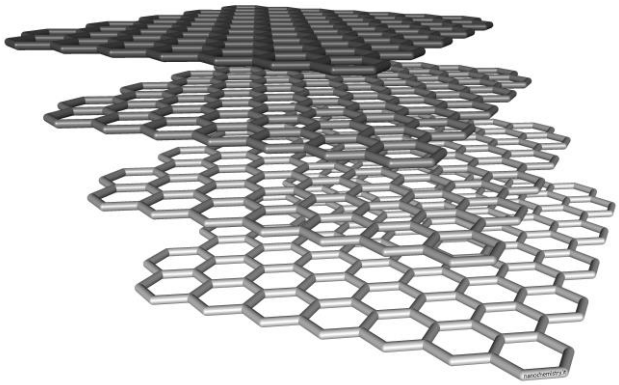

BULK GRAPHENE PRICING REPORT

by Fullerex

2019

CONTENTS

EXECUTIVE SUMMARY

This report aims to provide sufficiently in-depth and relevant insight and data that bulk graphene producers can utilise to confidently price their materials both in relation to their competition and by examining commercial requirements to penetrate relevant market sectors. Additionally, the contents of this report will empower end-users with greater visibility into the market for bulk graphene, thereby strengthening negotiations with suppliers and increasing market confidence.

Current Environment

The graphene market is fast growing and has significant commercial potential. Some successful applications have already emerged, with products reaching the market in automotive, consumer electronics, and sporting goods. However, the market as a whole is remains diffuse and fragmented. Material standards are still in an early stage of development. A very large number of other applications have been identified and proposed for the different material grades but as yet many are not fully proven.

There is no single type of graphene, but instead a large family consisting of 'graphenes' or graphene-based materials. There is a very wide variance from producer to producer regarding the materials sold and the specifications reported across different product datasheets. Standards defining the terminology for describing this broad class of materials were published in 2017 by ISO but have not yet been widely adopted by graphene producers. Further standards for material characterisation are anticipated. Meanwhile, characterisation good practices to follow were released by the NPL and NGI.

There have been many different material grades tested and evaluated in the research literature for the numerous proposed application areas, each with ranging levels of success. Assessment for material quality in industry is currently made on a similar basis, relative to efficacy in application, rather than collectively agreed, industry-wide standards. Without a robust quality assessment framework, establishing a fair value for different products cannot be done quickly and easily at present. Therefore, making any objective comparison of product quality or suitability between the graphene materials of various different producers requires investigation as provided by this report.

There are over 150 companies producing and selling graphene in one form or another. Graphene suppliers are primarily differentiated by their production method, which determines their cost, capacity, and quality of production. As graphene producers look to penetrate markets that currently use more traditional materials, many are choosing to demonstrate the advantages of the new technology to potential customers by creating value-added graphene products, supplied to customers in ready-to-use intermediate formats such as dispersions or concentrates. Having a "drop-in" system such as an intermediate also substantially lowers the barrier to entry for industrial trials given the relative reluctance end users have for processing the raw material directly. There has been a steadily downward pressure on graphene pricing, with early stage commercial levels of demand and an overcapacity situation, particularly driven by the increasing competition in production within export-oriented trading nations such as China and India. Preserving pricing and protecting margin in the face of reducing prices is another reason for the continuing trend towards producers offering intermediate, downstream products.

Methodology

There is limited commercial trade data available for comprehensive market based pricing. Therefore, in order to bridge this information gap we examine competition based pricing and demand based pricing in this report.

Competition based pricing is determined by collecting and updating list prices for many commercial graphene products, including price breaks for various purchase volumes. These prices are aggregated by grouping graphene products into appropriate classifications. The lower limit prices for each product category are obtained and trends across product type and purchase size can be extracted and analysed.

Demand based pricing is established by identifying the price threshold for a given application, that being the cost that an end-user (buyer) is willing to accept. With such a wide range of applications for graphene this opens up myriad price targets for a producer to achieve in order to successfully enter each of these markets. This theme has been

developed somewhat extensively in these pages to illustrate the market value for graphene from the end-user perspective.

Information gathered in this report was collected using a variety of means, including meetings and conference calls with key decision makers at hundreds of companies over a period of several years, both producer firms and industrial end-users. Additionally, useful data and insights were captured by networking with relevant market influencers at numerous industry events and conferences each year and dedicated research and information sourcing across a wide range of international academic and industry research papers. Data has also been contributed from annual surveys of graphene producers, application developers and end-users conducted by The Graphene Council.

Limitations of the Report

Establishing accurate pricing for a particular graphene product is a challenging task due to the nascent nature of the market. As mentioned above, there is limited trade data to achieve accurate price discovery. The most easily obtained pricing information from graphene suppliers is typically R&D quantity pricing, with many producers either cautious or simply unable to provide pricing details on commercial-scale orders. This has often resulted in misleading pricing estimates from the business press and from other contemporary sources of market information. The data set behind our competition based pricing calculations importantly contains considerable commercial pricing information, which although we do not claim to be exhaustive, we believe to be reliable. In a similar vein, obtaining accurate material consumption data is also a challenge. Many producers freely state production capacity figures however these are nameplate capacity figures and not actual sales volumes. Figures determined for sales volumes are therefore based on internal calculations as well as aggregating data from various sources.

Findings and Recommendations

Graphene pricing across most grades has continued to decrease. Products which consist of very few layers and typically exhibit high yields of single layer material, such as reduced graphene oxide, remain the most expensive product type. Prices for very few layered material has not significantly changed in the last couple of years. Prices for all other product groups have come down.

There are yet more graphene startups entering the market, with more companies engaged in production, applications development and research than ever before.

In this report we look at several target markets for graphene which include industrial materials with a range of prices spanning some three orders of magnitude. Initially graphene producers have focused on high-value/low-volume applications to maximise margins, but suppliers are also looking to enter high-volume/low-value markets to continue revenue growth. This transition into larger volume sales goes hand in hand with production scale up and marginal costs coming down, which has been steadily witnessed in the market. As the market matures and more producers are able to meet the price and performance requirements for a particular application, that market segment will eventually become saturated. Wherever graphene producers are able to generate a strong IP position around applications technology to successfully address an unmet need in industry whilst keeping out other entrants, they may enter a high-volume/high-value scenario.

Producers need to achieve several key targets in order to successfully commercialise graphene which have been highlighted in this report. Crucially, by understanding the market and determining their true competitors, along with relevant industrial applications for their materials, producers can position themselves strongly with appropriate pricing that can help unlock these opportunities.