GRAPHENE FLAGSHIP

FLAGERA TRANSNATIONAL CALL

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WP leader " Materials"

CSIC

Consejo Superior de Investigaciones Científicas

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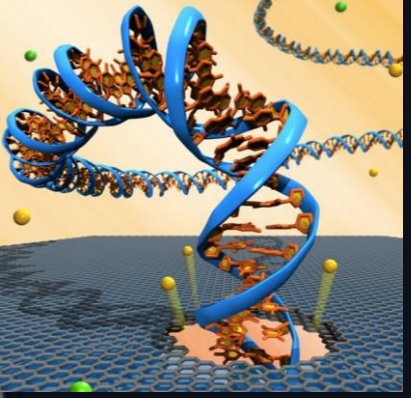
Outline

- Flagship goals and contents
- Consortium expansion stages
- NEXT: FLAGERA & Associate members

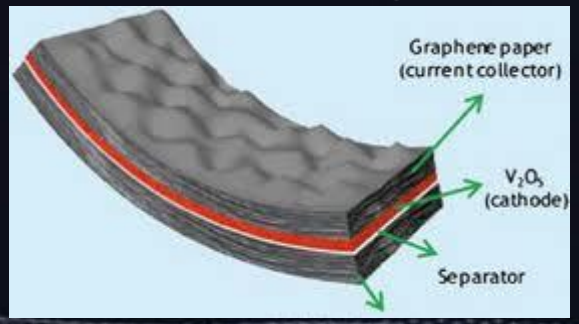
Leitmotiv FG: Driving GRAPHENE from research labs to the markets

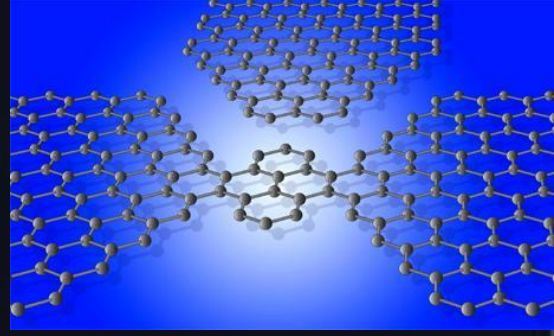
graphene applications



medical applications: drug delivery; lab-on-chip; DNA sequencing

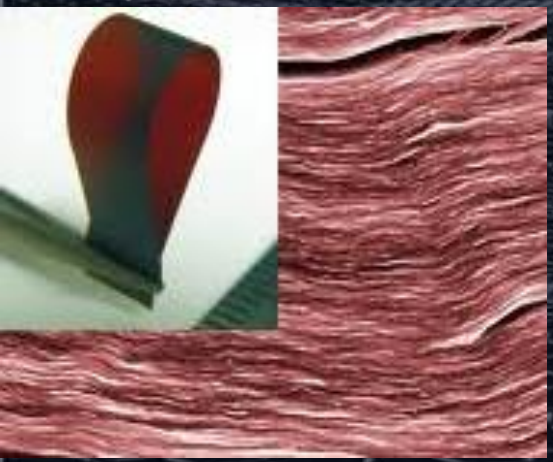
batteries; supercapacitors
conductive inks; etc.

