

02 | SiN/AlGaIn/GaN field-effect transistor.

## 02 SWITCHING

Power electronics for generating and converting energy is covering a large range of applications from power supplies for ICT, to motor drives, solar converters, or hybrid electrical vehicles: today, more than 60% of energy passes through Si! Improving the performance of power electronics systems appears more and more as a key lever to significantly reduce or keep under control electrical power consumption.

Imec is developing power transistors on its GaN-on-Si (Galliumnitride-on-Silicon) platform. These will be key components to realize devices with high breakdown voltages that reliably and sustainably operate at high operating temperatures. Galliumnitride is a promising material for advanced power electronic components because it has outstanding capabilities for power, low noise, high frequency, high temperature operations and has very promising cost reduction perspectives. However, to make GaN-based devices a competitive alternative to silicon devices, GaN manufacturing technology needs to achieve the same economies of scale as Si.

Within imec's industrial affiliation program (IIAP) on GaN-on-Si technology,

imec and its partners focus on lowering the cost of GaN technology by using large-diameter GaN-on-Si and by developing processes compatible with standard Si process flow.

## 03 STORAGE

Imec is working on new solutions for highly efficient supercapacitors and batteries. One road we pursue is leveraging our nanotechnology expertise to increase the surface-to-volume ratio in devices for electrical and electrochemical energy storage. In cooperation with experts on novel catalysts, our expertise is also applied for the development of solar fuels, converting energy-poor molecules to energy-rich molecules using sunlight as the energy source.

## 04 SAVING

Imec is working on the improvement of the efficiency of GaN high-brightness LEDs. GaN exhibits excellent light emission properties in a very broad range of the visible and ultraviolet (UV) spectrum. However, solid state lighting by these

devices can only become broadly acceptable if new large-volume manufacturing processes are developed that enable 150lm/W LEDs at competitive costs. Today, state-of-the-art LED manufacturing processes are typically performed on expensive 4 inch sapphire substrates. By depositing the GaN material on 6 inch and 8 inch silicon substrates, the productivity of GaN-based device manufacturing can be significantly increased. Imec aims at developing GaN-based LEDs manufactured on a fully 6 inch and 8 inch CMOS-compatible process. The integration of imec's proprietary concept of surface roughening in combination with mirrors will allow a higher external quantum efficiency of thin-film textured LEDs.

### State-of-the-art research facility:

A 24h/7 days operational **200mm compatible high-end flexfab facility with GaN-on-Si capabilities** for power devices and LEDs including a MoCVD deposition tool for depositing GaN layers on 200mm Si substrate.

# LET US TAKE ON THE ENERGY CHALLENGE TOGETHER

## Why imec?

Imec is an independent research center, carrying out R&D programs in which companies, universities and other research institutes can participate. Imec has dedicated cooperation schemes that are **tuned to the needs of the industry**. Imec is bridging the gap between proof-of-concept in the lab and industrial manufacturing.

Benefit from imec's offer formed by its unique combination of energy-relevant competences. More than 25 years of knowledge in photovoltaics and micro- and nanoelectronics, including GaN-on-Si technology, new materials, characterization and reliability ...

## What we offer?

Imec offers a variety of business solutions ranging from research collaborations at various levels of scope and depth to license agreements and transfer of IP.

### 01 Silicon solar cell industrial affiliation program (IIAP)

Multi-partner R&D program exploring technologies to reduce Si use in Si solar cells, whilst increasing cell efficiency and hence further lowering substantially the cost per Watt peak.

- Accelerates development of new crystalline silicon solar cells.
- Provides a toolbox of innovative processing technologies to complement and enhance partner's existing proprietary processing technologies
- Sharing of talent, risk, cost and intellectual property (IP)
- Opportunities for proprietary evaluation of IIAP results.
- Industrial residents join imec's research team to build up fundamental understanding and develop robust solutions for next generation silicon-based solar cells.
- Build on imec's more than 25 years track record in silicon solar cells.

### 02 GaN-on-Si industrial affiliation program (IIAP)

Multi-partner R&D program to develop reliable and cost-efficient GaN high-breakdown-voltage power-switching devices (>600V) and GaN-based LEDs manufactured on a fully 6" and 8" CMOS compatible process.

The GaN-on-silicon program can rely on imec's high-end flexfab facility.

