Situated on the east coast of Sicily, this innovative industrial demonstration plant uses Parabolic Trough CSP technology to generate electricity during sunny hours as well as under overcast conditions or at night. Jointly developed by Italian utility ENEL and the Italian National Agency for New Technologies ENEA, it began operating in July 2010 and is named after the mathematician and engineer Archimedes who lived in the nearby town of Syracuse.

Archimede incorporates 30,000 square meters of reflective parabolic mirror surface, in the shape of troughs. The sun's rays are concentrated onto long thin tubes, which together make up a receiver pipeline running along the inside of the curved surfaces and stretching for 5,400 meters. This pipeline contains a heat transfer fluid made of 60% sodium nitrate and 40% potassium nitrate, commonly used as fertilizer.

During the start-up of the power plant this mixture is heated to at least 240° C (464° F) so that it melts and can pass into the tubes. Once it is molten, it is heated further by the sun and channeled to a dedicated steam generator where it produces high-pressure steam that drives a turbine in the adjacent combined-cycle power plant.

"The annual solar-to-electricity conversion efficiency is over 15% better than other CSP plants."

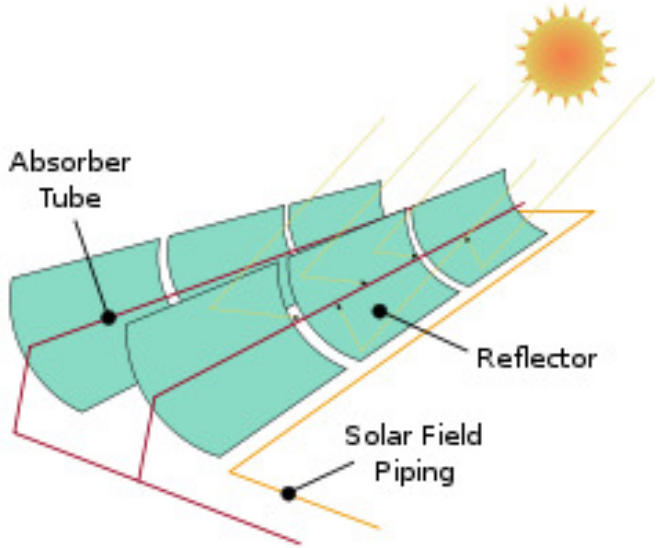
The Molten Salt Advantage

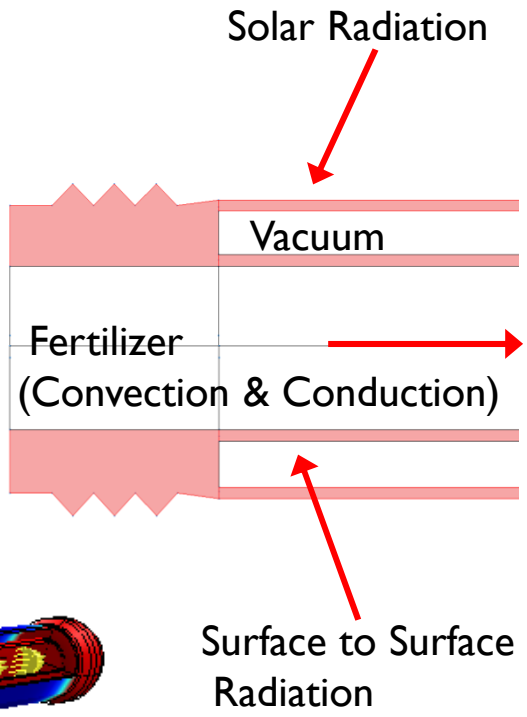
Mainly located in the US and Spain, there are several CSP plants already in operation. They all depend on pipes filled with diathermal oil to absorb solar heat and older CSP plants can only operate in the daytime under direct sunlight. Newer plants have extended their operating hours through the use of molten salt as a medium for storing heat in large, well-insulated tanks.

