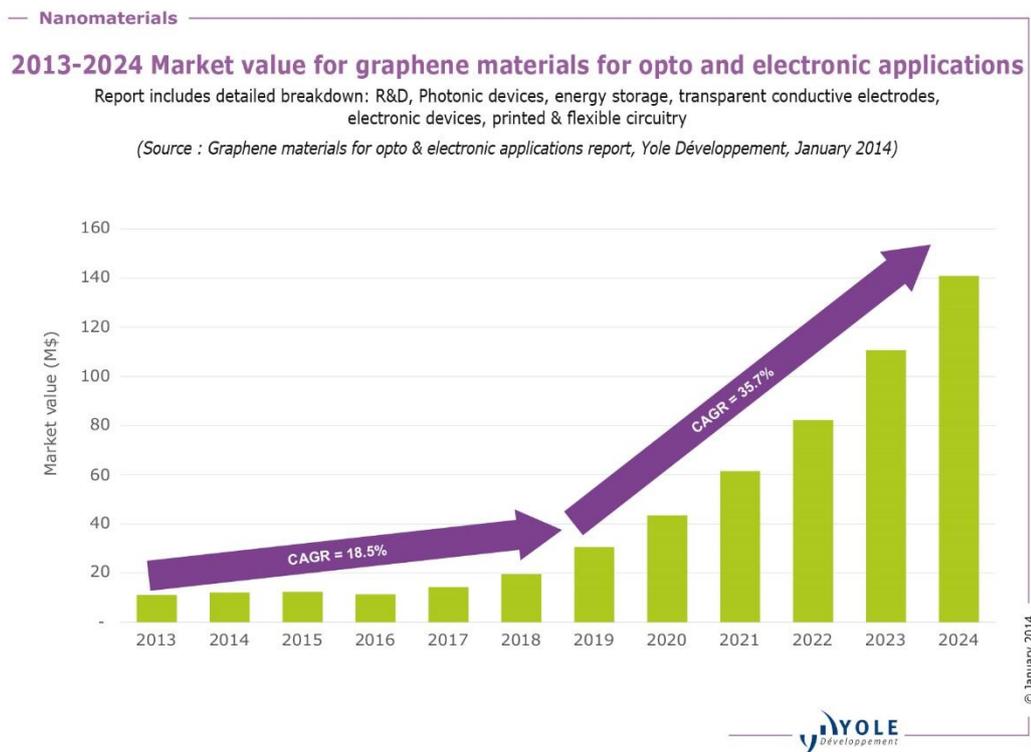


Graphene materials: what is the industrial potential behind the academic R&D hype?

Graphene materials for opto & electronic applications report, 2014 edition

Lyon, France – January 30th, 2014 – “\$141M graphene materials market in 2024 will be driven mainly by transparent conductive electrodes and energy storage applications”, announces Yole Développement. This week Yole Développement releases its new report: **Graphene materials for opto & electronic applications**.

Graphene is a two-dimensional (2D) material with exceptional properties, such as ultrahigh electrical and thermal conductivities, wide-range optical transmittance and excellent mechanical strength and flexibility. These properties make it a promising material for emerging and existing applications in printed & flexible circuitry, ultrafast transistors, touch screens, advanced batteries and supercapacitors, ultrafast lasers, photodetectors and many other non-electronic applications.



“Although today there is no graphene-based electronic application in mass production, several companies already offer commercially graphene materials. The graphene material market value in 2013 was about \$11 million, represented principally by the demand for the R&D and prototyping”, underlines Dr Rosina. Two scenarios for the future market growth are presented in the report. According to the base scenario, the global annual market value for graphene

materials in opto and electronic applications will reach \$141 million in 2024, featuring a 2013-2019 CAGR of 18.5%. Accelerated market growth is expected after 2019, with a 2019-2024 CAGR of 35.7%. In 2024, the graphene material market will be represented mainly by the demand for transparent conductive electrodes and advanced batteries and supercapacitors.

How can graphene technology challenges and application potential be transformed into business opportunities?

In order to reach the best possible performance on lab-scale devices, high quality materials are required. Material suppliers able to consistently deliver high-quality materials have a competitive advantage on the graphene market.

The booming interest in graphene technologies has led to a high demand on graphene equipment. As shown in the report, CVD equipment makers today mainly focus on the R&D equipment used to produce high-quality graphene.

