EUROPEAN DEFENCE AGENCY

Fact sheet

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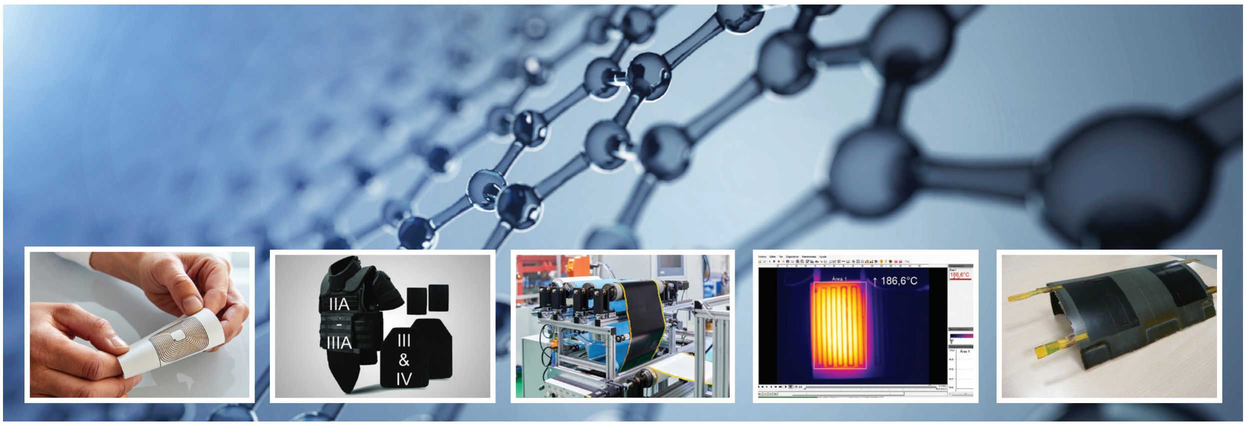
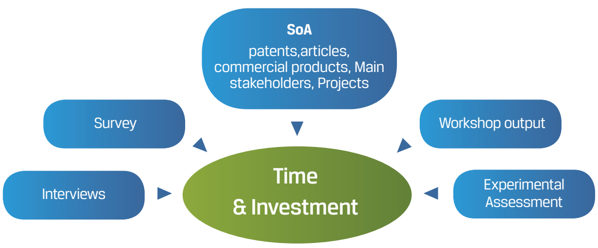
Graphene Applications for Defence



In December 2017, EDA launched a study to assess the potential use and impact of graphene on defence applications. The study was assigned to Tecnalia Research and Innovation (Spain) in collaboration with the Technical University of Cartagena (Spain) and Cambridge Nanomaterial Technology Ltd (United Kingdom). The project was launched on December 2018 and finished in March 2019.

The overall purpose of the project was to get a comprehensive view of the potential use of graphene in defence applications. Graphene presents unique properties in thermal/electrical conductivity, mechanical resistance and straightforward functionalisation, which makes it attractive for several defence applications: (opto)electronic devices, flexible systems, energy devices, multifunctional coatings, ballistic protection materials, camouflage and signature management, membranes and filters, biomedical devices, sensors and energetic materials. The technology readiness level, investments needed, and relevance to military tasks have been analysed.

Project Outline



Schematic illustration of the roadmapping process

State of the art analysis and roadmapping process

An analysis of publications and patents illustrates that graphene is a science-based technology still in an emergent stage.

The level of maturity of graphene-based materials and demonstrators is mostly still too low to realistically assess marketability and cost/benefit. Many companies are waiting for higher maturity and for the technology to be proven. The lack of private investment has become one of the biggest barriers. A huge effort in IP protection is observed. The projects targeting defence applications are in most cases non-public.

The current major barrier is the step from "proof of principle" to actual mature demonstrators prepared with commercially feasible processes. This demands further material understanding as well as engineering to show the full graphene potential in relevant applications, allowing a reasonable comparison to be made with competing or state-of-the-art technologies in terms of performance and cost/benefit ratio.