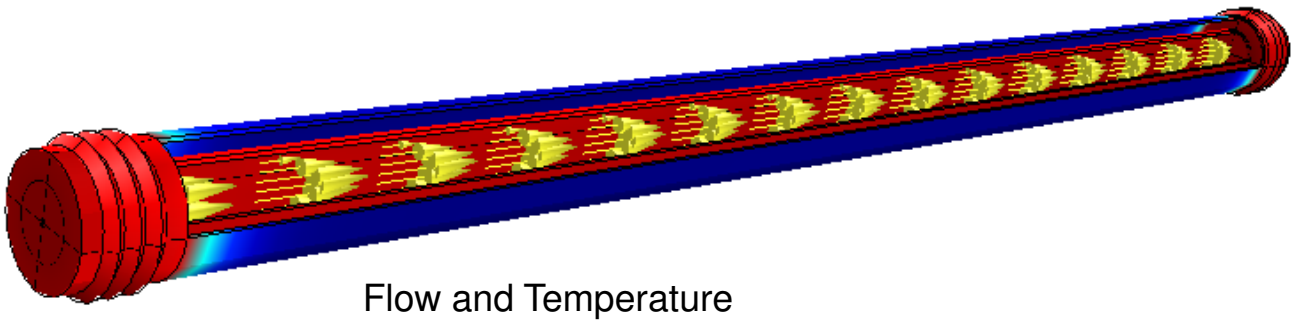
COMSOL

Solar Thermal Collector

- Solar to Steam





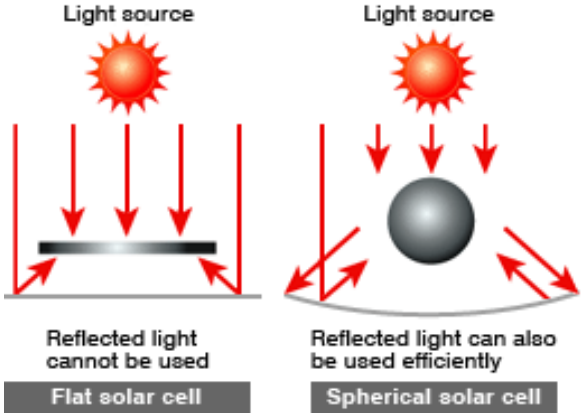


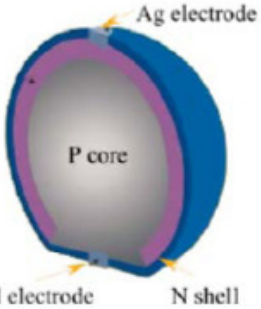
Flow and Temperature

Solar Energy

<u>Spherical Photo Voltaic Cells</u>

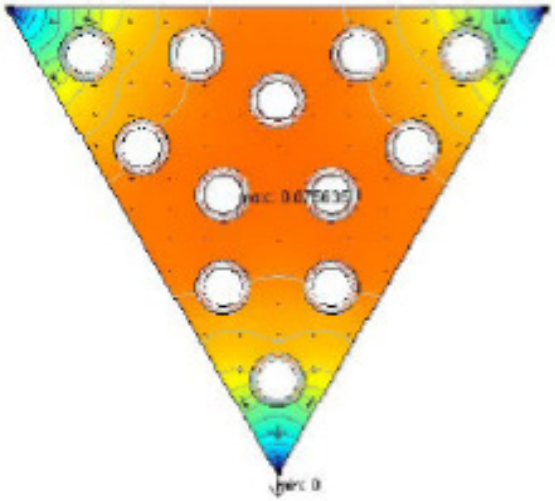
- Optimal Layout of Cells
- Missing Cells for Cu Leads

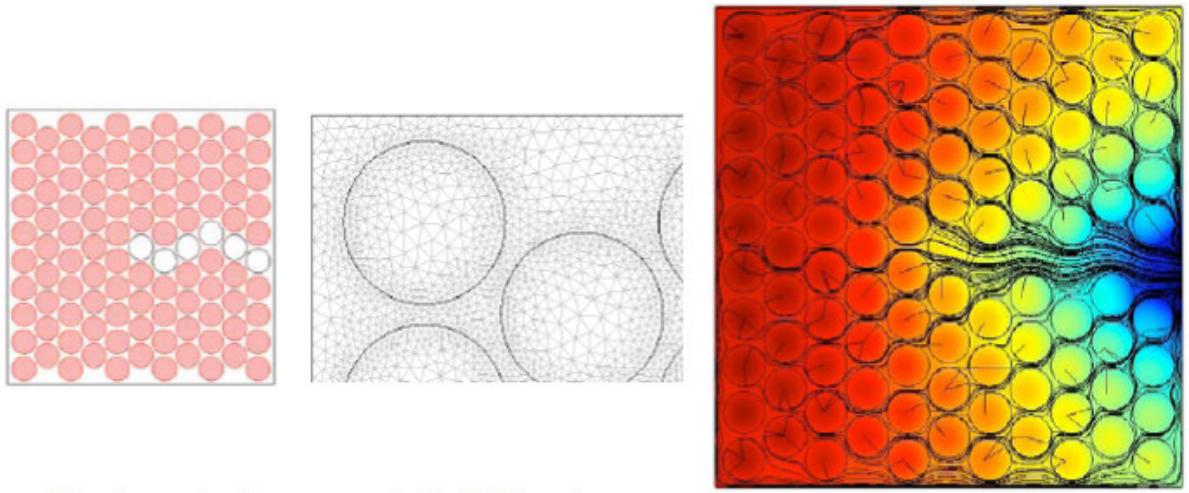




a. Cross sectional structure of a spherical SPVC

Electric Field of first order ensemble of SPVC





a. The elemental cell. *b*. The FEM mesh. *c*. The electrical field

Figure 7: The honeycomb elemental SPVC.

Excerpted from "Optimal Design of Spherical Photovoltaic Cells", Keynote Address
Morega, Ordonez, Negoias, Morega & Hovsapian COMSOL Users Conference 2006

COMSOL

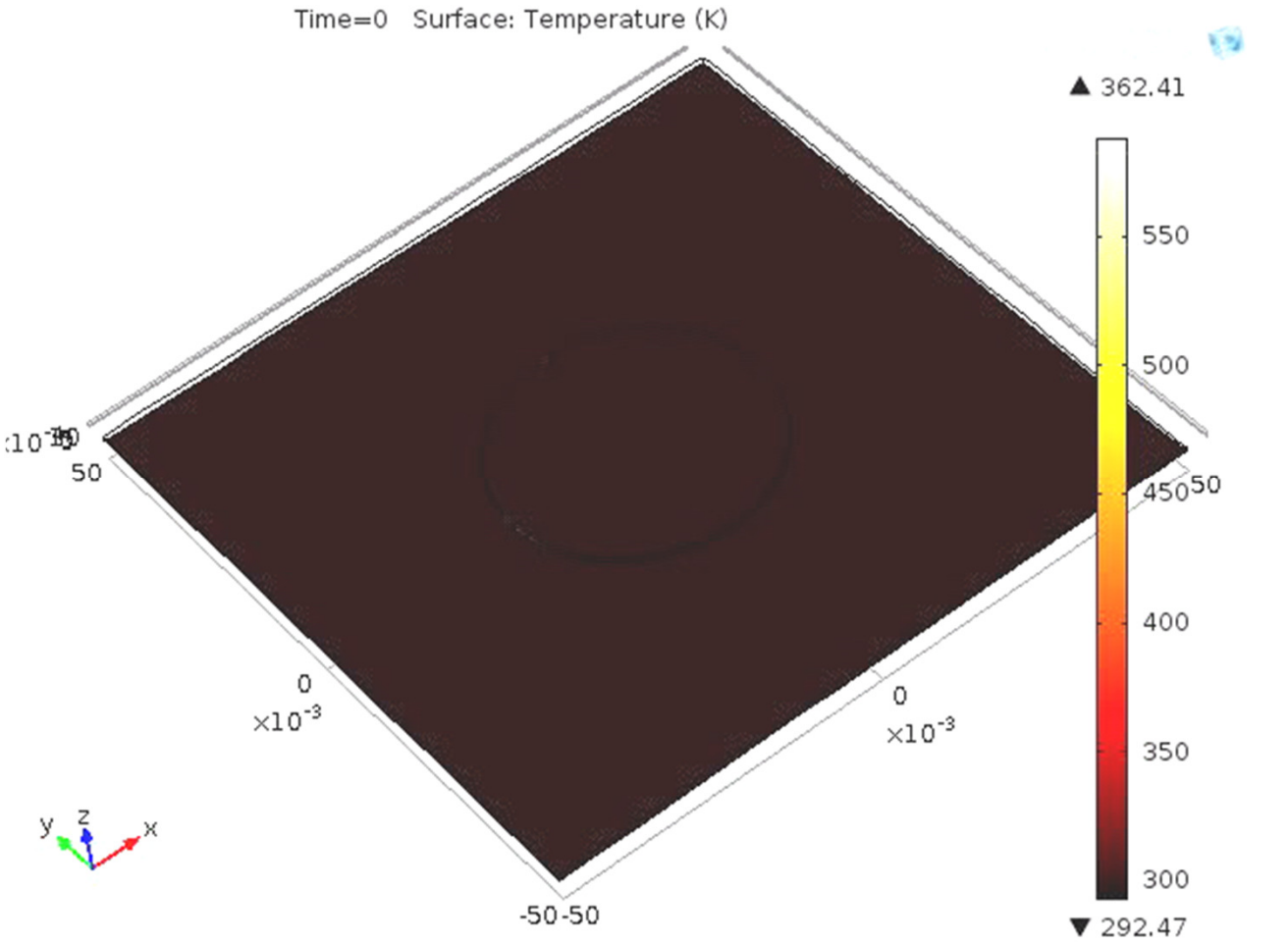
Laser Heating

- Lasers are commonly used to achieve precision heating or welding. The beam often moves over the surface of the substrate.