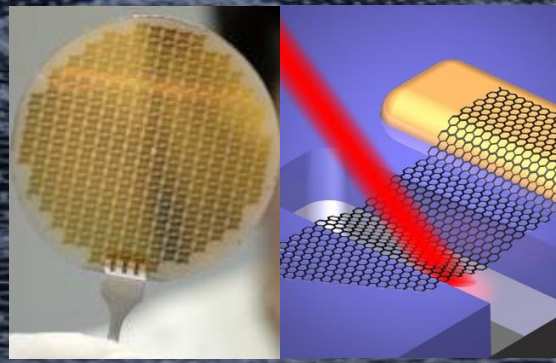




graphene electronics

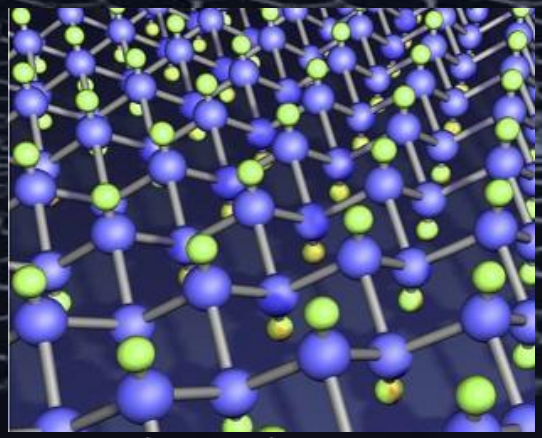
composites; barrier films





ultra-high frequency electronics; optoelectronics

MEMS; various sensors



graphene derivatives;
e.g., 2D analogue of Teflon

flexible
LCD and LED
wall lightning

Flagship goals

Scientific objectives

- *Material technologies for ICT and beyond*
  - Identify and explore new layered materials (LMs) and assess their scientific and technological potential.
  - Develop reliable, reproducible, sustainable and safe large scale production technologies for LMs.
  - Broaden the applications of graphene and other LMs beyond ICT
- *Component technologies*
  - Identify new device concepts enabled by graphene and LMs.
  - Develop component technologies that utilize the potential of these new materials platforms.
- *Systems integration*
  - Integrate graphene-based components to systems that provide new functionalities.
  - Integrate graphene and other LMs with existing technology platforms.

Operative targets

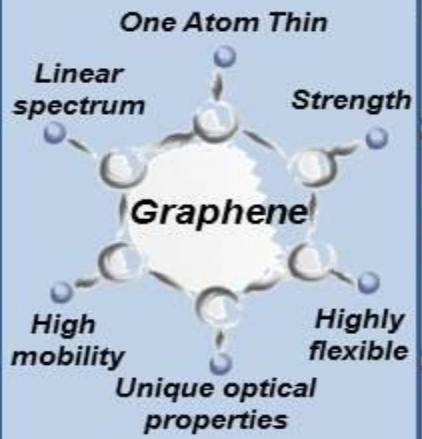
- Bring together a large core consortium of European academic and industrial partners,.
- Create a highly effective technology transfer highway.
- Align the Flagship with European and national priorities (***ERA-NET***).
- Engage the European societies with the Flagship.

Societal goals

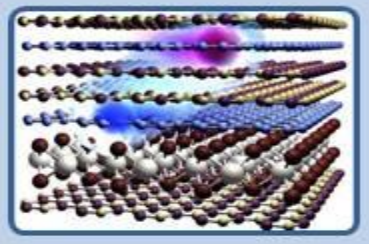
- Contribute to sustainable development based on abundant, safe and recyclable natural resources.
- Boost economic growth in Europe by creating new jobs and investment opportunities.

Scientific and technological roadmap

Platform



Hybrid 2d structures



Industrial
Academic

Industrial workshare
Academic workshare

System Integration

- Flexible electronic
- Superfast optical communication
- Ultrafast low-power electronics
- Self-powered devices
- Automotive
- …

Components

- Transistors
- Spin valves
- Flexible displays
- RF tags
- Ultra-light batteries
- Solar cells
- Ultrafast lasers
- Composite materials
- Prostheses
- Sensors
- …

Production techniques

- Large scale synthesis
- On demand growth
- Nanoribbons
- Growth on flexible substrates
- Inks
- Interfaces
- Doping
- Superstructures
- Toxicology
- …