Another important drawback is the lack of a supply chain for most of the key applications. While there are enough graphene manufacturers in Europe to meet current demands, the lack of established standard methods for classifying the materials and the need for specific developments in processed graphene for each application is delaying the establishment of a complete value chain for many of the applications.

A toolbox of qualitative and quantitative methods, including literature, online survery, workshop, interviews, patents, market studies, project data bases and other data analysis, has been used to develop the roadmaps and the SWOT analysis.

Experimental assessment

Different graphene-based materials have been investigated: reduced graphene oxide, graphene nanoplatelets and few layers graphene in powder format, as well as graphene free-standing films. Processability for their integration in epoxy resins and adhesives has been thoroughly addressed.

- **Electro-optical properties.** The main alternative of this technology, as replacement of the rigid Indium Tin Oxide (ITO) solutions, is the use of silver nanowires which also has flexibility capabilities. For example, this is useful in transparent electrodes. Graphene enhances the robustness of this technology.
- **Electrical/Thermal conductivity.** Composites integrating free-standing graphene films have shown optimised electrical conductivity, a property that could be used to address functionalities such as electromagnetic interference (EMI) shielding or anti-icing systems. Thermal conductivity increases by more than two orders of magnitude with the introduction of free-standing graphene films.
- **Electromagnetic properties.** The use of graphene coatings as a radar absorbing coating in the X-Band has been corroborated with a reduction in the cross-section of over 15dB.
- **Mechanical properties.** Several doping percentages of three different types of graphene were analysed. The addition of few-layer graphene in a nanocomposite of Urethane-Acrylate thermoset resin significantly improves its mechanical properties in terms of energy absorption of an impact.
- **Ballistic properties.** An improvement of 16.2 % in the ballistic limit was obtained at 2 % doping of few- layer graphene.

Based on future military needs established through the **Generic Military Task List (GMTL)** and the EU's **Capability Development Plan (CDP)**, as well as the state-of-the-art analysis and inputs from experts, a set of high priority graphene key applications have been identified.

Key applications

The following key applications have been selected: Electronics and optoelectronics. Flexible systems. Energy. Ballistic protection materials. Multifunctional coatings. Camouflage and signature management coatings. Filters and membranes Sensors. Biomedical applications. Energetic materials.

Graphene impact to systems/ products

Drones will clearly benefit from graphene developments for many of their components: lightweight structure, electronics, cameras, or sensors.

High thermal dissipation materials. The unique thermal properties of graphene mean that low investments and short development phases are required to reach the defence market.

Multifunctional coatings are close to the market (3 to 5 years); however, further cost/benefit analyses are needed and the technical enhancement must be demonstrated. As multifunctional coatings are widely used in non-defence sectors, the defence sector could just follow the developments and acquire the technologies from the civilian sector as required.

Radar signature reduction coatings. The tunability of graphene over a broad spectrum of electromagnetic wavelengths or its selective absorption provide a positive cost/benefit ratio as compared to other camouflage solutions.

Lightweight ballistic protection materials. Additional developments (3-5 years) are needed before they are ready for the market. Further cost/benefit analyses are needed and the technical enhancement must be demonstrated.

Flexible lightweight batteries. The weight reduction, the high specific surface area and flexibility of graphene make a clear difference from the products currently available.

Low-light working devices. Photodetectors are benefiting from the unique property of graphene being transparent in the infrared spectrum. The investments needed are high as is the uncertainty regarding the time needed to fully develop them for defence purposes.

Membranes for water and air filtration. The specific surface area of graphene meets the need to have lightweight, portable and specific membranes for military applications.

Supercapacitor electrodes are already demonstrating that graphene enhances the capability to withstand higher loads than commercially available ones. Their arrival on the defence market is expected in four years.

Chemical/Biological/Radiological/Nuclear sensors. Selectivity and sensitivity will be the main features to be targeted in future developments, together with packaging issues. High investments and a long pre-market development phase are expected.

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