

Graphene Global Outlook: Roadmap for applications and opportunities

Anthony Schiavo
Analyst

Prepared for:
Graphene Malaysia

About Lux Research

Unmatched
Intelligence
on Emerging Technology

200+ External Conferences Annually

Advanced Analytics & Member Tools

Coverage in 15+ Industries

5,000+ Webinar Registrants Annually

1,000+ Event Attendees Annually

6,000+ Press Quotes Annually

4,000+ Client Inquiries Annually

100+ Consulting Engagements Annually

2,800+ Deliverables Published Annually

10,000+ Start-up Profiles

5 Global Offices

300+ Clients

22 Coverage Areas

20+ Government Clients

Clients in 75 Countries



luxresearch

TECHNICAL EXPERTISE • BUSINESS ANALYSIS • PRIMARY DATA

INDEPENDENT • BOLD • OPINIONATED

Agenda

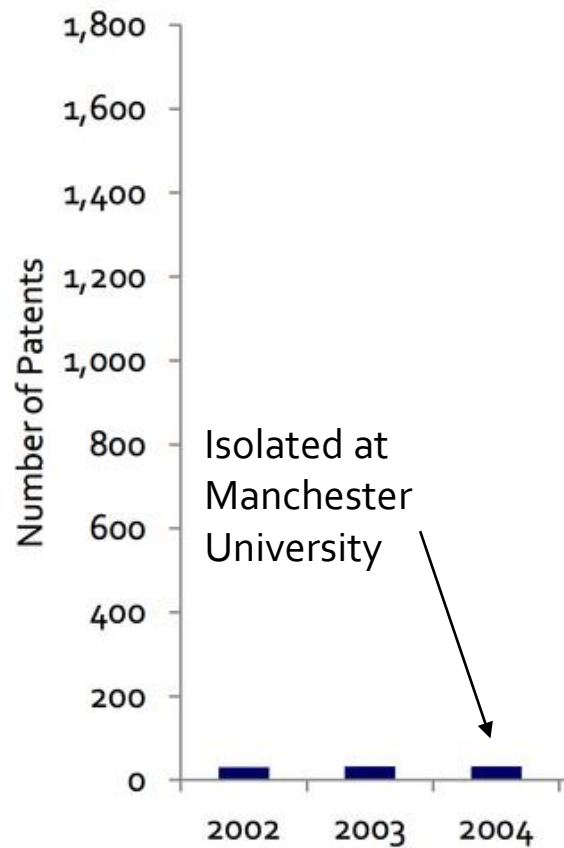
- › Graphene landscape 2016
- › Roadmap for graphene adoption
- › Key innovators in graphene

Agenda

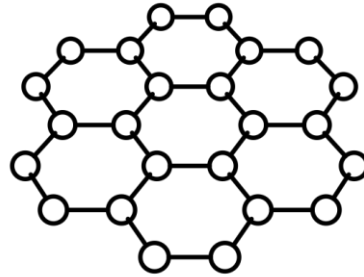
- **Graphene landscape 2016**
- Roadmap for graphene adoption
- Key innovators in graphene

Graphene interest boomed with the 2010 Nobel Prize

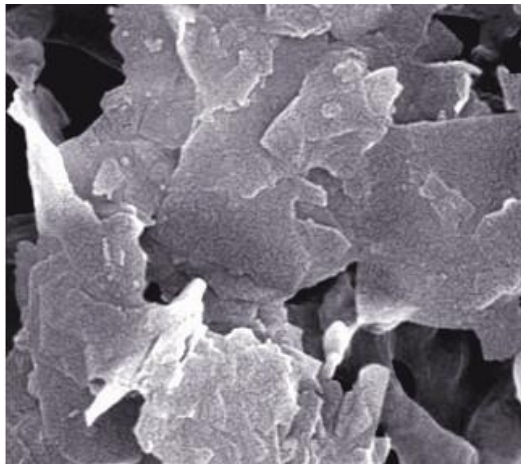
Graphene Patenting activity, 2002 to 2012



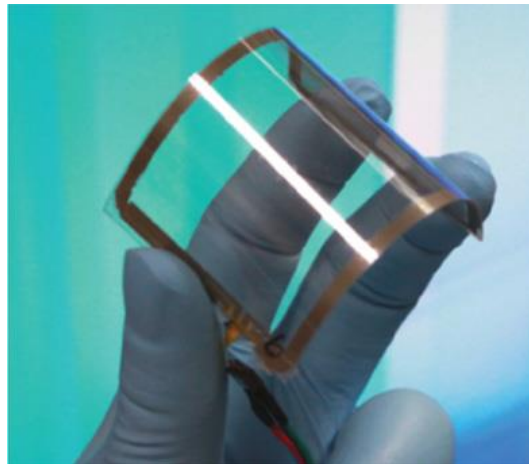
GNPs and graphene films dominate start-up efforts, while GO has emerged as a trendy material



Graphene Nanoplatelets (GNPs)



Graphene Films



Graphene Oxide (GO)



Start-ups like XG Sciences sought to capitalize on the hype...