Industrial workshare
Academic workshare

Vision beyond 2023

ICT

- Faster
- Cheaper
- Flexible

Energy storage and conversion

- Efficient
- Cost effective
- Renewable
- Sustainable

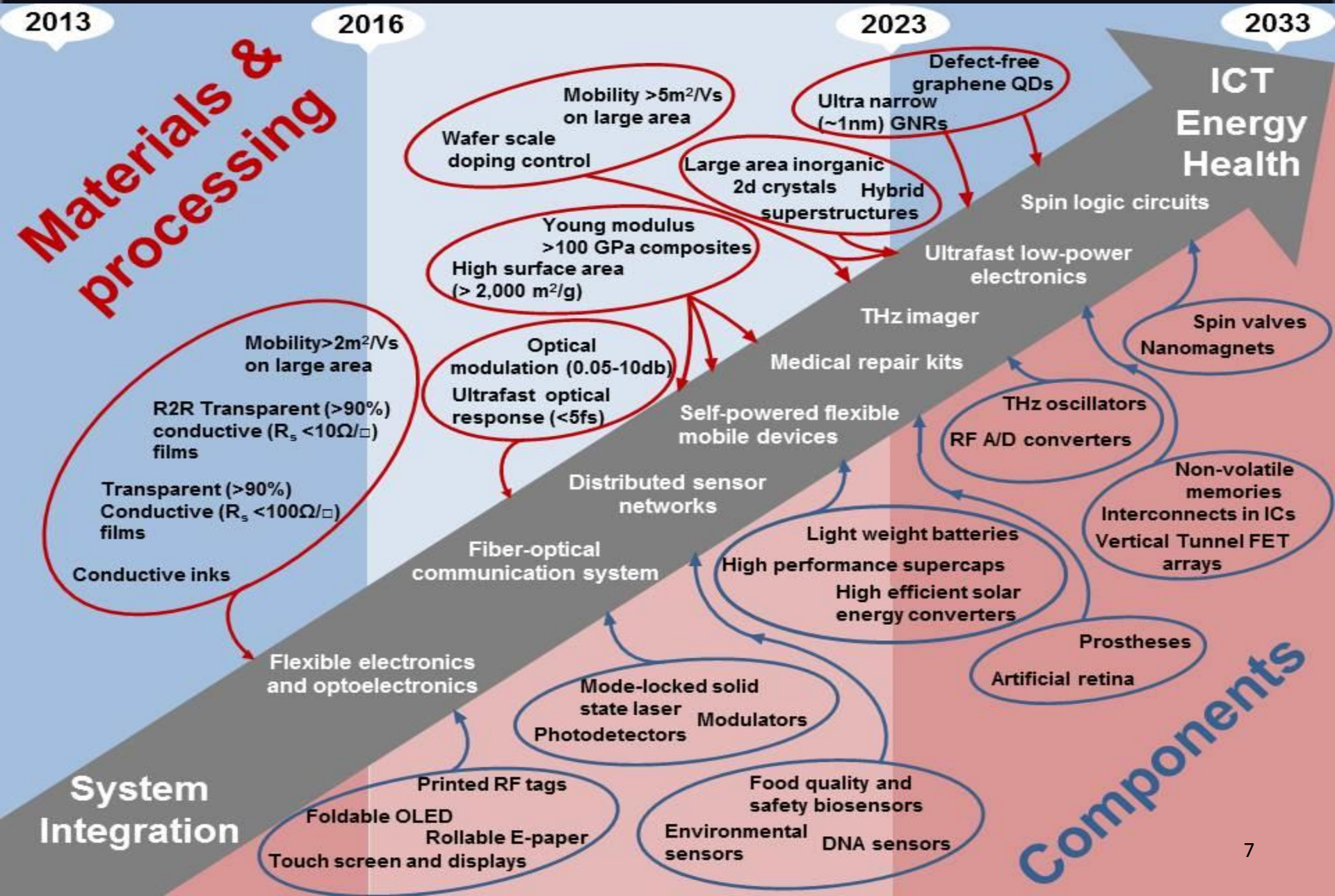
Health

- Cost effective
- Bio compatible

- **Societal benefits**
- **Jobs**
- **Education**

2013 2016 2023

Scientific and technological roadmap



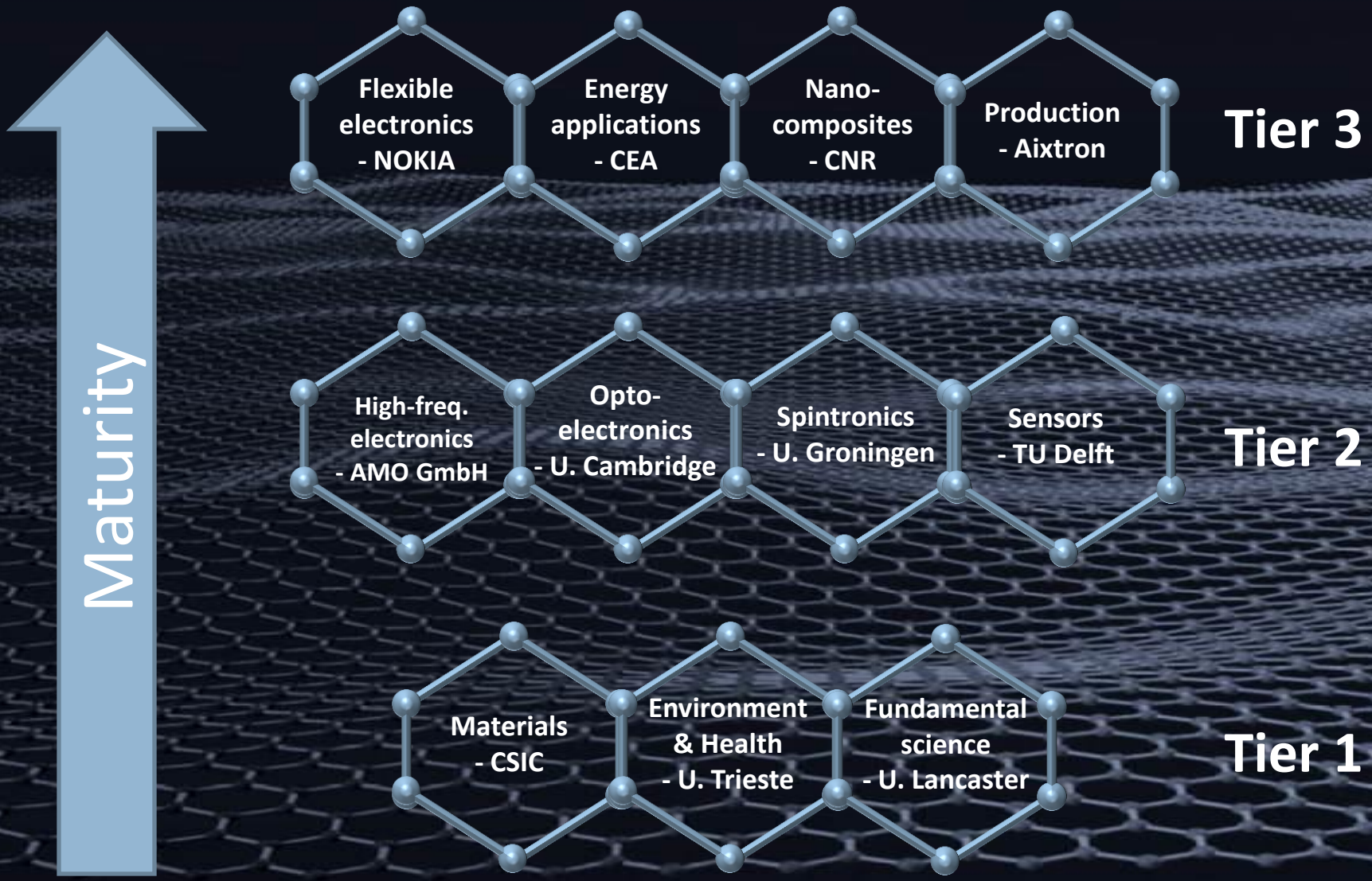
Flagship (CP-CSA) consortium

- **INITIAL CONSORTIUM**
  - **75 partners (128 groups) from 17 countries, selected by WP leaders based on their contributions to flagship goals**
  - **Universities, research centers, companies (*e.g.*, Nokia, Airbus, Philips, Repsol, ST Microelectronics, Alcatel Lucent, AMO GmbH, Graphenea, Aixtron, Oxford Instruments)**

- **COMPETITIVE CALL:**
  - **66 new partners**

TOTAL : More than 140 institutions from 23 Countries

Different maturity levels



Another WPs to be created after incorporation of competitive call partners

- Probably:
- Medical Applications
- Membrane applications

What is next?

