IOP Publishing *J. Phys. Mater.* **4** (2021) 042007 https://doi.org/10.1088/2515-7639/ac1247

Journal of Physics: Materials

OPEN ACCESS

RECEIVED
31 December 2020

REVISED
8 June 2021

ACCEPTED FOR PUBLICATION
7 July 2021

PUBLISHED
19 August 2021

TOPICAL REVIEW

Experimental advances in charge and spin transport in chemical vapor deposited graphene

H Mishra[1], J Panda[1], M Ramu[2], T Sarkar[2], J-F Dayen[3,4], Daria Belotcerkovtceva[1] and M Venkata Kamalakar[1,*]

[1] Department of Physics and Astronomy, Uppsala University, Box 516, SE-751 20 Uppsala, Sweden
[2] Department of Materials Science and Engineering, Uppsala University, Box 35, SE-751 03 Uppsala, Sweden
[3] Institut de Physique et Chimie des Matériaux de Strasbourg, Université de Strasbourg, CNRS UMR 7504, 23 rue du Loess, BP 43, Cedex 2, F-67034 Strasbourg, France
[4] Institut Universitaire de France, 1 rue Descartes, 75231 Paris cedex 05, France
[*] Author to whom any correspondence should be addressed.

E-mail: venkata.mutta@physics.uu.se

Keywords: CVD graphene, ballistic transport, spin transport, flexible 2D spintronics, graphene spintronics

Abstract

Despite structural and processing-induced imperfections, wafer-scale chemical vapor deposited (CVD) graphene today is commercially available and has emerged as a versatile form that can be readily transferred to desired substrates for various nanoelectronic and spintronic applications. In particular, over the past decade, significant advancements in CVD graphene synthesis methods and experiments realizing high-quality charge and spin transport have been achieved. These include growth of large-grain graphene, new processing methods, high-quality electrical transport with high-carrier mobility, micron-scale ballistic transport, observations of quantum and fractional quantum Hall effect, as well as the spintronic performance of extremely long spin communication over tens of micrometers at room temperature with robust spin diffusion lengths and spin lifetimes. In this short review, we discuss the progress in recent years in the synthesis of high-quality, large-scale CVD graphene and improvement of the electrical and spin transport performance, particularly towards achieving ballistic and long-distance spin transport that show exceptional promise for next-generation graphene electronic and spintronic applications.

1. Introduction

Since its experimental isolation [1], graphene has emerged as an extraordinary modern material for its superlative electrical and thermal conductivity, mechanical strength, and unique optical properties [2]. Of particular importance for device applications are its high carrier mobility, charge, and spin transport attributes. These properties originate from graphene's unique electronic structure first discussed half a century ago by Wallace [3]. The uniqueness of graphene begins with its structure, a single atomic layer of sp^2 hybridized carbon atoms arranged in a two-dimensional honeycomb lattice that leads to a gapless electronic band structure with conduction and valence bands touching at the Dirac points. In addition, the linear symmetric electronic dispersion at lower energies makes charge carriers in graphene behave like relativistic massless Dirac fermions with Fermi velocity $v_F = 10^6$ m s^{-1} (1/300 times the speed of light) and results in ambipolar functionality [2]. Thus, the charge carriers possess very high mobility, and external electric fields can tune their concentration and polarity. Furthermore, the fact that its hexagonal lattice can be described by two interpenetrating triangular sublattices (A and B) leads to valley degeneracy $g_v = 2$ and an additional degree of freedom called pseudospin and chirality of the massless Dirac fermions. As a consequence of these unique attributes, graphene shows fascinating quantum transport phenomena of anomalous integer quantum Hall effect at relatively low fields [4], fractional quantum Hall effect [5, 6], Klein tunneling with unit transmission probability [7], the existence of minimal conductivity [8], and micrometer ballistic transport lengths [9, 10]. In addition to these properties, from the perspective of spintronics, graphene has two crucial traits: a weak spin–orbit coupling and negligible hyperfine interaction [2], which make graphene