Ceramic Leadership Summit 2011

Advanced Ceramics for Sustainability -

View of Siemens Corporate Technology

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Siemens Corporate Technology

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Contents

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Siemens - the integrated technology company

Advanced Ceramics at Siemens:

- **Key enabler for innovation and sustainability**
- **Key components in distinguished applications**
- **Solution provider for system development and engineering**

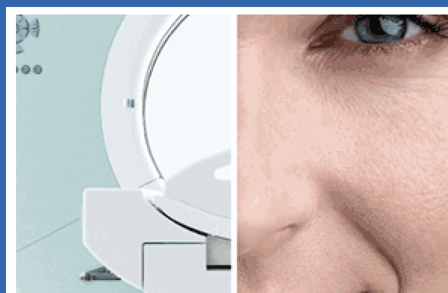
Industry

- Drive Technologies
- Industry Automation
- Building Technologies
- Mobility
- Lighting (OSRAM)
- Industry Solutions

Energy

- Fossil Power Generation
- Renewable Energy
- Oil & Gas
- Energy Service
- Power Transmission
- Power Distribution

Healthcare



- Imaging & IT
- Workflow & Solutions
- Diagnostics

Megatrends
are significantly shaping the future of our planet

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Efficient use of resources

Urbanization

Demographic change

Climate change

Globalization

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The result is huge challenges in terms of infrastructure and efficiency

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Efficient use of resources

Urbanization

- By 2050, the urban population will **double** to **6 billion people**.
- By 2025, China will have over **200 cities** with more than **one million** inhabitants each.

Demographic change

- In the United States, **expenditure** on **healthcare** already accounts for 16 percent of GDP.
- At current trends, a **girl born** in Germany today has a 50% chance of reaching the **age of 100**.

Climate change

- Limiting global **warming to 2°C** requires a 15-fold increase in carbon productivity
- This results in investment needs of **10.5 trillion €** in the energy sector **by 2030**

Globalization

- While the **emerging regions** of Asia/ Pacific and Africa/ Middle East provide only about 32% of today's global economic output, they will contribute **50% of growth by 2020**.

Source: McKinsey; International Energy Agency (IEA)

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Siemens views these challenges as an opportunity asking for more efficiency and sustainability

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Efficient use of resources

Urbanization	**Effective** and **environmentally friendly infrastructure**, whether in developed or rapidly growing emerging nations (e.g. the supply of energy, power and water; mobility)	
Demographic change	**Efficient and affordable long-term medical care** and **age-appropriate infrastructure** (e.g. mobility, medical care, nursing care, administration)	
Climate change	**CO_2 reduction** and **energy efficiency** (e.g. in power generation, transport and distribution; industry; buildings; mobility; households)	
Globalization	Specific requirements of **regional markets** and the management of **global processes and development** (e.g. products for emerging countries, global value chains)	

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Sustainability: Three Joint Target Fields for Maximum Impact

> Sustainability is the capacity to endure <

- Environmental -

Responsibility for climate and environment

- Economic -

Value-oriented action

- Social -

Responsibility for people

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Advanced Ceramics for Sustainability

1 Starting Point: Megatrends Require Sustainability

2 **Advanced Ceramics – Proven Solution Provider**

3 Sustainability as Opportunity for Advanced Ceramics

4 Final Remarks

Advanced Ceramics:
Examples for proven value drivers in system engineering

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Osram LED-Lighting

OSTAR® - Product Family

- Osram's **most powerful** cold-white LED
- **Brightness of 1,000 lumen** at 20 W (= 50W halogen lamp)
- **Flat**, **compact** and **integratable**

Energy saving** and **longest life time

- **Improved luminescent ceramics** & advanced thin-film technology
- **Optimized ceramics integration to LED chip**

Siemens Gas Turbine – Unmatched Efficiency

Gas Turbine SGT5-8000H

- **Fast** start-up capability & **operational flexibility**
- **High reliability and availability**
- In combined cycle duty **efficiency** of **over 60%**

***Lowest** life cycle costs and **reduced** investment costs/kW*

- High temperature alloys
- **Ceramic thermal barrier coatings**

World's first dual source Computed Tomography

Somatom Definition:

- **Faster** than **every beating heart**
- Full cardiac detail at **half the dose** (**50% lower** radiation exposure)
- **One-stop shop** scanning in acute care