- **FLAGERA CALLS**
- **ASSOCIATED MEMEBERSHIP**

FLAGERA TOPICS

– Computational modeling of devices and systems

Development of Graphene based devices requires detailed understanding of transpor and kinetics. Computationally crossing scales from micro to mesoscopic

- **Meet the challenges of huge ab initio calculations**
- **Meet the challenges of inconmensurate lattice in 2d Multistacks**

- ***New computation strategies, realised in codes tailored for atomically thin 2d crystals***

- ***Dedicated computational tools for multi-scale modelling of graphene-based devices***

- ***Design tools to implement transistors and other components based on GRMs in electronic circuits***

- Advanced nanofabrication and spintronics

Single electron transistors or FET require reproducible fabrication methods for nanoribbons

⇒ Meet challenge of nanofabrication in the 10 nm range

Graphene in spintronics required nonstandard FM contacts that cause problems in manufacturing spintronics devices

⇒ All graphene spintronics

⇒ *Reproducible and scalable fabrication methods few nm scale. Band engineering in nanoribbons*

⇒ *Introduce spin-orbit coupling or Ferromagnetism in graphene for all graphene spintronics devices*

Active THz components

Social demand for RT ultra-fast THz detectors, modulators, spectroscopy systems and sensors

- Meeting the challenge of enhancing absoption to profit G broadband
- Demonstration of high speed emitters and detectors (THz) and their coupling to low loss waveguides in networks
- Assess the capability to detect biomolecules using G as transducer
  - *Building up of optoelectronics networks*
  - *Development and characterization of opto-electronic arrays based on the modulation of THz absorption for highly selective and sensitive in-situ recognition with detection limits < picoMolar levels*
  - *Exploring of novel approaches to photodetection using othe 2D materials (Hg Te, BiTe)*

-Multifunctional Composites

Increasing demand for higher transmission capacities in power lines . Conductive materials with improved electrical resistance, rheological and fatigue properties, resistance to corrosion

- **Graphene/metal composites as conducting cable**
- **Graphene polymer composites as inner cable shielding**

- ***Develop metal/Graphene composites with high electrical and thermal conductivities***
- ***Develop metal/polymer/ elastomers with high electrical conductivity and high electrical shielding***

- ***Explore graphene based multifuntional architectures for cabling***

- Funtional coatings

GRMs can be ideal coatings to modify/improve the properties of an interface. Graphene's excellent mechanical, thermal, gas barrier and electrical properties have potential for high performance coatings with elevate stability, to prevent electrical or heath damage in harsh environments.

- **Meet requirements of high added value applications (Aeronautics Automotive, aerospace....)**
- **Add new funtionalities**

- ***Functional coatings at interfaces (external or buried) of technologically relevant composites GRMs at intefaces of complex multiscale architectures containing micro/mesos copic additives***
- ***Target funtionalities: Electrical conductivity, Heat management, resistance to gas permeation, improved chemical properties…***

- Nanofluidics applications

Graphene membranes can improve fluidic transport up to several order of magnitud due to a variety of driving forces gradients

- **G-membranes could challenge the continuum fluid transport in porous systems**
  - ***Ultra-filtration, desalinization***
  - ***Energy harvesting. Osmotic power***
    Demonstrators should target electric power conversion > 5 W/m^2.

Biological and chemical sensors

Graphene extremelly sensitive to interaction with molecules.
Perfect tansducer to the limit of single molecule. Therasnostics applications based on electrical, optoelectrical or chemical principles

- **Charge transfer very sentitive to magnetic moment of molecules which adds an extra degree of freedom**

- **Low noise and easy integration in flexible substrates makes Graphene ideal candidate for neuron prothesis and interface with live matter**

- ***Development of new devices with subcellular resolution to interface sensors to biological systems . Time reolved***
- ***Cell-bionic systems & technologies for bidirectional communication with living matter, aiming at cellular resolution.***
- ***Challenge mechanical mismatch between electronic device and soft biological tissue.***

The direct effects on DNA need to be assessed on different cellular models and organisms (e.g. bacteria, nematodes, insects, higher plants, etc.).

