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GRAPHENE AND GRAPHENE-LIKE MATERIALS: INNOVATION AND FORESIGHT IN SPACE TRANSPORTATION TECHNOLOGIES

Abstract

Graphene is a one-atom-thick layer of carbon atoms arranged in a hexagonal lattice. Graphene has a set of unique and outstanding properties, being the thinnest, strongest and lightest known material, flexible and extremely electrically and thermally conductive. Since 2004 graphene, as well as the graphene-like nanomaterials, have found hundreds of innovative applications, from sensors and electronics to energy storage and healthcare. The several available graphene-based materials open a whole new world of possibilities. The properties of few-layers graphene, graphene platelets, graphene quantum dots, graphene oxide (GO) and reduced graphene oxide (rGO) make these materials ideal for a number of applications in space transportation. Actually, the European Commission launched in 2013 the Graphene Flagship programme which, with a budget of 1 billion, represents one of Europe's biggest ever research initiatives. Within such initiative, some experiments were conducted, in collaboration with the European Space Agency, to test the viability of graphene materials for space applications. In this review, the state-of-the-art of graphene and of its analogues are analysed with a particular focus on space transportation-related applications. Among these applications, the use as additive to improve the performances of propellants is included. For example, graphene-based nanocomposites have demonstrated to play a positive role in improving the combustion properties of solid propellants used in solid rocket propulsion. In addition, conductive porous graphene foams have been proposed to enhance burn rates of solid fuels. As regards the liquid propellants, experiments show that the use of GO significantly decreases the leakage and could provide an effective way for the treatment and reuse of liquid propellant oxidants. Beyond the use as additive in solid or nanofluid-type fuels, graphene has been proposed for solar sails, innovative propulsion systems able to drive flights and orbital manoeuvres of spacecrafts in deep space. In this review the scientific literature and the worldwide patents are analysed for the period 2010-2021. The aim is to identify global trends, the International Patent Classifications (IPC), the country distributions, top assignees and funding sponsors. Patent and literature indicators could contribute in providing a clear evaluation of the related technology trends and readiness levels of graphene and graphene-based materials in the space transportation domain.