- One difficulty with modeling a laser heat source is the fact that the beam is very narrow (nm-mm). Another is that the laser has a certain penetration depth which is important.

- The scenarios that can be investigated are:
  - Stationary laser with constant & pulsed power
  - Moving laser with constant & pulsed power

Laser Heating



COMSOL

344 Papers on laser applications at **www.comsol.com**

- Propagation of a 3D Gaussian Beam Laser Pulse
- COMSOL Assisted Simulation of Laser Engraving
- Simulation of Laser-Material Interactions for Dynamic Transmission Electron Microscopy Experiments
- Modeling 2D and 3D of Hybrid Laser Nd:Yag - MIG Welding Processes
- Laser Welding of a Titanium Feed Through
- Laser Interstitial Thermo Therapy (LITT) for Prostate Cancer Animal Model: Numerical Simulation of Temperature and Damage Distribution
- Development of laser-driven micromachines using total internal reflection
- ....

COMSOL

COMSOL Search

Search for:

laser OK

All results
463 hits

Papers & Presentations
344 hits

Support Knowledge Base
0 hits

Model Gallery
4 Hits

Success Stories
5 Hits

Community
78 Hits

Video
0 hits

Blog
2 Hits

Conference
0 hits

Showing results 1-20 of 344

COMSOL Assisted Simulation of Laser Engraving : Papers & ...
... **Papers** & Presentations. Browse by Application Area Browse by Conference. ... More services... COMSOL Assisted Simulation of **Laser** Engraving. ...
http://www.comsol.com/papers/7574/

Simulation of Laser-Material Interactions for Dynamic Transmission ...
... **Papers** & Presentations. ... More services... Simulation of **Laser**-Material Interactions for Dynamic Transmission Electron Microscopy Experiments. ...
http://www.comsol.com/papers/8864/

Modeling 2D and 3D of Hybrid Laser Nd:Yag - MIG Welding Processes ...
... **Papers** & Presentations. Browse by Application Area Browse by Conference. ... More services... Modeling 2D and 3D of Hybrid **Laser** Nd:Yag - MIG Welding Processes. ...
http://www.comsol.com/papers/5214/

A Study of Distributed Feed-Back Fiber Laser Sensor for ...
... **Papers** & Presentations. ... More services... A Study of Distributed Feed-Back Fiber **Laser** Sensor for Aeronautical Applications Using COMSOL Multiphysics. ...
http://www.comsol.com/papers/8026/

Laser Welding of a Titanium Feed Through : Papers & Presentations ...
... **Papers** & Presentations. Browse by Application Area Browse by Conference. ... More services... **Laser** Welding of a Titanium Feed Through. Meshing around the **laser** beam ...
http://www.comsol.com/papers/7787/

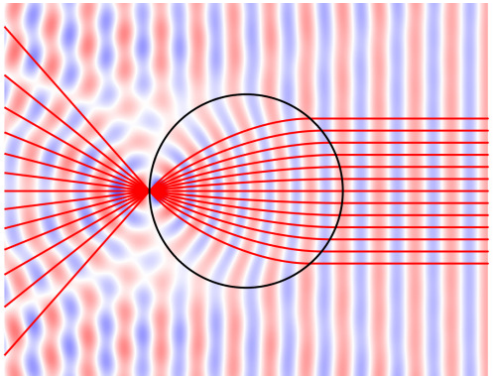
Modeling of Laser Processing For Advanced Silicon Solar Cells ...
... **Papers** & Presentations. Browse by Application Area Browse by Conference. ... More services... Modeling of **Laser** Processing For Advanced Silicon Solar Cells. ...
http://www.comsol.com/papers/8050/

Laser Interstitial Thermo Therapy (LITT) for Prostate Cancer ...
... **Papers** & Presentations. ... **Laser** Interstitial Thermo Therapy (LITT) for Prostate Cancer Animal Model: Numerical Simulation of Temperature and Damage Distribution. ...
http://www.comsol.com/papers/8230/

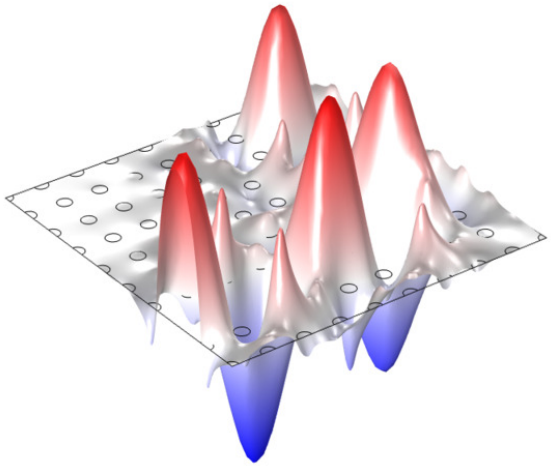
Formation Of Porosities During Spot Laser Welding : Case Of ...
... **Papers** & Presentations. Browse by Application Area Browse by Conference. ... Formation Of Porosities During Spot **Laser** Welding : Case Of Tantalum Joining. ...
http://www.comsol.com/papers/7825/