- Immunogenomics and proteomics

Funtion or misfuntion of a living organism depends largely on the expression of key proteins in DNA and RNA

- **In depth knowledge of the effect of GRM on gene regulation and mutagenesis is still missing**
- **Graphene based Microarray technology on the entire genome expression can be applied to all isolated RNA**
- ***Identification and characterization of the proteomic impact***
- ***The direct effects of GRM on DNA need to be assessed on different cellular models and organisms (e.g. bacteria, nematodes, insects, higher plants, etc.).***

- New layered materials and heterostructures

Functional electronics and optoelectronics applications, based on materials with a spectral gap in the band structure, would require either modification of graphene, or its combination with other semiconductors in hybrid devices.

➡ **Multistacking has proven feasible with flakes G/BN, G/MoS2**

➡ ***Scalable growth of other 2d systems (dichalcogenides) and heterostructures .***

➡ ***Growth of graphene on III-V films***

➡ ***Characterisation of electronic and optical properties and implementation of hybrid graphene systems in functional devices.***

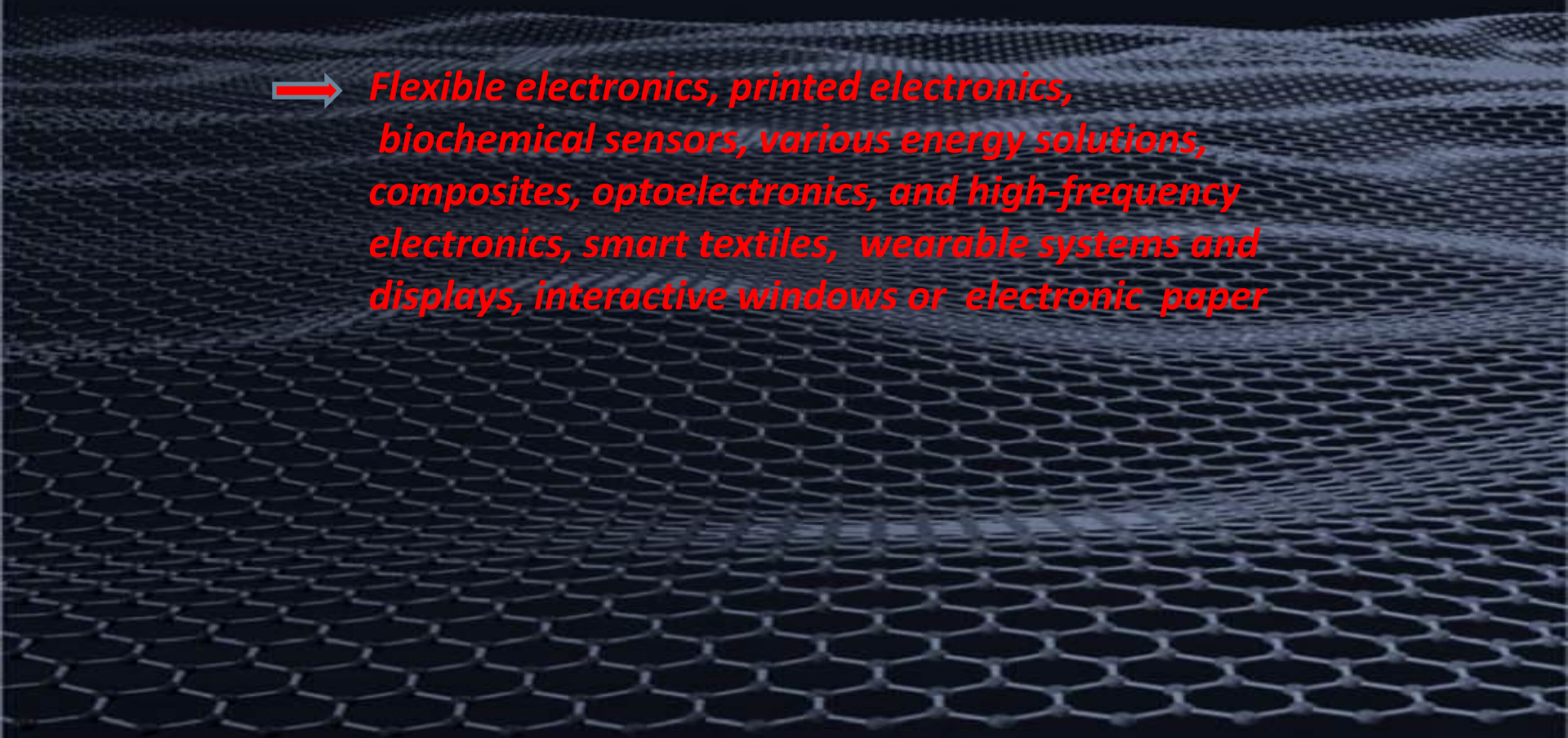
-Energy

Graphene in photovoltaic modules, fuel cells, batteries and super-capacitors, and devices for hydrogen generation technology offers opportunities to tackle challenges driven by the increasing global energy demand

