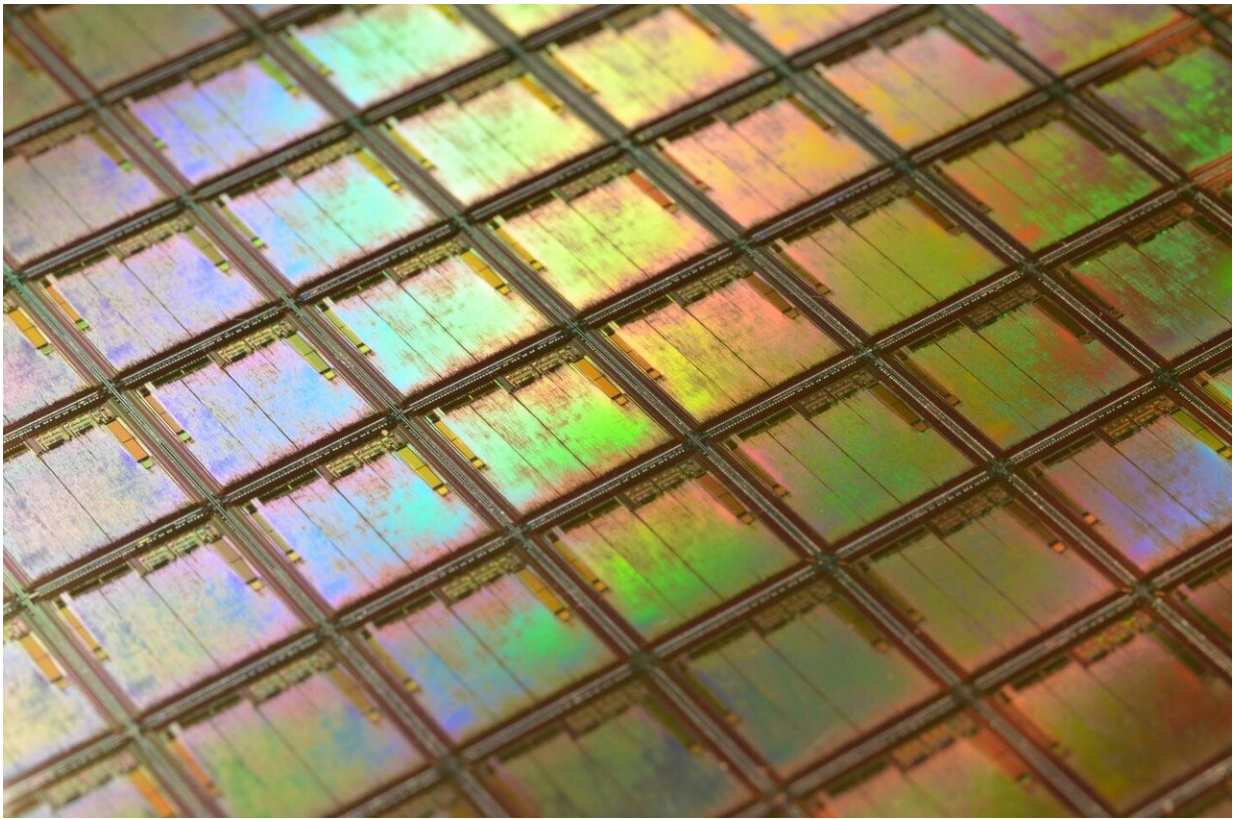


Wafer-scale production of graphene-based photonic devices

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Graphene Flagship researchers have devised a wafer-scale fabrication method that paves the way to the next generation of telecom and datacom devices.

Credit: Unsplash

Our world needs reliable telecommunications more than ever before. However, classic devices have limitations in terms of size and cost and,

especially, power consumption—which is directly related to greenhouse emissions. Graphene could change this and transform the future of broadband. Now, Graphene Flagship researchers have devised a wafer-scale fabrication technology that, thanks to predetermined graphene single-crystal templates, allows for integration into silicon wafers, enabling automation and paving the way to large scale production.

