

# Graphene: The Game Changer?

It has only been eight years since the isolation of graphene<sup>1</sup> and over a year since the 2010 Nobel Prize in Physics was jointly awarded to Andre Geim and Konstantin Novoselov “for groundbreaking experiments regarding the two-dimensional material graphene.”<sup>2</sup> Nevertheless, the number of graphene publications is still rapidly growing. The American Physical Society condensed matter physics journals (*Applied Physics Letters*, *Physical Review B*, *Physical Review Letters*) have published the largest number of graphene papers to date, but in recent years, there has been a surge of papers in leading American Chemical Society nanoscience and nanotechnology journals (*ACS Nano*, *Journal of Physical Chemistry C*, *Nano Letters*). This is not surprising since graphene first captured the attention of physicists due to the novel transport properties of its carriers behaving as massless Dirac fermions. In addition, graphene is the thinnest, strongest material known, is highly transparent, and has high electrical and thermal conductivity. Hence, in recent years, chemists, materials scientists, and nanoscientists have been actively looking for applications and ways to enhance graphene's properties through functionalization or by forming hybrids and composites that incorporate graphene.

At *ACS Nano*, we have observed a surge in the number of graphene manuscript submissions. Many of these manuscripts are certainly publishable and would have been reviewed in *ACS Nano* even a year ago; however, we now regularly have to turn away many manuscripts without review as there are related published papers in the literature, and *ACS Nano* aims to publish novel ground-breaking research of broad interest. Many groups all over the world are doing exciting work using graphene and its hybrids in applications such as supercapacitors,<sup>3</sup> fuel cells,<sup>4</sup> batteries,<sup>5</sup> photocatalysis,<sup>6</sup> photovoltaics,<sup>7</sup> chemical and biosensors,<sup>8</sup> photonics,<sup>9</sup> and optoelectronics.<sup>10</sup>



Photo Courtesy of NUS Graphene Center

Singapore's Deputy Prime Minister Mr. Teo Chee Hean accompanied by Nobel laureate Konstantin Novoselov in the new National University of Singapore (NUS) Graphene Research Center cleanroom.

As is the case in the fields of carbon nanotubes and other nanomaterials, there is an ease of entry into graphene research for groups with modest research budgets. The United States leads in total number of graphene publications to date, followed by China, Japan, Germany, South Korea, England, and France (Table 1). Singapore, a small country of 5 million people, is next on the list and is the highest in terms of graphene publications *per capita*. In institutional rankings, the Chinese Academy of Science (a multi-institutional organization) tops the list (Table 2). Interestingly, the two major universities in Singapore, the National University of Singapore (NUS) and Nanyang Technological University (NTU), are second and third, respectively. Graphene has captured the attention of researchers in Singapore, as reflected by the opening of the Graphene Research Center at NUS on 12 June 2012. The Director of the

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**TABLE 1. Country Rankings in Graphene Publications to Date (source: Thomson Reuters ISI Web of Science; search dated 15 June 2012 using "Topic=graphene"; 19,017 records)**

rank	country	record count
1	USA	5483
2	People's Republic of China	4580
3	Japan	1729
4	Germany	1323
5	South Korea	1220
6	United Kingdom	873
7	France	843
8	Singapore	734
9	Spain	712
10	Russia	611

**TABLE 2. Institution Rankings in Graphene Publications to Date (source: Thomson Reuters ISI Web of Science; search dated 15 June 2012 using "Topic=graphene"; 19,017 records)**

rank	country	record count
1	Chinese Academy of Sciences	1036
2	National University of Singapore	378
3	Nanyang Technological University	369
4	Tsinghua University	320
5	Consejo Superior de Investigaciones Científicas (Spain)	315
6	Russian Academy of Sciences	303
7	MIT	278
8	University of California, Berkeley	268
9	Peking University	255
10	University of Texas at Austin	253

Center is the leading graphene theorist Antonio Castro Neto, and Nobel laureates Kostya Novoselov and Andre Geim act as scientific advisors. Many Asian countries such as South Korea, Singapore, and China are investing heavily in graphene research and its applications and look to lead graphene research in the years ahead.

*Disclosure:* Views expressed in this editorial are those of the author and not necessarily the views of the American Chemical Society.



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