The leading device manufacturers are currently evaluating the graphene technology potential; most of them have internal R&D activities or are developing R&D partnerships with graphene material suppliers. But today's graphene supply chain is widely dispersed and makes choosing the right supplier difficult. A large (and growing) number of start-up companies are looking to catch graphene market opportunities in their initial stage. Securing graphene IP is crucial to a strong competitive position. As detailed in the report, strong vertical integration trends within the supply chain are expected, due to specific challenges in production and the handling of graphene materials, namely CVD-made graphene sheets. The manufacturers of graphene nanoplatelets will also vertically integrate to gain a higher product value and better differentiation from competitors by offering application-specific materials, such as conductive inks and composite materials for graphene batteries and supercapacitors.

As pointed out in the report, many different graphene material types and quality levels exist. A higher level of standardization is therefore important in graphene technology, especially for the suppliers of high-quality graphene materials to differentiate better from other suppliers, and for companies with a long-term business strategy. The lack of suitable graphene quality characterization tools provides opportunities for companies developing specialized tools.

Graphene materials: quality, quantity, reproducibility and low cost needed

The development and industrial production of new graphene applications require a reliable supply of graphene with consistently high quality.

Graphene materials can be produced as tiny flakes (nanoplatelets) or in the form of a large-size sheet on different substrates, such as a metal foil or silicon carbide (SiC).

The catalytic chemical vapor deposition (CVD) of graphene on metals, featuring the high potential for both scalability and high material quality, has the largest potential for mass production of graphene opto and electronic devices. Although the market potential of high-quality epitaxial graphene on SiC is limited by the dimensions and high costs of SiC wafers, it may be successfully applied to produce some high-end electronic applications. The

nanoplatelets produced by different methods, such as liquid phase epitaxy or reduction of graphene oxide can be used to produce conductive inks for printed electronics and additive materials for energy storage devices, such as Li-ion batteries and supercapacitors.

The choice of the graphene production technique is of crucial importance to a device manufacturer because it influences not only the graphene size, quality and costs, but also the design of the production line for device manufacturing.

As shown in the report, it is possible today to produce large volumes of graphene materials at relatively low costs and also to produce the high-quality graphene. The main challenge is to satisfy both conditions simultaneously...

More information about this report? Please contact Clotilde Fabre (fabre@yole.fr) to watch Yole Webtalk, an interview of Dr Rosina, Yole Développement.

About “Graphene materials for opto & electronic applications” report

- Author: **Dr Milan Rosina** is an analyst at Yole Développement for photovoltaic market & technologies. Before joining Yole Développement, he worked as a research scientist and a project manager in the fields of photovoltaics, microelectronics and LED. He has more than 12 years scientific and industrial experience with prominent research institutions and an utility company. Amongst his experience are new equipment and processes development, due diligences, photovoltaic technology and market surveys, and analysis of various photovoltaic technologies and elaboration of photovoltaic roadmaps. He is the co-author of two issued patents in the field of solar cell processing.
- Catalogue price: Euros 5,990.00 (Full report - Multi user license) – Euros 2,490 (Executive Summary) - Publication date: January 2014. For special offers and the price in dollars, please contact David Jourdan (jourdan@yole.fr).
- Companies cited in the report – *Non exhaustive list*

2D-Tech, AIXTRON, AMO, Angstrom Materials, Annealsys, Applied Graphene Materials, Bluestone Global Tech, Cabot, CalBattery, CEA, CrayoNano SA, CVD Equipment, Graphene Laboratories, Graphene Platform, Cambridge Graphene Platform, Graphene Square, Graphene Works, Graphenea, Graphensic, Gwangju Institute of Science and Technology, Haydale, IBM, IEMN, IMEC, Intel, ITME, Chalmers University of Technology, LG, Lomiko Metals, Mason Graphite, Nano Carbon, NanoXplore, National University of Singapore, Nokia, Oerlikon Leybold Vacuum, Plasmionique, Pohang University, Princeton University, Samsung, PNNL, SHT Smart High Tech, Texas Instruments, Thales, Thomas Swan, UC Santa Barbara, UCLA, University of Exeter, University of Manchester, University of Oxford, VG Scienta, Vorbeck Materials, XG Sciences...



About Yole Développement

Founded in 1998, Yole Développement has grown to become a group of companies providing marketing, technology and strategy consulting, media in addition to corporate finance services. With a strong focus on emerging applications using silicon and/or micro manufacturing, Yole Développement group has expanded to include more than 50 associates worldwide covering MEMS, Compound Semiconductors, LED, Image Sensors, Optoelectronics, Microfluidics & Medical, Photovoltaics, Advanced Packaging, Manufacturing, Nanomaterials and Power Electronics.

The group supports industrial companies, investors and R&D organizations worldwide to help them understand markets and follow technology trends to develop their business.

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