### 03 Bilateral collaborations

Companies can also partner with imec under a bilateral agreement, developing advanced and disruptive photovoltaic technology in organic solar cells, solar concentrators with photovoltaic stacks and thermophotovoltaic cells. Such R&D programs are jointly defined and may be tailored towards the needs and applications of the industrial partner.

# IMEC ENERGY

Powering a sustainable world



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## POWERING A SUSTAINABLE FUTURE

The cornerstone of imec's energy strategy is the development of key technologies for the future smart grid, a grid in which energy will be generated, stored, transported and consumed in a much more intelligent and sustainable way. Imec has chosen 4 domains that are critical for the smart grid on which it focuses its R&D. These are imec's 4S-activities (pronounce "force"): solar energy, switching energy, storing energy, and saving energy.

A smart grid delivers electricity from suppliers to consumers using two-way digital technology. It incorporates the use of superconductive transmission lines and efficient switching systems that reduce power losses. It integrates sources of renewable energy such as solar and wind, and it has the capacity to store and retrieve energy. And most important, the smart grid monitors and controls appliances at consumers' homes to save energy, reduce cost and increase reliability and transparency.

The technology challenges to build a smart grid are huge. More renewable energy, at a reduced cost, must be generated. New energy storage systems must be developed. Huge amounts of data

on the cost and consumption of energy will have to be collected, analyzed and distributed over the energy network. The network has to cope with various sources of energy, each with their own peaks and troughs. And appliances have to be managed to switch off and on, depending on their knowledge of price, energy availability and consumption rates.

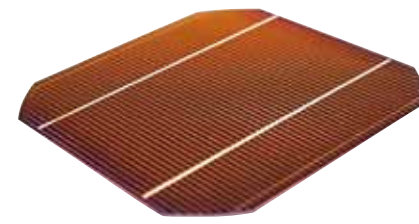
**Solar energy:** Electricity generation from photovoltaic devices has the largest technical potential of all renewable energy sources for electricity production. In order to make photovoltaic energy generation a substantial part of the energy mix of the future, the cost of photovoltaic cells, modules and systems has to decrease substantially by a factor of 2-3.

**Switching energy:** The smart grid of the future will be characterized by an important contribution of intermittent renewable energy sources (solar, wind, tidal ...) to the total energy mix. The variability of these sources will require extensive switching of electrical energy packets to ensure stability and service quality of the grid. Voltage conversion, DC/DC, AC/DC, DC/AC, will be necessary at numerous points in the grid. Highly efficient, low-

cost switches will be key in the technical realization of the smart grid.

**Storing electrical energy:** The future electrical energy supply will be characterized by variations in demand and supply of electrical energy at every moment. This can be overcome by building a buffer in the form of a storage capacity for electrical energy. Such storage will also be a critical enabler for e-mobility and its link to the smart grid.

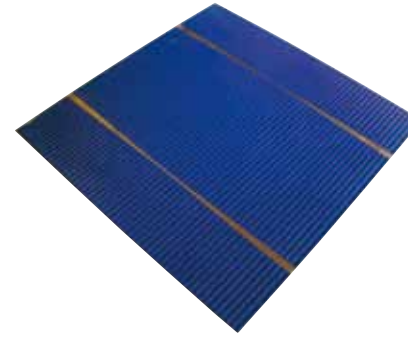
**Saving energy:** Smart meters will empower customers to make choices on how much energy they use and will enable suppliers to differentiate their tariffs and services. They are an important step towards reduced consumption of energy. Another obvious step towards mastering our energy future is increasing the energy efficiency of the electrical appliances we are using. The energy used for lighting purposes makes up for 20-30% of the electricity consumption in the developed countries. Important savings for lighting can be realized by evolving from incandescent light sources towards Light-Emitting Diodes (LEDs).



**01A-1** | Cu-plated large-area silicon solar cell with 18.8% efficiency.



**01A-2** | Large (156mm x 156mm) multicrystalline silicon solar cell.



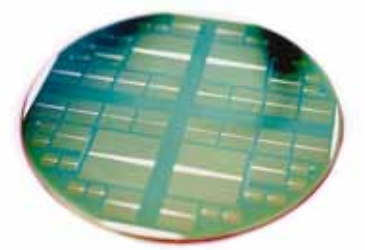
**01A-3** | Large-area (70cm<sup>2</sup>) epitaxial solar cell with an efficiency of up to 16.3% on high-quality substrate.