"We ship products daily to customers in North and South America, Asia and Europe, and are a leading supplier of graphene nanoplatelets and integrated products" – XG CEO, 2015

... but commercialization has been rough going



- 2015 sales: \$164,153
- 2015 losses: \$5,635,517
- Headcount cut by nearly 50%

“XG Science has redefined its value proposition to focus on showing value in customer applications with the intent of being the industry standard for providing product and customer service on a per-application basis.” XG CEO, 2016

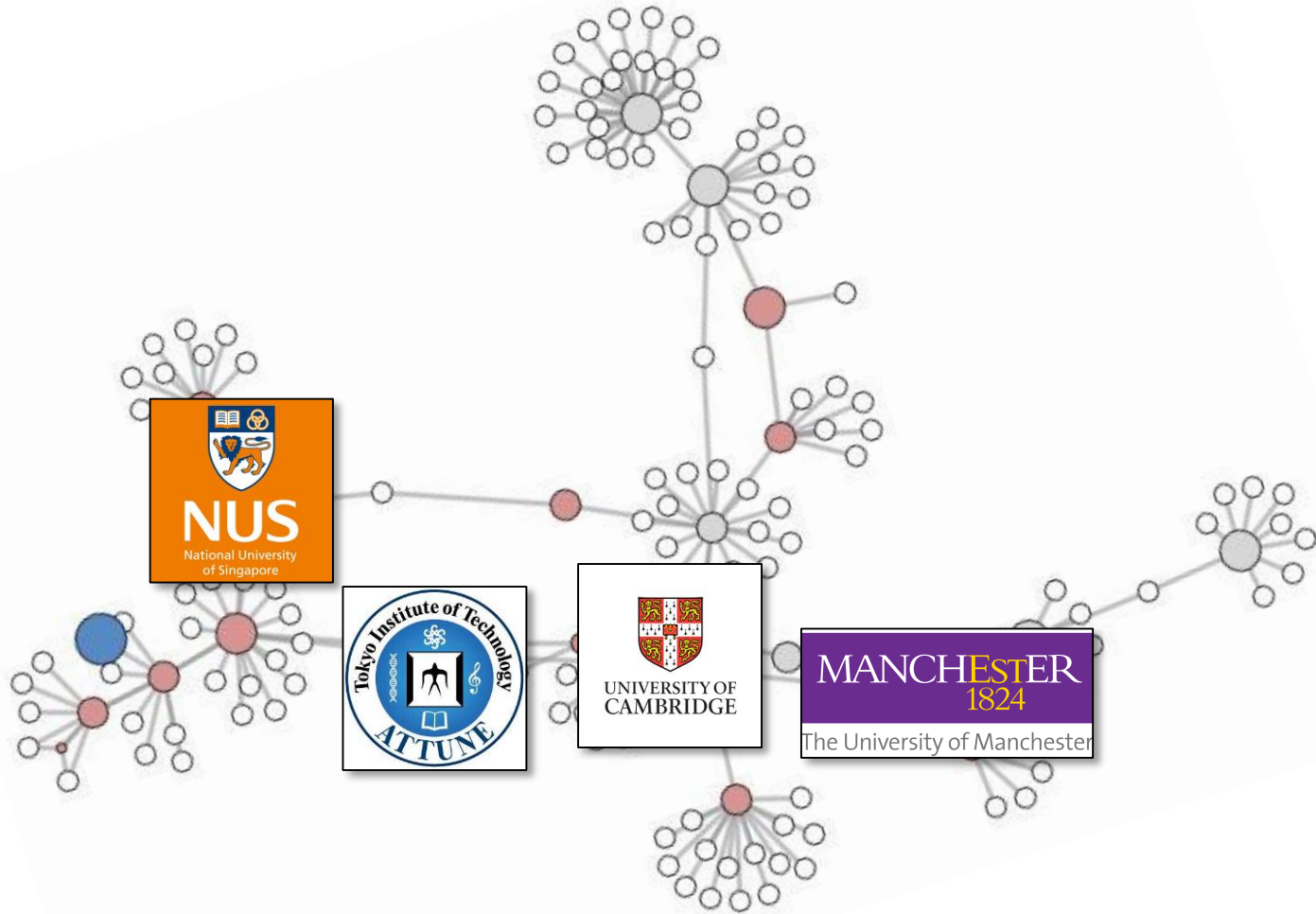
Graphene start-ups have strengthened academic relationships in response