*Scan **every heart at any heart rate** without **beta-blockers***

- **Ultrafast ceramic scintillator material**
- **Improved machining and assembly technology**

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Gas Turbine Technology: A high-impact showcase for sustainable power generation

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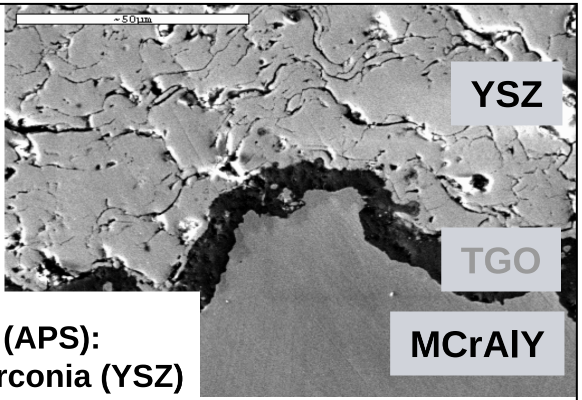
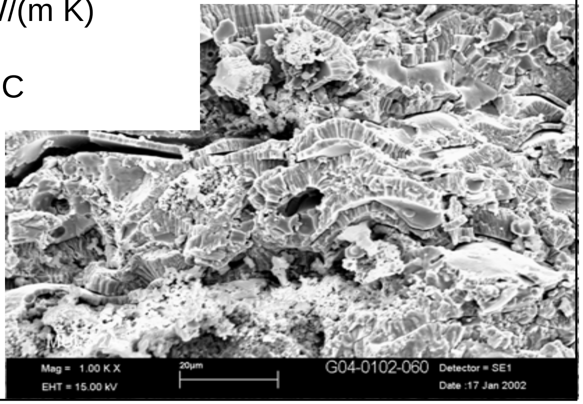
Ceramic Thermal Barrier Coatings for efficiency and life time

Development on all hierarchic levels: Thermal conductivity & failure tolerance



Plasma Sprayed TBCs (APS):
8% Yttria-stabilized Zirconia (YSZ)

- Heat conductivity: 2 W/(m K)
- CTE: $11 \cdot 10^{-6}$ K^{-1}
- Melting temp. > 2200°C



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Gas Turbine Technology:
A high-impact showcase for sustainable power generation

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1992

**Killingholme,
2 x 450 MW**

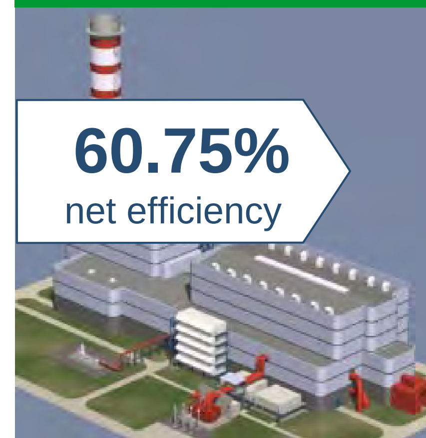
1996

**Didcot “B” 1&2,
710 MW + 702 MW**

2001

**Mainz-Wiesbaden,
> 400 MW**

2008/2011



**Irsching 4 with
SGT5-8000H,
> 578 MW**

**Continuous Progress in Efficiency Increase
(Combined cycle technology)**

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Advanced Ceramics for Sustainability

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Drivers for ceramics towards more global sustainability

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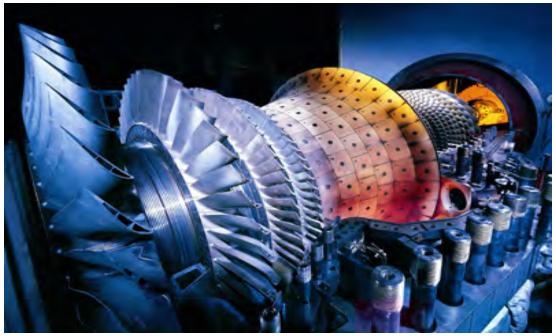
Energy efficiency

- Products and solutions with high energy efficiency
- Examples:
  - Gas and steam turbine power plants
  - High-voltage DC power transmission (HVDC)
  - Efficient lighting



Renewable energy

- Technologies for renewable energies
- Examples:
  - Wind farms
  - Concentrated solar power plants
  - Large photovoltaics
  - Fuel mix incl. hydrogen

Environmental technology

- Environmental technologies and resources
- Examples:
  - CO_2 capture and use
  - Water treatment
  - Air pollution control systems
  - Resource Efficiency
  - Recycling

‘Energy’ and ‘Environment’ are dominating fields …

e.g. ‘*Energiewende 2011*’ in Germany (‘change of energy mix’)

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Drivers for ceramics towards more global sustainability

… but the more detailed ‘picture’ is broader.