COMSOL

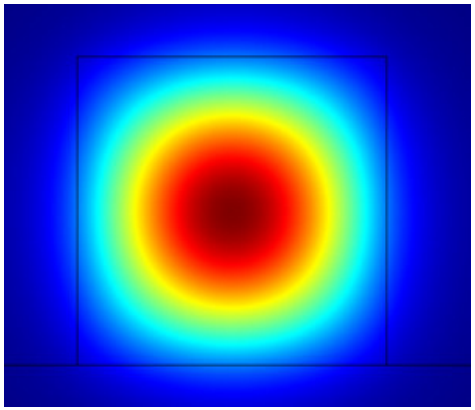
Optics Examples



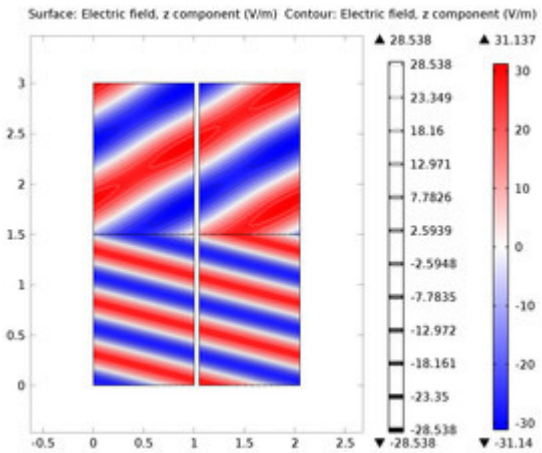
Luneburg lens



Photonic Crystals and Band-gap Materials



Stress-Optical Effects - with Generalized Plane Strain and in a Photonic Waveguide



Modeling of Negative Refractive Index

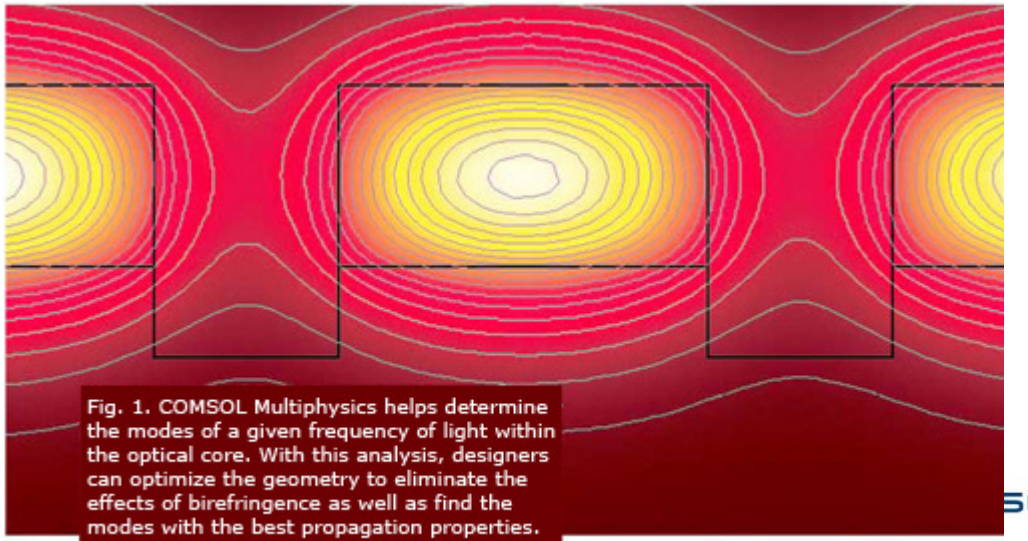
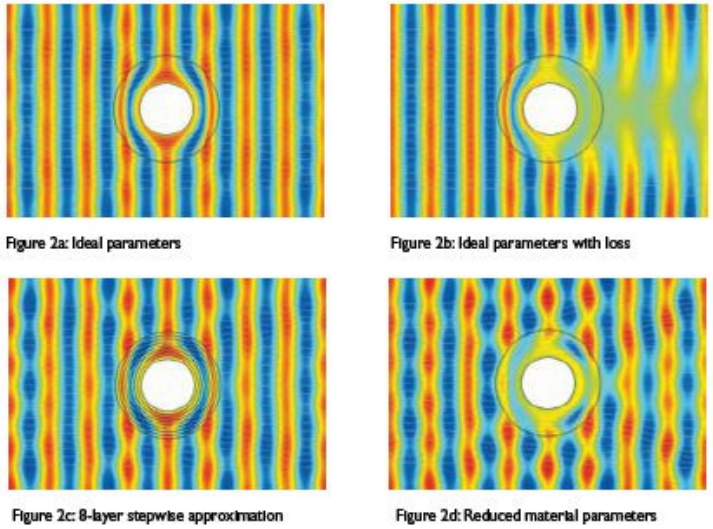


Fig. 1. COMSOL Multiphysics helps determine the modes of a given frequency of light within the optical core. With this analysis, designers can optimize the geometry to eliminate the effects of birefringence as well as find the modes with the best propagation properties. This image shows ho periodic bounary conditions canapproximate real-world effects.

Metamaterials

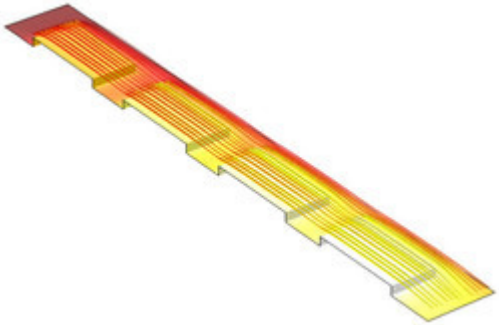
- The RF Module has applications for metamaterial and absorptive material design for RF, Microwave, and Optical frequencies.
- General solvers allow for microstructure simulations and also macroscopic simulations where negative values for refractive index, permittivity, and permeability is allowed.
- Anisotropic materials are supported.



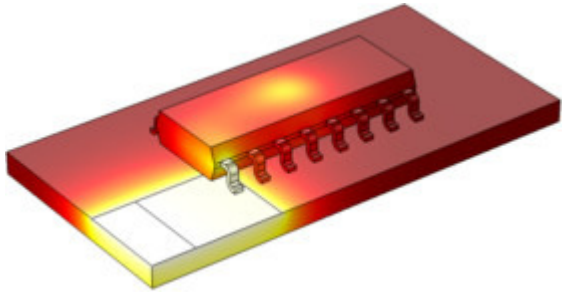
Cloaking model by Steven A. Cummer and David Schurig - Duke University, Durham, NC