MANCHESTER
1824

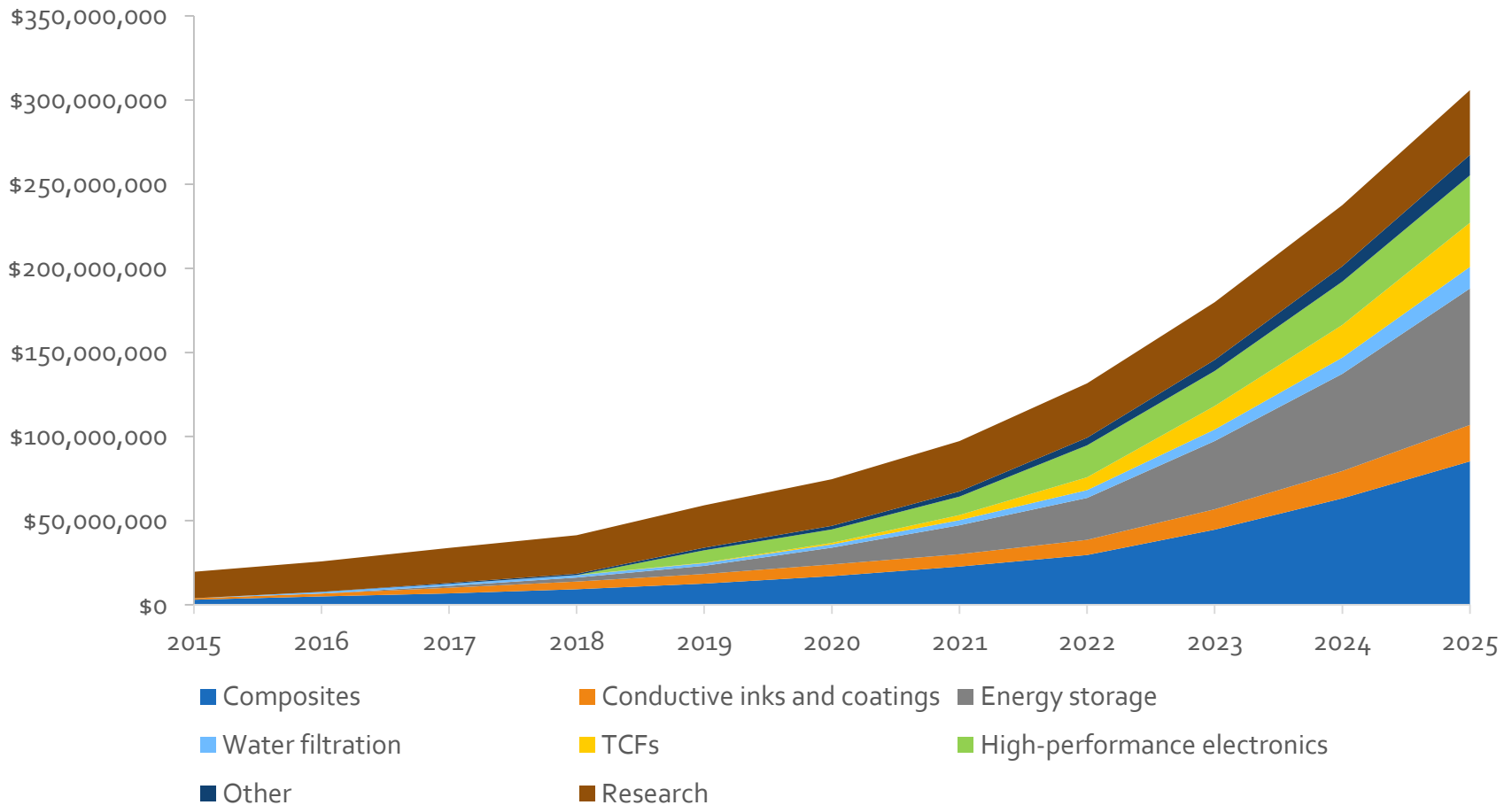
The University of Manchester



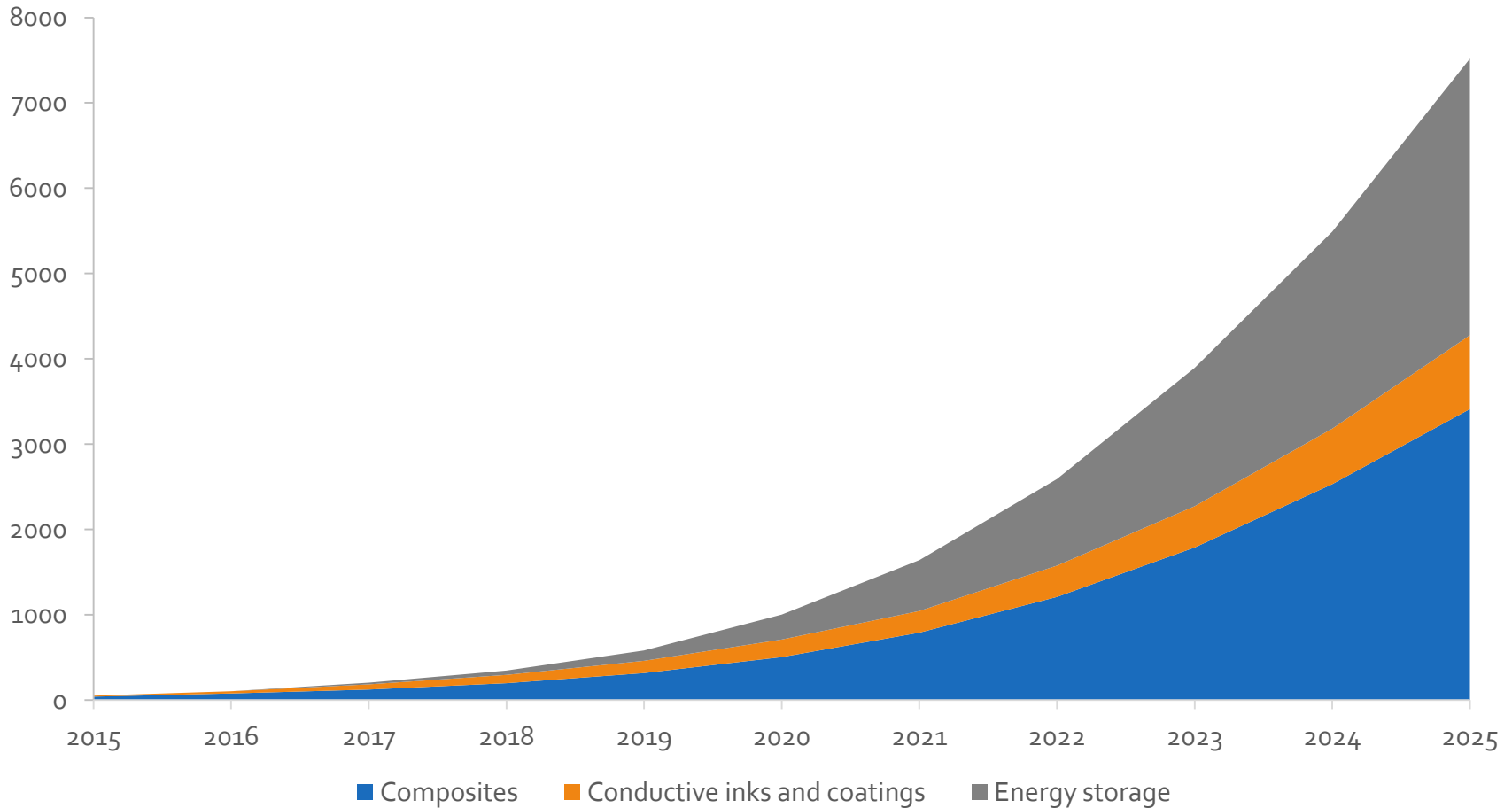
Universities form the key links in growing graphene partnership space



Total graphene market will grow to \$305 million by 2025



Graphene nanoplatelet demand to grow to 7,500 MT by 2025



Agenda

- › Graphene landscape 2016
- › **Roadmap for graphene adoption**
- › Key innovators in graphene