Sustainability – environmental, economic, social

- Energy efficiency
- Industrial productivity
- Affordable and personalized healthcare
- Intelligent infrastructure solutions

> Efficient Fossil Energy

> CO_2 Capture and Utilization

> Waste Heat Recovery

> Renewable Energy

> Energy Storage

> Industrial Drives

> Resource Efficiency

> Diagnostic Instrumentation

> Therapeutic Tools and Implants

> Smart Grid (incl. ICT)

> Electromobility

> Green Building

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Example:
Fossil power generation – ceramics for next efficiency level

Combined-cycle power plants belong to the most energy efficient fossil-fired power generators. The new gas turbine from Siemens in the Bavarian town of Irsching is has set a new efficiency record of 60.75 %. But there is still room for improvement by advanced high temperature materials

Future ceramics impact

- **Hot gas parts (TBC, CHS)**
- **New materials for blades, vanes**
- **Ceramic composites**
- **Coatings**
- **Sensors for condition monitoring**

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Example :
Power transmission - high-voltage direct current transmission

High transmission capacity, power transmission over long distances and low energy losses are future demands.
With HVDC electricity can be effectively transmitted over great distances and can reduce CO_2 emissions due to lower losses.
HVDC also provides an optimal grid access to renewable energy sources. With respect to increasing voltage and current loads advanced materials solutions are of critical importance.

Future ceramics impact

- **Transformer materials**
- **High voltage insulation**
- **Low loss conductors**
- **Superconductors**
- **Contact materials**
- **Ceramics and refractory metals**
- **Hybrid materials and composites**

Transformer for High-voltage direct current transmission (HVDC)

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Example:
Next dimension of electricity – renewable energy

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Solar thermal energy offers big opportunities to generate large power volumes with minimized CO_2 foot print. Global power production by STE is expected at 31 GW in 2020 with about 90% by trough based solar power plants.

Since 2003, just Siemens has installed wind turbines with an output of over 3,300 megawatt. Off-share installation asks for highest life time, reliability and efficiency and is stimulating new technologies (e.g. gear-less generators)

Future ceramics impact

- **Multifunctional 'optical' coatings**
- **Heat transfer and storage media**
- **Protective coatings**
- **New magnetic materials**
- **Long-life bearings**
- **Condition monitoring in harsh environment**
- **Hydrogen generation**
- **Fuel cells**

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Example:
Next dimension of electricity - e-mobility and smart grid

Electric power generated by renewable energy offers a new ‘quality’ of power supply but needs more ‘intelligent’ distribution, consumption and storage. For example smart grids are required for stable and reliable electric supply including electric storage capacities from the kW to the 100 MW range. As an example electric cars can be part of the grid acting simultaneously as consumer and storage medium with very large and flexible capacity.

Future ceramics impact

- **Fuel cells**
- **Battery technologies**
- **Electric storage media**
- **Power and control electronics**
- **Inductive power coupling**
- **Intelligent sensors (metering)**

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Example:
Healthcare - medical diagnostics and therapy

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With respect to demographics change medical care is facing higher requirements for diagnostics and therapy. Beside improving performance energy efficiency is a matter of actions. For example, energy consumption accounts for over three quarters of the environmental impact of medical products. When developing new products, Siemens makes sure that new devices consume less energy .

Future ceramics impact

- **X-ray detection materials (scintillators)**
- **Superconductors**
- **Piezoelectrics (ultrasound imaging)**
- **X-ray generation materials**
- **Power electronics**
- **HV insulation**
- **Bio-medical sensors**
- **Drug delivery materials**
- **Functionalized 'particles'**

Courtesy: Radiation Monitoring Devices, Inc.