- **Expected improvements strongly dependent on quality and formulation of materials used**
  - ***Focus on breakthrough material production and functionalization (single and double sided) protocols to shape catalytic and photo-catalytic GRM nano-assemblies for solar energ storage.***
  - ***Bio-inspired functions of GRM should be implemented in the field of water splitting and CO_2 photo-reduction to address solar fuel production with visible light irradiation***
  - ***Innovative organic-inorganic graphene textures and bio-hybrid composites for H2 storage and CO2 capture***

- Prototypes

Of any type, demonstrating the potential graphene based solutions to present day industrial and technological challenges in the fields of :



Flexible electronics, printed electronics, biochemical sensors, various energy solutions, composites, optoelectronics, and high-frequency electronics, smart textiles, wearable systems and displays, interactive windows or electronic paper

Associated members

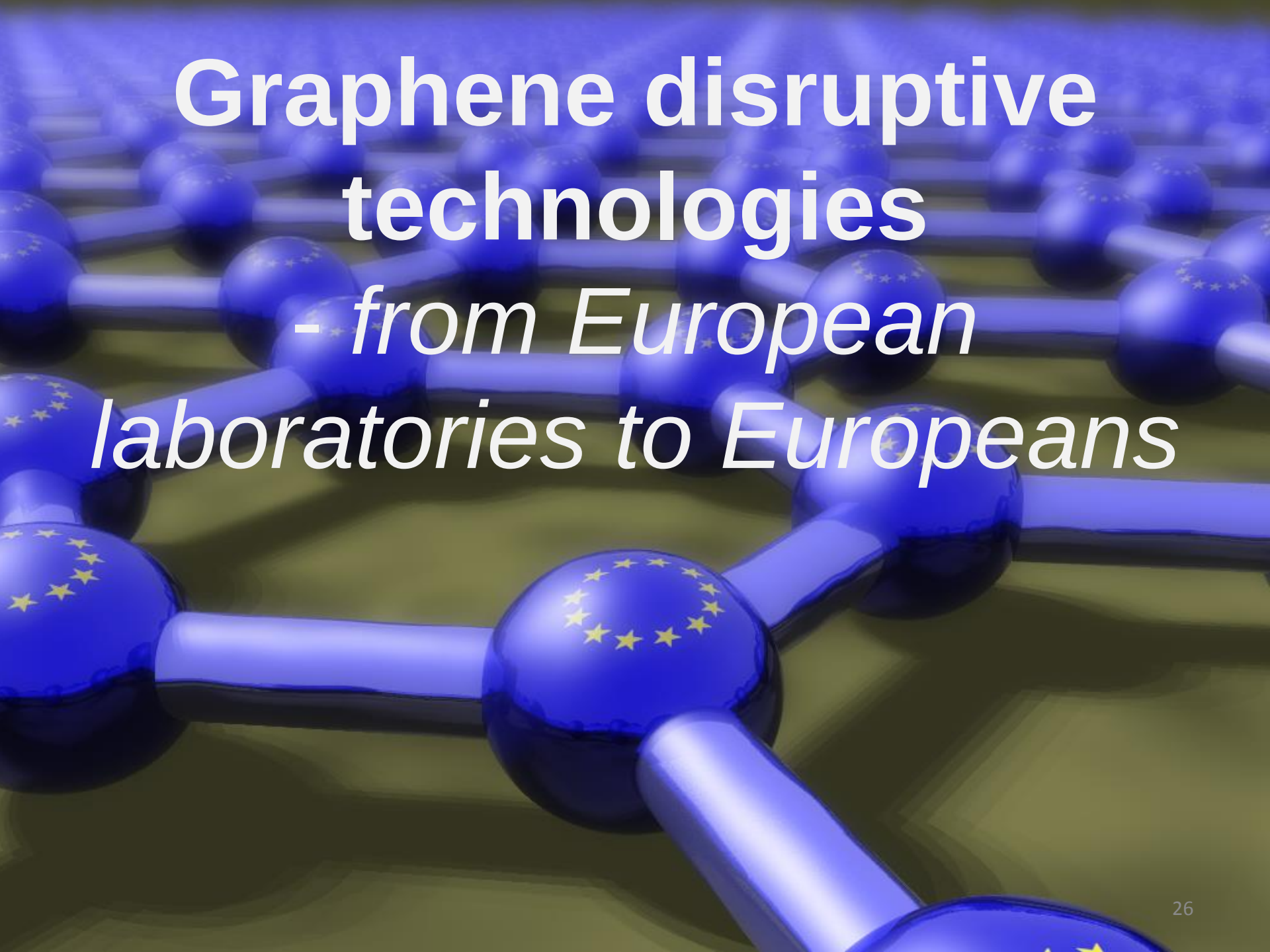
- Groups funded by sources other than the CP-CSA may become Associated Members (AMs)
- AMs are not partners in the CP-CSA but will have access to those functions of the CP-CSA that do not require confidentiality (winter schools, publication databases, information material)
- AMs are selected by the Executive Board (*does the proposed AM contribute significantly to the flagship goals?*)