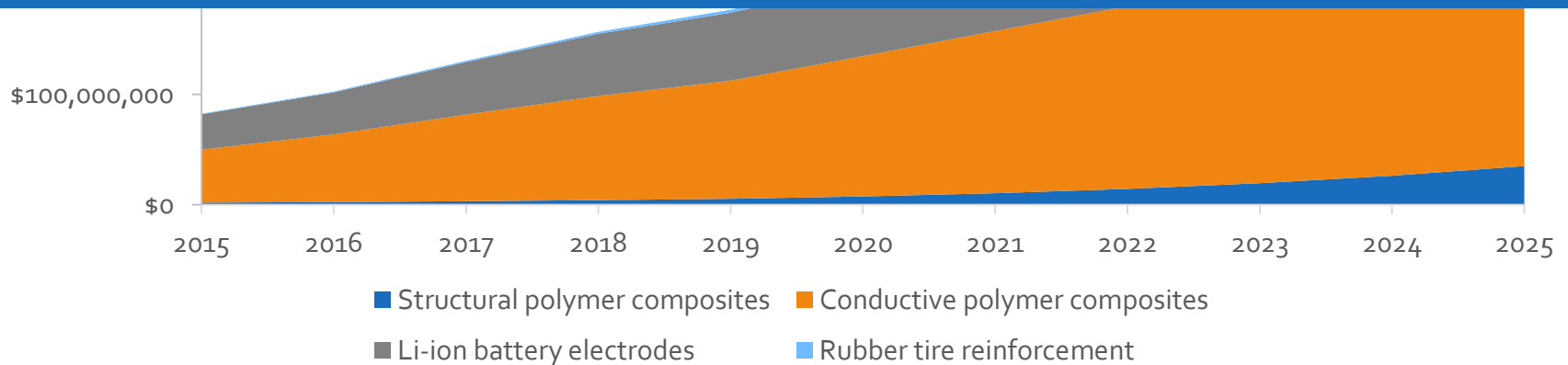
Product integration was the core challenge for CNTs

- Beyond pricing, **product integration challenges were a major impediment to adoption**
 - **Most formulators/compounders keep their composition a trade secret**
 - **After straight raw material business models failed, developers moved towards downstream integration**
 - **Developers had to invest considerable time and money into defining and justifying individual use cases**

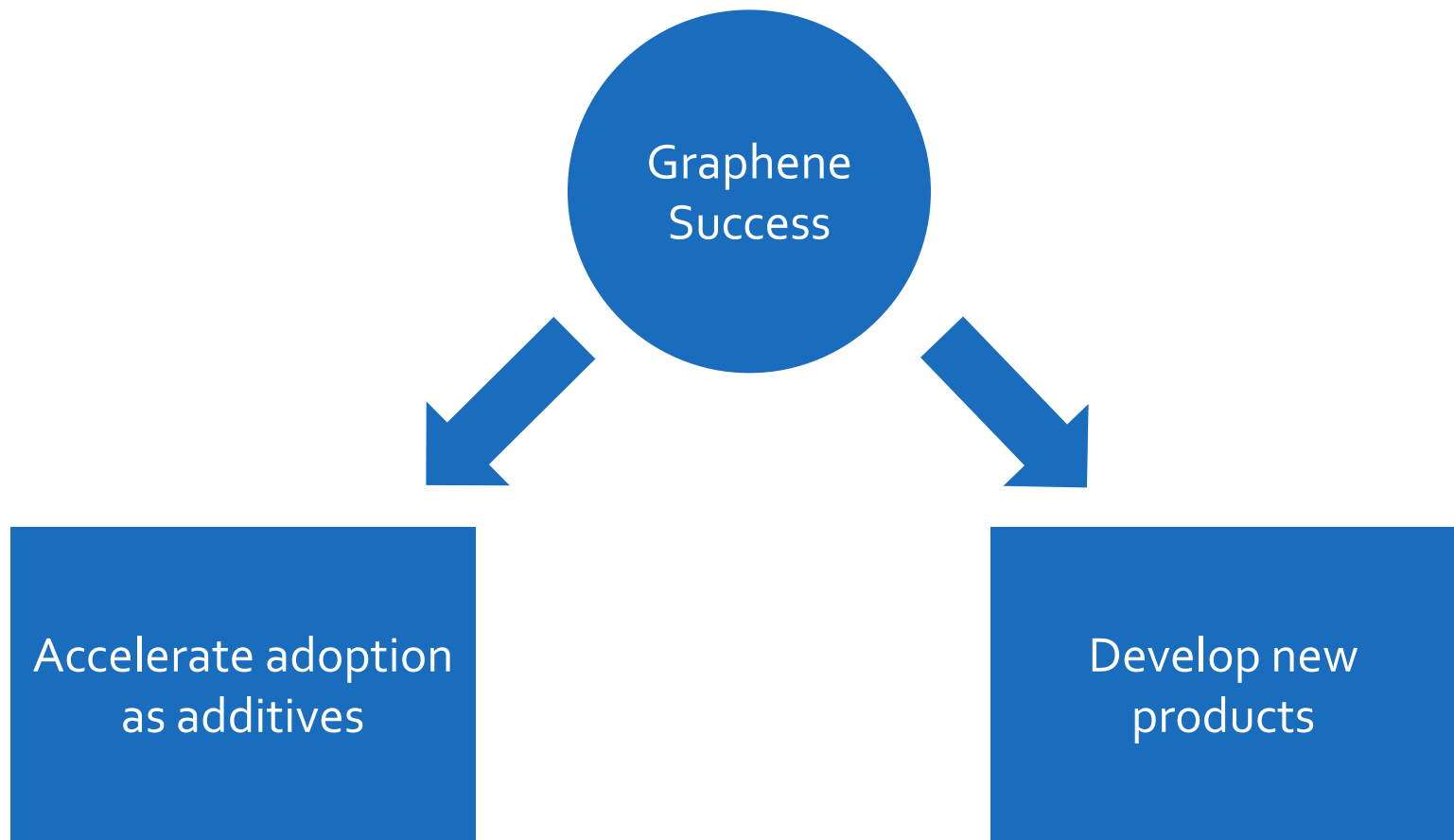
MWNT market will grow to \$560 million by 2025