Electronics

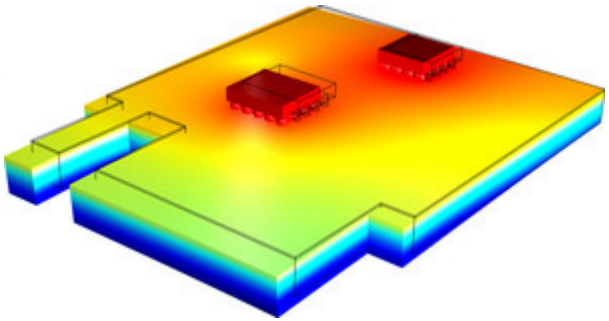
Convection Cooling



Heat Transfer in a Surface-Mount Package for a Silicon Chip

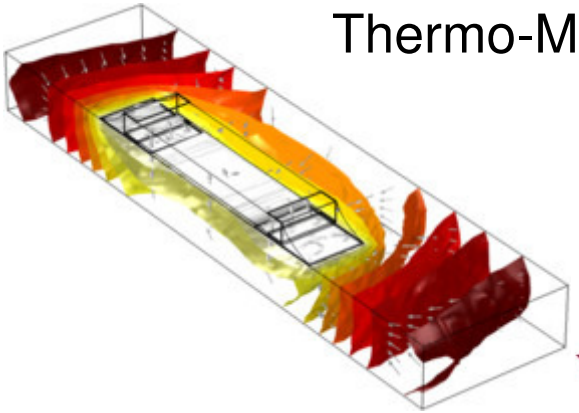


Viscoplastic Creep in Solder Joints



Surface Resistor

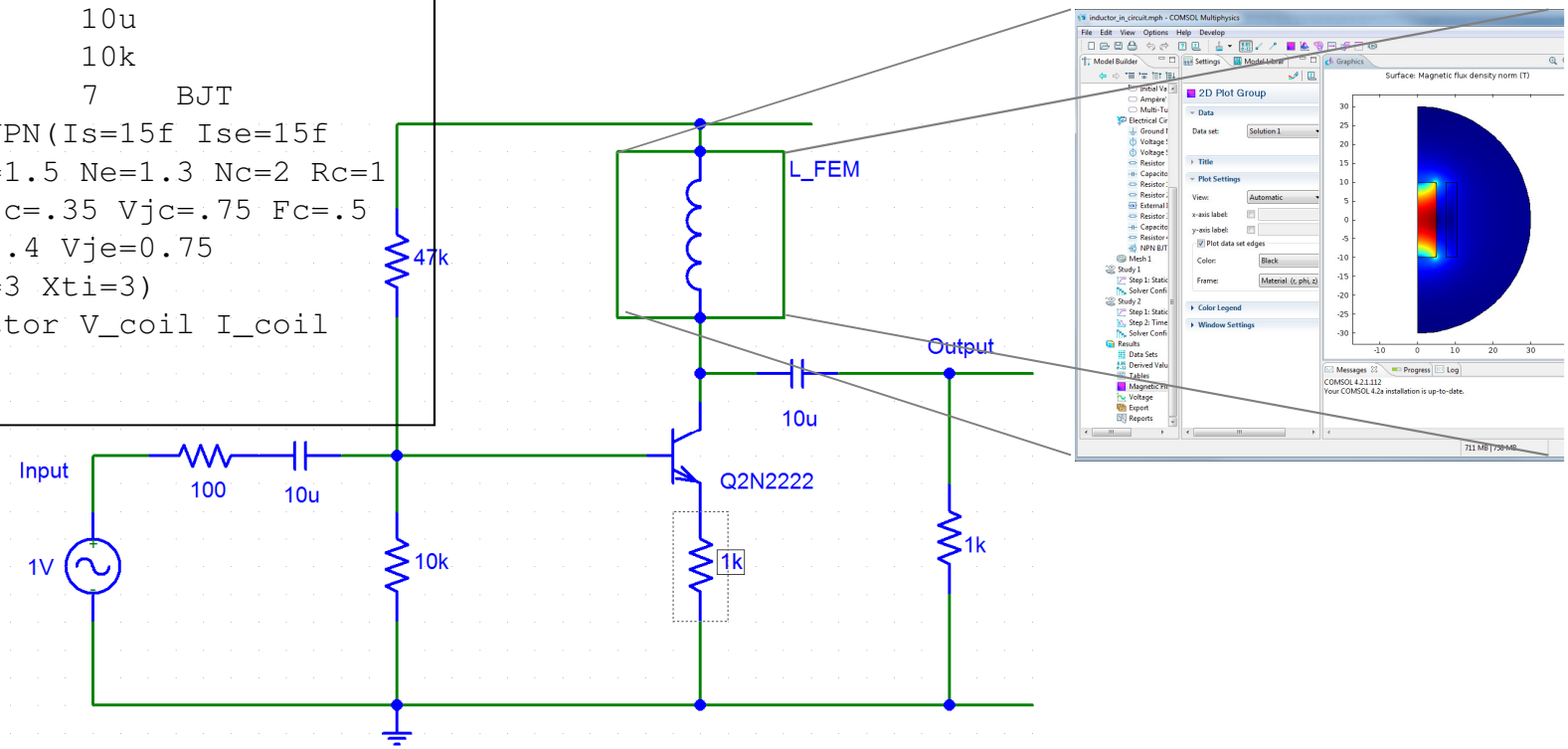
Thermo-Mechanical



COMSOL

Electrical Circuit Components
SPICE Import

```
X1      4     5     inductor
RE      7     0     1k
Cout    5     6     10u
Rl      6     0     10k
Q1      5     3     7     BJT
.MODEL BJT  NPN(Is=15f Ise=15f
+ Ikf=.3 Xtb=1.5 Ne=1.3 Nc=2 Rc=1
+ Cjc=7.5p Mjc=.35 Vjc=.75 Fc=.5
Cje=20p Mje=0.4 Vje=0.75
+ Vaf=75 Xtf=3 Xti=3)
.SUBCKT inductor V_coil I_coil
COMSOL: *
```