This work, published in the prestigious journal *ACS Nano*, is a great example of a collaboration fostered by the Graphene Flagship ecosystem. It counted on the participation of several Graphene Flagship partner institutions like CNIT and the Istituto Italiano di Tecnologia (IIT), in Italy, the Cambridge Graphene Centre at the University of Cambridge, UK, and Graphene Flagship Associated Member and spin-off CamGraphIC. Furthermore, Graphene Flagship-linked third party INPHOTEC and researchers at the Tecip Institute in Italy provided the [graphene](#) photonics integrated circuits fabrication. Through the Wafer-scale Integration Work Package and Spearhead Projects such as Metrograph, the Graphene Flagship fosters collaboration between academia and leading industries to develop high-technology readiness level prototypes and products, until they can reach market exploitation.

The new fabrication technique is enabled by the adoption of single-crystal graphene arrays. "Traditionally, when aiming at wafer-scale integration, one grows a wafer-sized layer of graphene and then transfer it onto silicon," explains Camilla Coletti, coordinator of IIT's Graphene Labs, who co-led the study. "Transferring an atom-thick layer of graphene over wafers while maintaining its integrity and quality is challenging" she adds. "The crystal seeding, growth and transfer technique adopted in this work ensures wafer-scale high-mobility graphene exactly where is needed: a great advantage for the scalable fabrication of photonic devices like modulators," continues Coletti.

It is estimated that, by 2023, the world will see over 28 billion connected

devices, most of which will require 5G. These challenging requirements will demand new technologies. "Silicon and germanium alone have limitations; however, graphene provides many advantages," says Marco Romagnoli from Graphene Flagship partner CNIT, linked third party INPHOTEC, and associated member CamGraphiC, who co-led the study. "This methodology allows us to obtain over 12.000 graphene crystals in one wafer, matching the exact configuration and disposition we need for graphene-enabled photonic devices," he adds. Furthermore, the process is compatible with existing automated fabrication systems, which will accelerate its industrial uptake and implementation.

In another publication in *Nature Communications*, researchers from Graphene Flagship partners CNIT, Istituto Italiano di Tecnologia (IIT), in Italy, Nokia—including their teams in Italy and Germany, Graphene Flagship-linked third party INPHOTEC and researchers at Tecip, used this approach to demonstrate a practical implementation: "We used our technique to design high-speed graphene photodetectors," says Coletti. "Together, these advances will accelerate the commercial implementation of graphene-based photonic devices," she adds.

Graphene-enabled photonic devices offer several advantages. They absorb light from ultraviolet to the far-infrared—this allows for ultra-broadband communications. Graphene devices can have ultra-high mobility of carriers—electrons and holes—enabling data transmission that exceeds the best performing ethernet networks, breaking the barrier of 100 gigabits per second.

Reducing the energetic demands of telecom and datacom is fundamental to provide more sustainable solutions. At present, Information and communication technologies are already responsible for almost 4% of all greenhouse emissions, comparable to the carbon footprint of the airline industry, projected to increase to around 14% by 2040. "In graphene, almost all the energy of light can be converted into electric signals,

which massively reduces power consumption and maximizes efficiency," adds Romagnoli.

Frank Koppens, Graphene Flagship Leader for Photonics and Optoelectronics, says: "This is the first time that high-quality graphene has been integrated on the wafer-scale. The work shows direct relevance by revealing high-yield and high-speed absorption modulators. These impressive achievements bring commercialisation of graphene devices into 5G communications very close."

Andrea C. Ferrari, Science and Technology Officer of the Graphene Flagship and Chair of its Management Panel added: "This work is a major milestone for the Graphene Flagship. A close collaboration between academic and industrial partners has finally developed a wafer-scale process for graphene integration. The Graphene Foundry is no more a distant goal, but it starts today."

More information: Marco A. Giambra et al, Wafer-Scale Integration of Graphene-Based Photonic Devices, *ACS Nano* (2021). [DOI: 10.1021/acsnano.0c09758](https://doi.org/10.1021/acsnano.0c09758)

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