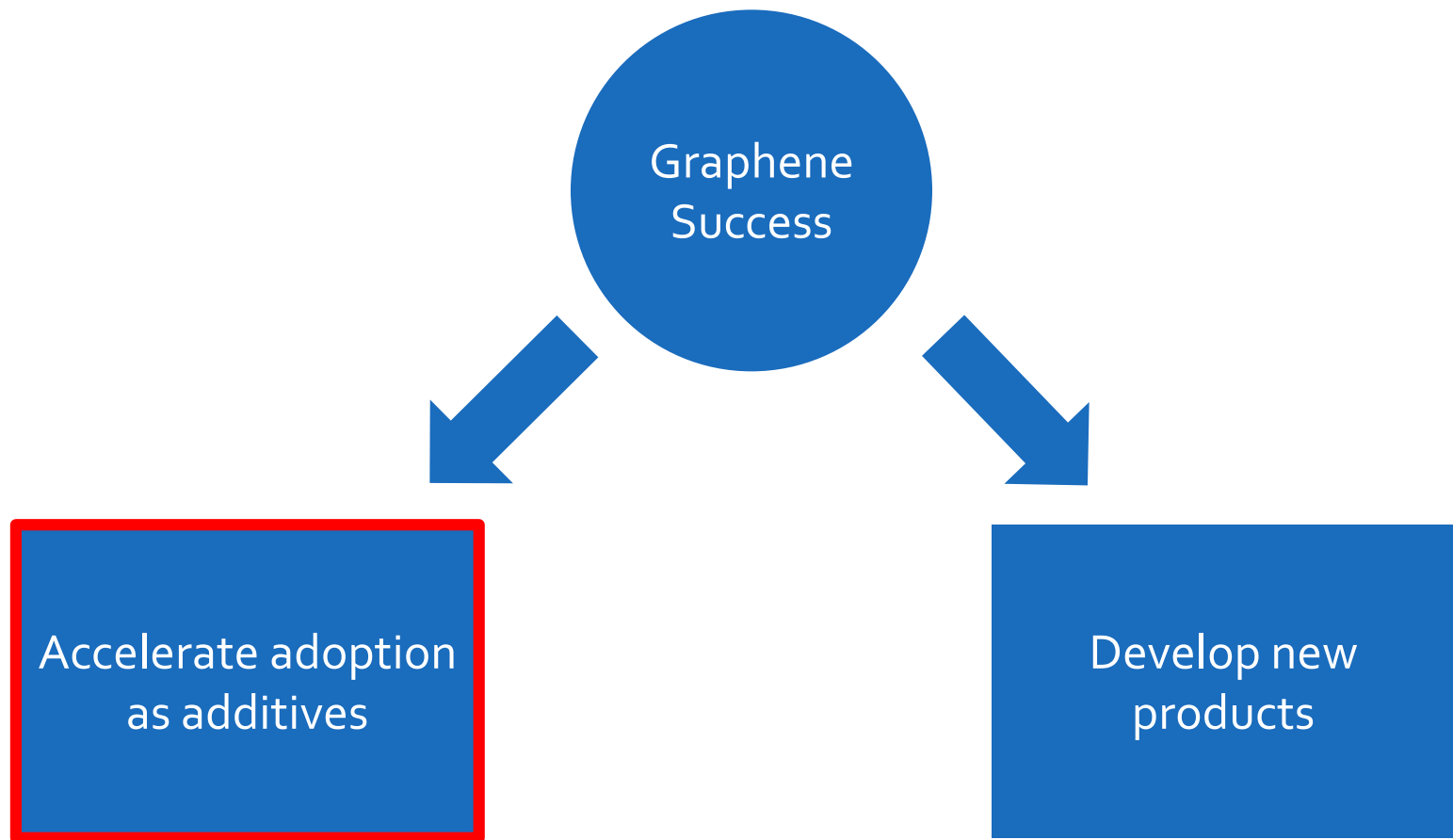
CNTs will only be adopted as additives in understood applications



Graphene success depends on emulating CNTs while simultaneously exploring new routes