[1] Inclusion of published results by permission only. Work not funded by the CP-CSA will be clearly identified.
[2] Unless otherwise agreed in the additional collaborative agreement

Benefits	Non-Member	Associated Member	Associated Member with additional collaborative agreement	Partner
Participation to open activities	Yes	Yes	Yes	Yes
Publications listed on web page	NO	Yes	Yes	Yes
Job listings published on web page	NO	Yes	Yes	Yes
Automatic subscription to newsletter	NO	Yes	Yes	Yes
Coverage of activities by Flagship Science Writer/Communications Officer	NO	Yes	Yes	Yes
Included in the Flagship mailing list	NO	Yes	Yes	Yes
Direct invitation to industrial workshops (priority access)	NO	Yes	Yes	Yes
Direct invitation to Flagship conferences and schools (priority access)	NO	Yes	Yes	Yes
Inclusion of results in Deliverable Reports to the EU	NO	Yes	Yes[1]	Yes
Attendance to non-confidential part of the Flagship General Assembly	NO	Yes	Yes	Yes
Participation in confidential S&T activities	NO	NO	Yes	Yes
Attendance to WP meetings	NO	NO	Yes	Yes
Access rights to foreground and background	NO	NO	NO	Yes
Direct funding from Flagship CP-CSA	NO	NO	NO	Yes

Nomination procedures

- **When AM are nominated by FLAG-ERA**. It is expected that FLAG-ERA may nominate all projects to be funded in the Joint Call for Associated Membership status.
- **When AM are nominated by National Bodies**, Case for membership consisting of 1 A4 page. The nominated AM will have to provide an additional 2 A4 pages describing: list of all personnel who will be involved in the activities; how the research conducted in such organization aligns and complements the activities of the Flagship;
- **When AM are nominated by the European Commission**, an EU official will be requested to attend the EBM and present a case for membership consisting of 3 A4 pages: 1 A4 page description of the organization nominated as AM, with a clear indication of the PI responsible for such organization, who will become the main point of contact with the Flagship, and the list of all personnel who will be involved in the activities; 1 A4 page detailing how the nominated organization will facilitate alignment and information flow with the Flagship, and related national and international activities, as well as how the research conducted in such organization aligns and complements the activities of the Flagship; 1 A4 page describing how and why the EC nominated such organization for Associate Membership.


Graphene disruptive technologies
- from European laboratories to Europeans