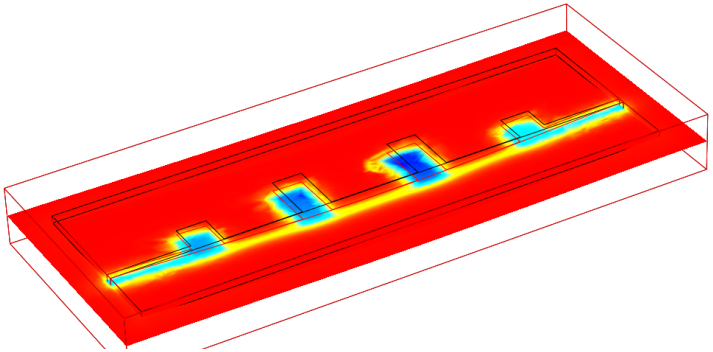


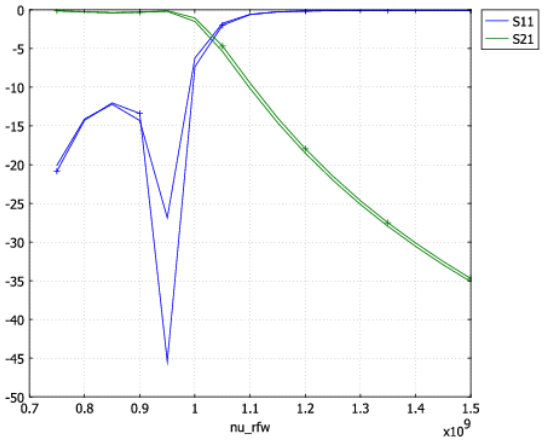
Inductor in an Amplifier Circuit

COMSOL

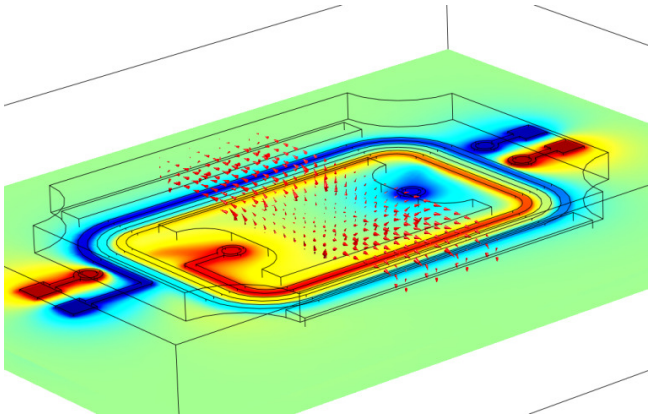
ECAD Import: ODB++ file import

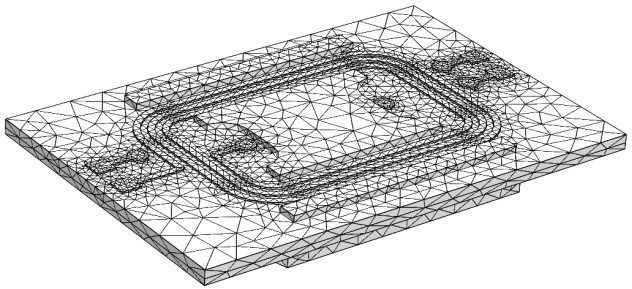
Mechanical deformation + RF simulation of
PCB Microwave Low-Pass Filter