Graphene success depends on emulating CNTs while simultaneously exploring new routes



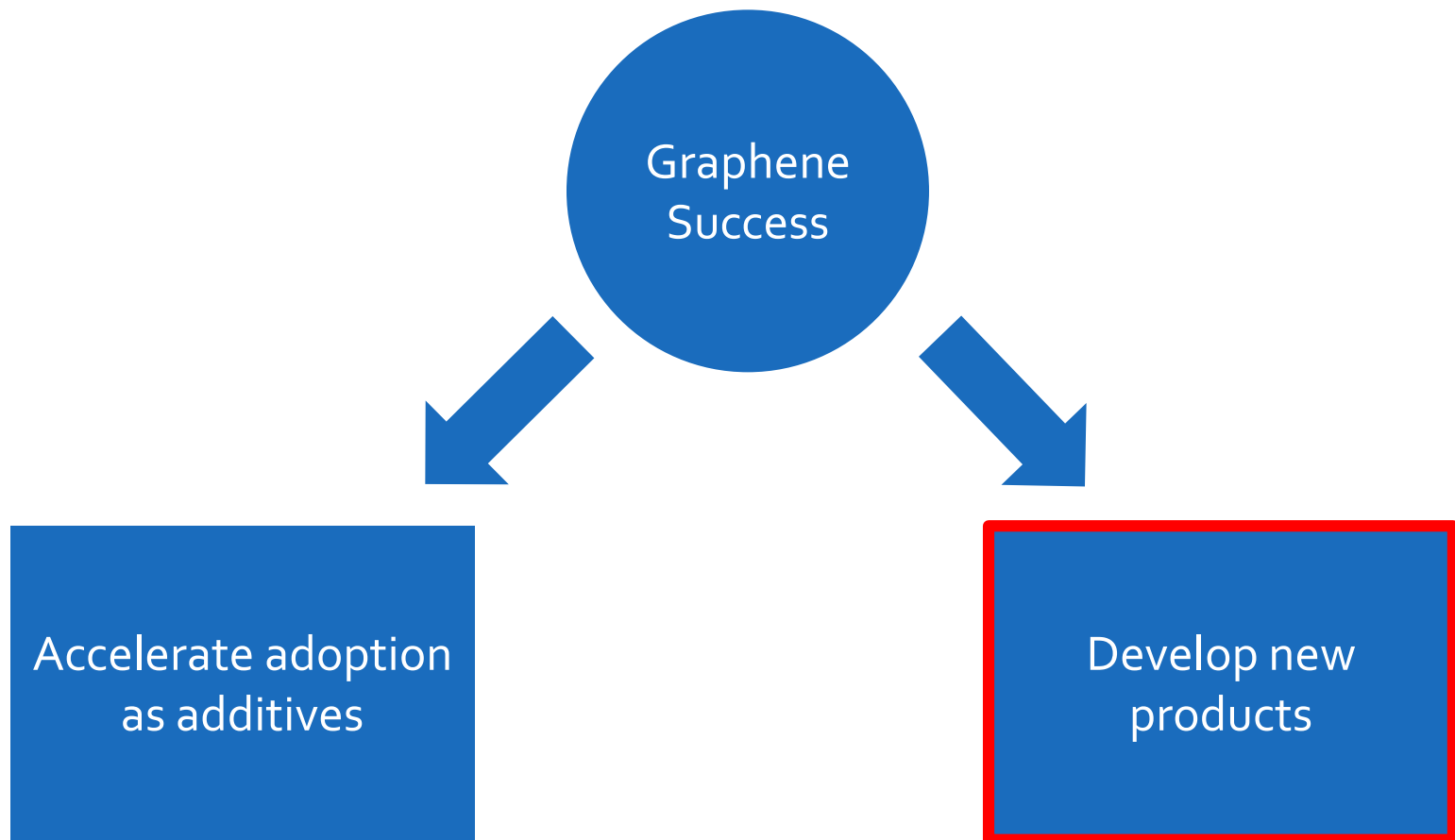
Case study: Nanocyl

- Nanocyl is the leading provider of CNTs for established applications
- **Quality over scale**
- **Fortitude and persistence**
- **Understanding regional differences**



Key Stats	
Headquarters:	Belgium
Business Model:	Provides Services; Sells Product
Employees:	44
Cash:	<i>\$1.1 Million</i>
Revenue:	<i>\$5 Million</i>

Graphene success depends on emulating CNTs while simultaneously exploring new routes