**01B** | Flexible organic solar cells (5x5cm<sup>2</sup>).



**01C** | Mechanically stacked GaAs/Ge solar cell.



**01D** | Thermophotovoltaic cells on a germanium substrate with a rough surface.

## 01 SOLAR

### 01A Silicon-based solar cells

#### Highly efficient crystalline-silicon solar cells

Imec's photovoltaics (PV) research aims at finding techniques to fabricate cheaper and more efficient solar cells. Imec is working towards this objective by following several technology tracks: crystalline Si-based solar cells which will be the dominant PV technology for at least the next decade, very low-cost PV technologies based on printing the active thin-film layer as well as the electrodes (organic solar cells), unique approaches for high-efficiency multijunction devices for concentration and thermophotovoltaic cells.

Imec reduces the active silicon layer thickness from 150µm down to 40µm to lower the production cost of crystalline Si solar cells. To meet efficiencies of more than 20% on large-area thin wafers, alternative back-side dielectric stacks using a PERL-style (PERL = passivated emitter and rear local back surface field) passivation, and interdigitated back-side contacts (i-BC) are being introduced, both in an industrial process flow. Cell-module integration is investigated, as reduced wafer thickness will impose specific integration requirements. And reliability is assessed, as the guaranteed lifetime of cells will increase up to 25 years.

#### Thin-film crystalline-silicon solar cells

Besides wafer-based bulk silicon solar cells, imec aims at developing epitaxial thin-film (<20µm) silicon solar cells grown on low-cost silicon carriers. The epitaxial thin-film process on low-cost silicon carriers is generally similar to the bulk process and the epi-process can be implemented with limited equipment investment in an existing crystalline silicon solar cell manufacturing line. To improve the optical confinement of light in the active part of the cell, a buried porous Si reflector is developed.

Next to solar cell technology and the generation of electricity, imec also works on the PV modules, looking to embed additional functionalities. An example is an integrated miniaturized inverter – a component that converts DC to AC and that today is still bulky, expensive, and installed separately. Modules could also include local energy storage, helping to balance the electricity grid and allowing the optimization of the inverter design. And there could be integrated technology for maximum power point tracking, which could help overcome the negative effects of shading on the modules. The goal of this R&D is to realize reconfigurable smart PV modules, which would link up with the smart electricity grid of the future.

### 01B Organic solar cells

Organic solar cells have the potential to become a cost-efficient alternative to silicon solar cells. And they can be a solution for special applications, applied on irregular, flexible or transparent substrates. Imec aims to increase the efficiency and lifetime of organic solar cells, and imec is developing a manufacturing technology for all layers of organic monolithic modules.

### 01C Photovoltaic stacks

For specialized PV applications in earth-based solar concentrators and satellites, imec develops highly efficient mechanical stacks of solar cells, made of different semiconductors (III-V top cells and Ge bottom cells), each absorbing another part of the solar spectrum. The aim is to increase the cell efficiencies to 35-40%. And, imec's specific stacking approach will improve the spectral robustness of the cells, leading to a significantly higher concentrator PV energy yield.

### 01D Thermophotovoltaic cells

Thermophotovoltaic (TPV) cells convert the radiation from heat sources with a lower temperature than the sun. They could generate electricity from waste heat released during industrial steel or glass production, or during domestic hot water production. Imec uses high-efficiency, low-bandgap Ge to develop highly efficient TPV cells that are stable under high fluxes of infrared radiation. Moreover, imec is looking for technologies to reduce TPV cell cost.

### State-of-the-art research facilities:

- **pre-pilot line for silicon solar cells** to develop and refine solar cell processes until they are ready to be transferred to production lines. The equipment is similar to that of a state-of-the-art solar cell production environment. And the batch size is large enough to allow valid predictions of averages, standard variations and yield. Techniques used in the pre-pilot line include isotropic acidic texturing, plasma texturing, reduced pressure POCl<sub>3</sub> diffusion, large area PECVD deposition of Si nitride and belt furnace rapid thermal anneal.
- **pre-pilot line for organic solar cells**, an integrated processing facility for organic solar cells with all processing steps needed for the fabrication and characterization of state-of-the-art organic solar cells.