S-parameters, before and
after mechanical deformation

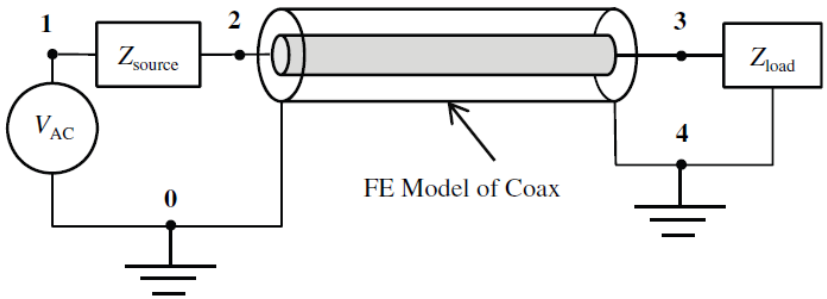


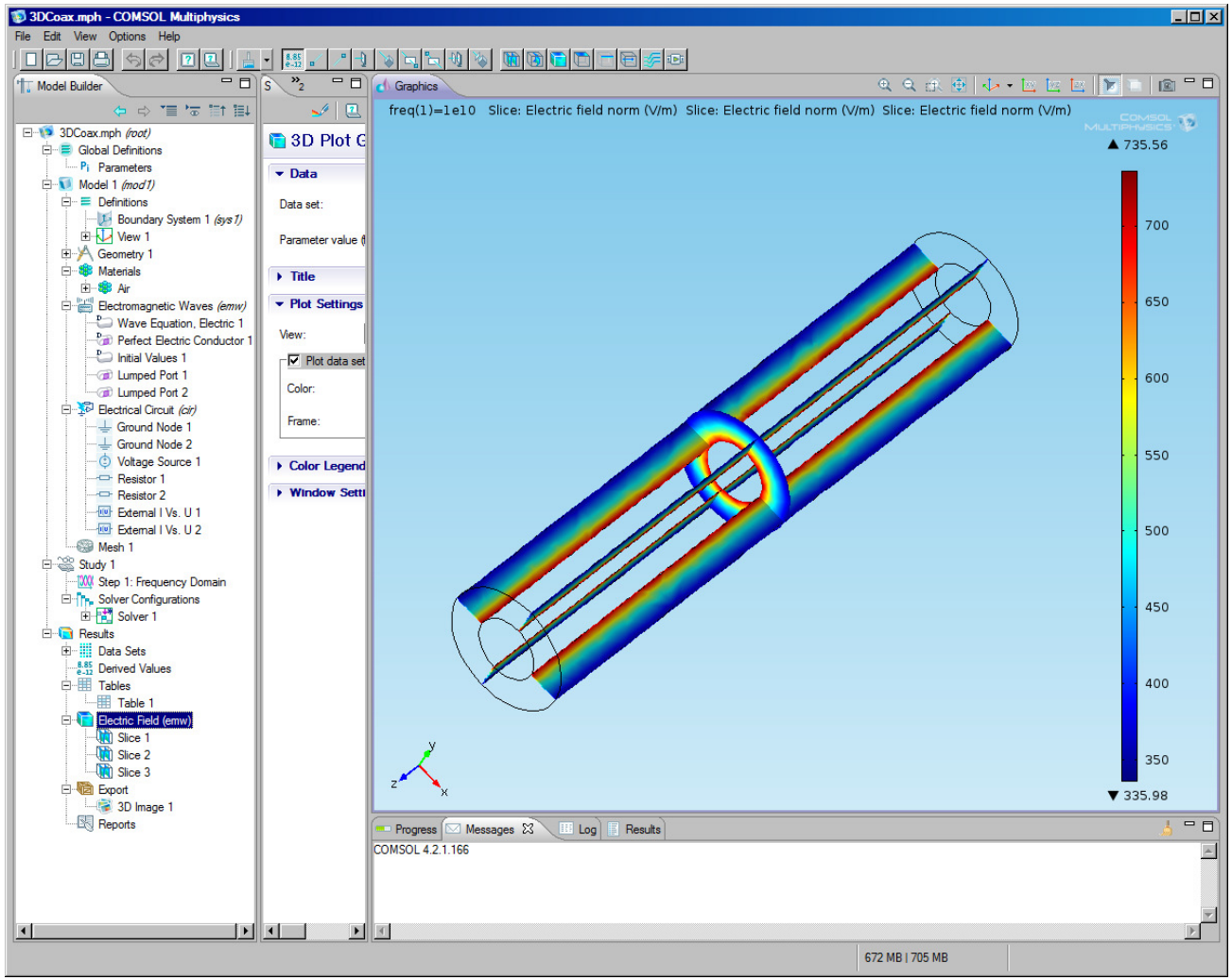


PCB Planar Transformer:
Self and Mutual Inductance Calculation

COMSOL

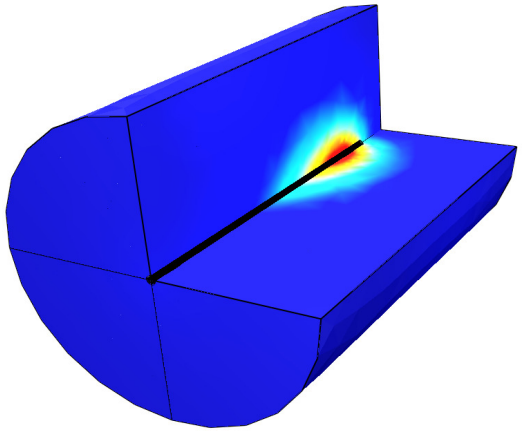
Connecting a 3D Electromagnetic Waves Model to an Electrical Circuit



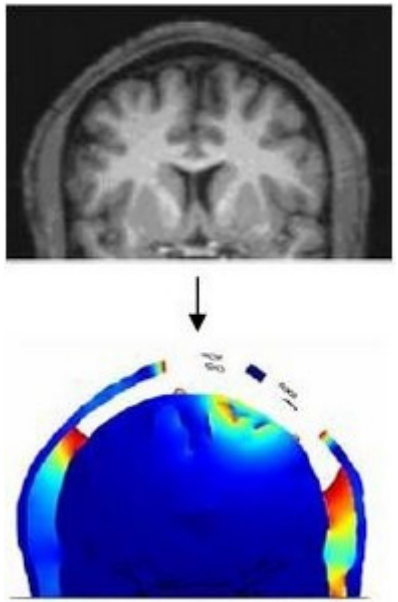


COMSOL

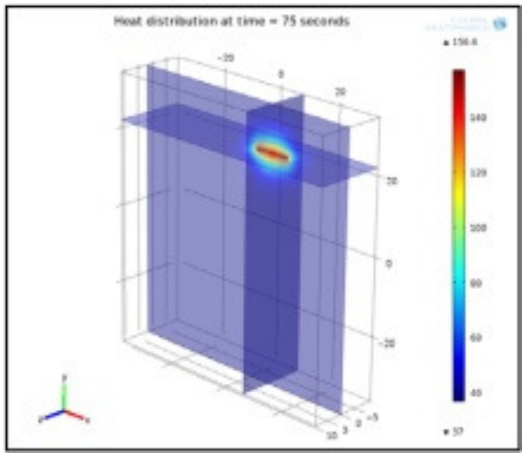
Biomedical Applications



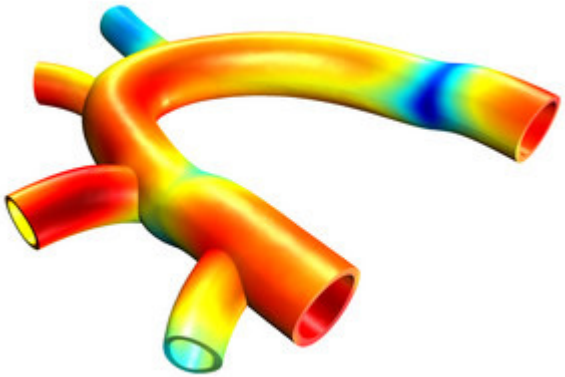
Microwave heating of tissue



Electrical Stimulation of Brain using a realistic 3D Human Head Model



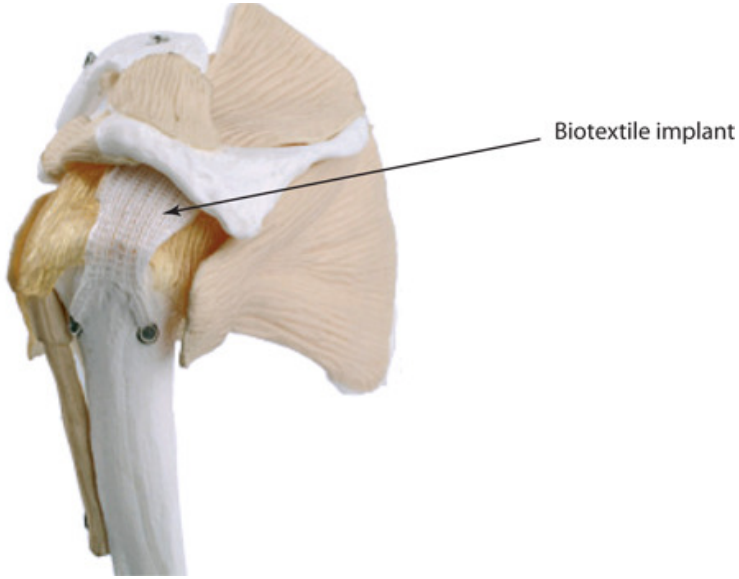
Laser Interstitial Thermo Therapy (LITT) for Prostate Cancer