Example:
Efficient electronics and lighting

Power electronics are facing higher demands by increasing power levels and reliability aspects. However current efficiencies have to be improved to avoid self heating and waste heat generation. New technologies are seen to open new perspectives like solid state lighting.

As an example the PARATHOM® PRO CLASSIC A 80 OSRAM is the first LED lamp that can replace a 60W incandescent lamp and saves up to 80% energy.

Future ceramics impact

- **New and more efficient phosphors**
- **Ceramic packaging**
- **Replacement of rare-earth based materials**
- **Ceramic chip-level processing**
- **Optical packages – photonic crystals**
- **Power electronics and supply**

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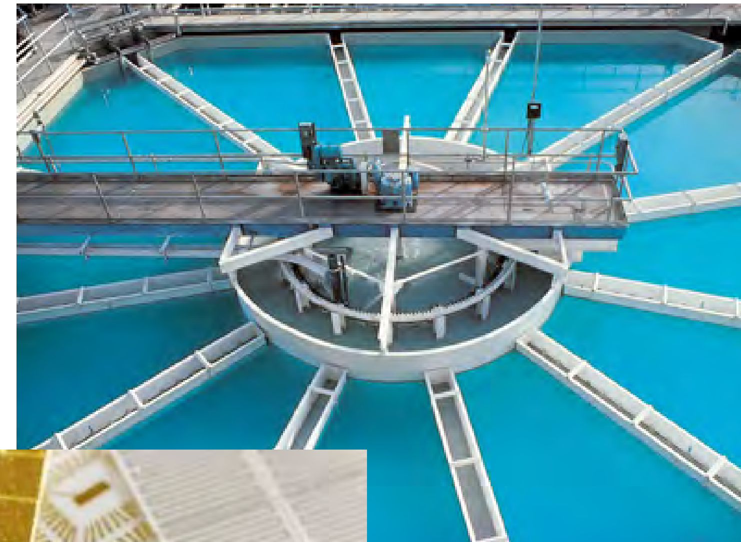
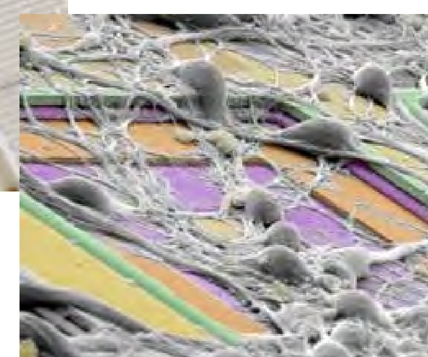
Example:
Environmental technologies – water and air

According to the UN, water consumption will increase 40 percent by 2025 while at the same time climate change will increase water scarcity in many regions.
Environmentally friendly water technologies are needed today more than ever.
As an example cell sensors could serve as early-warning systems for contaminated water or air by giving related information in an overarching process control system to initiate appropriate measures.

Future ceramics impact

- **Membranes**
- **Catalytic coatings and systems**
- **Photo catalytic materials**
- **Bioactive materials**
- **Sensor materials and packages**





Cell sensors for detecting contaminants by altering metabolism. (Picture shows the liver cells on a silicon chip.)

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Advanced Ceramics for Sustainability

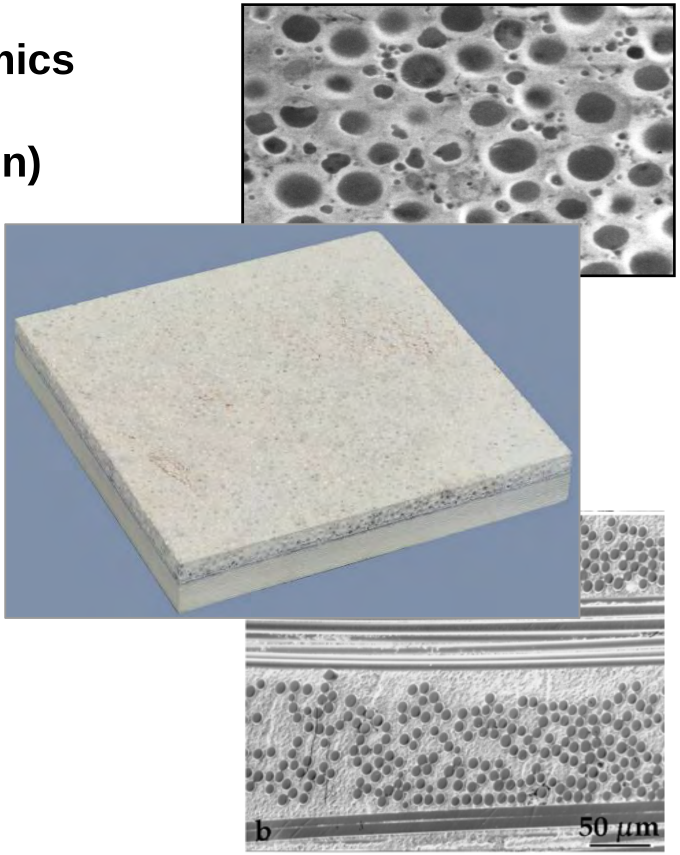
Drivers for Ceramics Towards More Sustainability