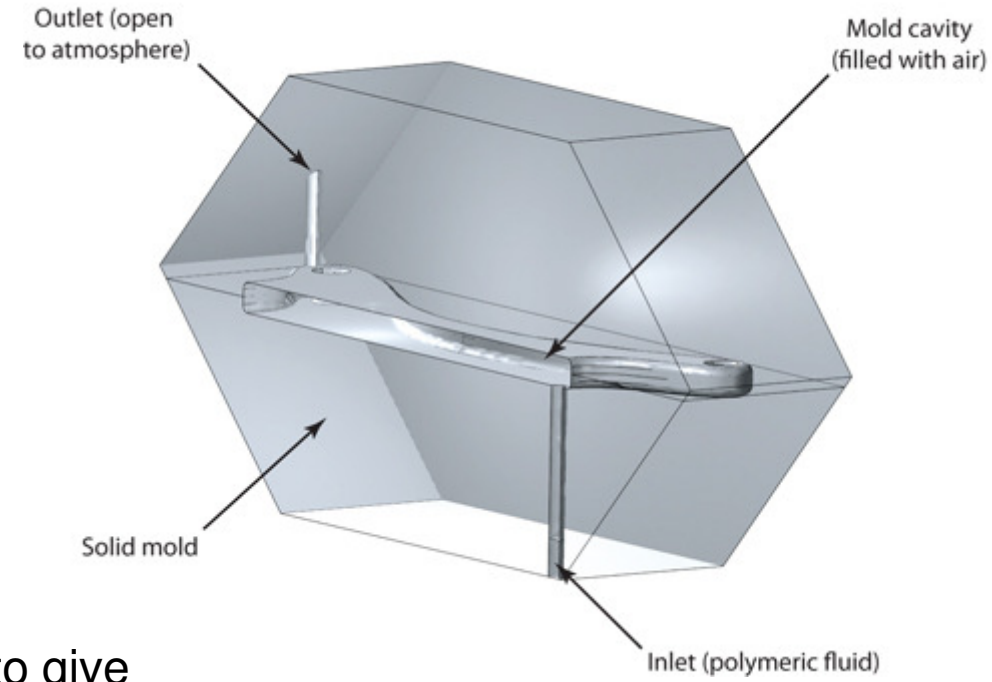


Fluid-Structure Interaction in a Network of Blood Vessels

COMSOL

Mixed Polymers Form Unique One-Piece Medical Implant





We then turned to simulation software to give us more insight into the process, and in the end it was only COMSOL Multiphysics that was up to the task. *DR. MARK YEOMAN, R&D DIRECTOR, CONTINUUM BLUE LTD*

COMSOL

Biomedical Engineering: Medrad (USA, PA) models diagnostic equipment and more

- Speed of delivery of a contrast material to the heart muscles
- Fluid-structure interaction in catheters so that they don't damage blood vessel walls
- Magnetic shielding of an infra-red IC communication device from the magnetic fields arising from MRI equipment
- Injection of non-Newtonian fluids (blood cells) with high shear-rates through thin syringes

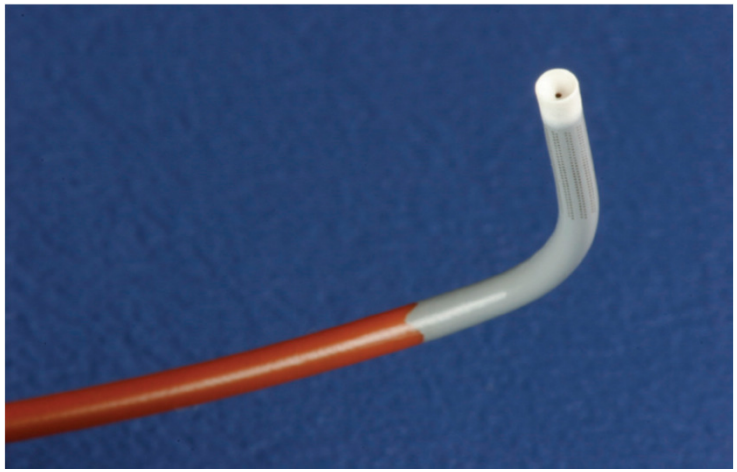


Figure: The Vanguard DX catheter allows for a very uniform distribution of contrast materials.
Laser-drilled holes or slits force the contrast material to be transported radially from the catheter.

Simulating Energy-Tissue Interactions for Improved Patient Outcomes

- Electrosurgery is the application of high-frequency electric current to biological tissue as a means to cut through the tissue (vaporize) and/or stop bleeding (coagulate). These types of surgeries are performed using an electrosurgical generator and a hand piece that includes one or several electrodes.
- "The end result of a better understanding of the relationship between the application of energy and the desired surgical effect and the ability to clearly demonstrate that relationship through images and animations increases everyone's understanding and comfort with new technologies and how they are best used in a surgical environment," asserted Mr. Ward.

Covidien's ForceTriad™ energy platform and a few of the associated electrosurgical devices that use it as an energy source.

COMSOL

www.comsol.com/community/

Useimmin avatut | Aloitussivu | http://www.google.co... | http://www.google.co...

COMSOL

HOME PRODUCTS SHOWCASE EVENTS SUPPORT COMMUNITY COMPANY

COMSOL Community

Community Home | Discussion Forum | Model Exchange | COMSOL Blog | Papers & Presentations

Discussion Forum

View all discussions | Start a new discussion

Subject	Last Post
Permanent magnet falling in a tube Posted by Shoval Zoran	2 minutes ago
Thermoelectric Model Posted by Piyush Shah	1 hour ago
Composite Posted by Deenadayalan D	2 hours ago
pointwise constraints Posted by Sirisha Govindaraju	3 hours ago
open boundary Posted by Bhageshvar Mohan	7 hours ago
initial conditions from BVP? Posted by Mads Sondergard	8 hours ago
How to check number of seats from command line? Posted by Mehmet Belgin	9 hours ago
How to define an area where heat is generated Posted by James Grant	12 hours ago
problem in Mie Scattering of Plasmonic Nanoparticle simulation(model 3459) Posted by Hao Li	13 hours ago
About Predefined Multiphysics Couplings Posted by Serhy	14 hours ago
moving wall? Posted by Abbie	14 hours ago

View all discussions | Start a new discussion

Subscribe to Latest Discussions | Subscribe to Active Discussions

Tykkää 168 henkilöä tykkää tästä. Ole kavereistasi ensimmäinen.

Share 14 Tweet 10 +1 2

Papers & User Presentations

- CFD Module , General Introduction, V4.2a
- FEM Simulation of Nanotubes Manipulation using Dielectrophoreseis
- An Integrated Approach for Simulating Bone Adaptation of Shape and Material Properties using FEMLAB with MATLAB and Simulink
- Modeling an integrated, high flow rate MEMS ferrofluid pump
- Multiphase, Dual Polymer Injection Molding and Cooling of an Open Cavity to Form both Distinct and Graduated Material Properties within a Complex Three-Dimensional Body

View all papers and presentations...

Model Exchange

- Solve the nonlinear PDE systems with Comsol 4.0
- capacitive sensor
- 1D resonant quantum tunneling
- Zernike Polynomial extraction of deformed optical surface
- Pyramidal Horn Antenna

View all contributions...

News

- COMSOL Version 4.2a Unveiled at the COMSOL Conference in Boston

Read more news | Subscribe to the COMSOL Blog

COMSOL MULTIPHYSICS®

Capture the Concept™

COMSOL