Perspectives within ‘traditional’ fields

Highest performance structural and functional ceramics
- chemical and microstructural optimization
- use of anisotropic behaviour (grain orientation)
- ceramic composites (e.g. CMCs)

Multifunctional ceramics and composites
- mixed conductors for fuel cells
- transparent electrodes, …
- catalytic function for hydrogen generation
- superconductors
- gas und liquid separation membranes

Adaptive ceramic materials
- tunable microwave ceramics for ICT
- self repairing materials systems



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Drivers for Ceramics Towards More Sustainability

Perspectives at the 'materials interfaces'

- **Battery materials and processing:**
  - **smart grid**
  - **e-mobility**
- **Thermoelectrics:**
  - **waste heat recovery (energy efficiency)**
  - **power electronics (efficient cooling)**
- **Permanent magnets:**
  - **wind power**
  - **e-car / e-mobility**
- **Refractory metals and composites:**
  - **power generation (gas turbine)**
  - **power distribution (HV)**
- **Materials substitution:**
  - **environmental dangerous substances (RoHS)**
  - **scarce substances (e.g. rare earth elements)**
- ***… more …***

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Drivers for Ceramics Towards More Global Sustainability

Goals and needs for research and development

- **New functionalities and improved performance of components and systems through advanced ceramics**
- **Towards more ‘intelligent’ ceramics: load and failure tolerant, self adapting, self repair (healing), etc.**
- **Integration of simulation and modeling from atomic level to technical processing: engineering on the ‘defect’ level**
- **New manufacturing processes: low temperature synthesis, free forming, near net shaping, etc.**
- **Cost efficient manufacturing to improve acceptance and performance-to-cost ratio**

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Ceramic Technologies for Sustainability

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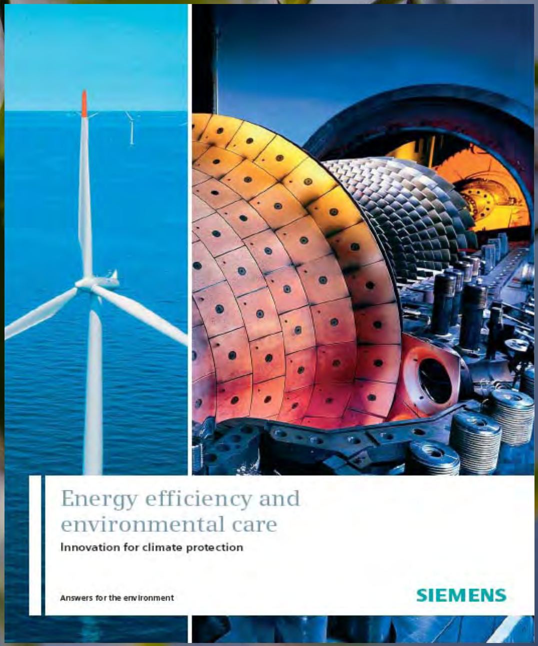
What 'ceramists' can do to strengthen sustainability and innovation potential:

- **Continue to approach new frontiers, mainly at the interfaces to other disciplines.**
- **Implement and improve application and system know-how on the system engineering level.**
- **Intensify dialogue with the general public about performance and potential of advanced ceramics to create sustainable benefit.**



Thank you for your attention!