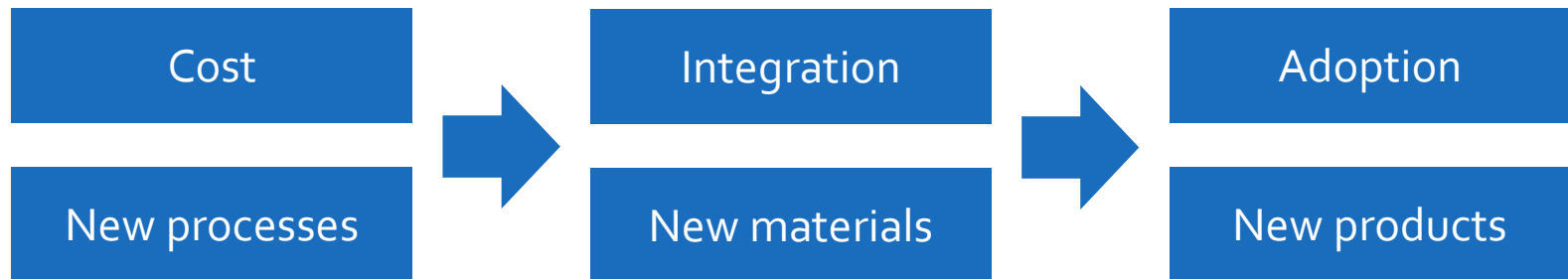
Case study: AzTrong

- › AzTrong produces electrically conductive and insulating and thermally conductive sheets made of GO and GNPs
- › Target established applications
- › Combine new materials and new form factors
- › Close collaboration with end users



Key Stats	
Headquarters:	United States
Business Model:	Licenses Technology; Sells Product
Employees:	15
Cash:	<i>\$1.13 Million</i>
Revenue:	<i>\$350,000</i>

Challenges create opportunities for graphene innovation



Agenda

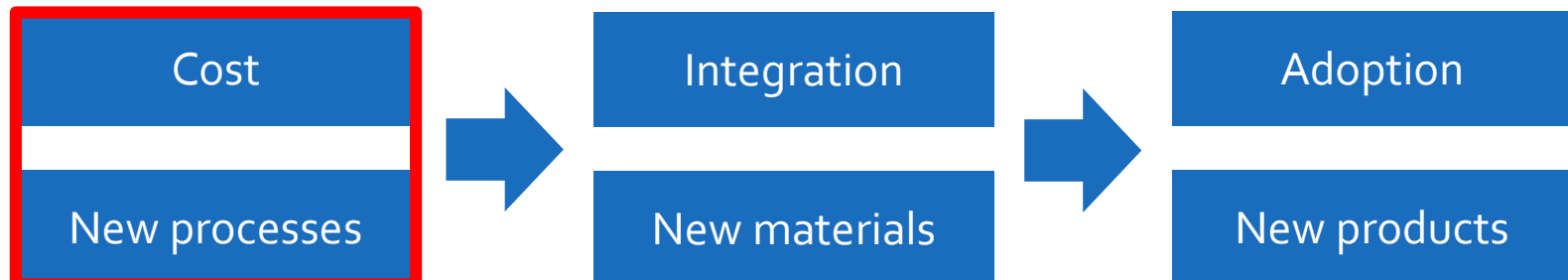
- Graphene landscape 2016
- Roadmap for graphene adoption
- **Key innovators in graphene**

Cambridge Nanosystems makes long term play with palm byproducts to graphene tech

- Produces graphene nanoplatelets (GNPs) by plasma cracking of natural gas without the need of any catalyst or additive
- Claims a high percentage of its GNPs are single-layer graphene with 99.6% purity and lower cost than competitors
- Acquired by FGV and jointly developing a technique to convert by-products of palm oil plantations to graphene

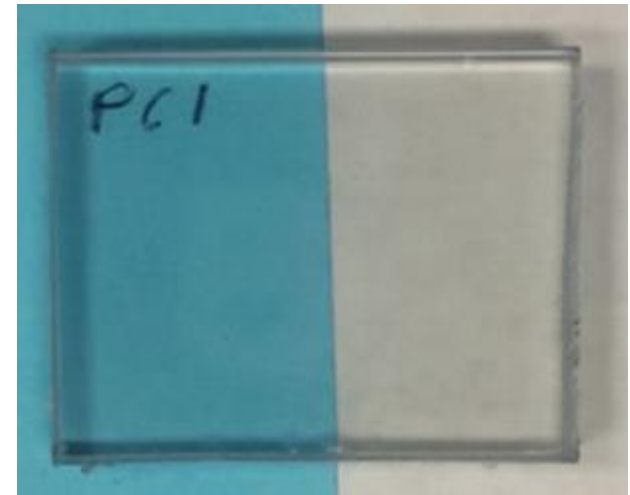


FGV



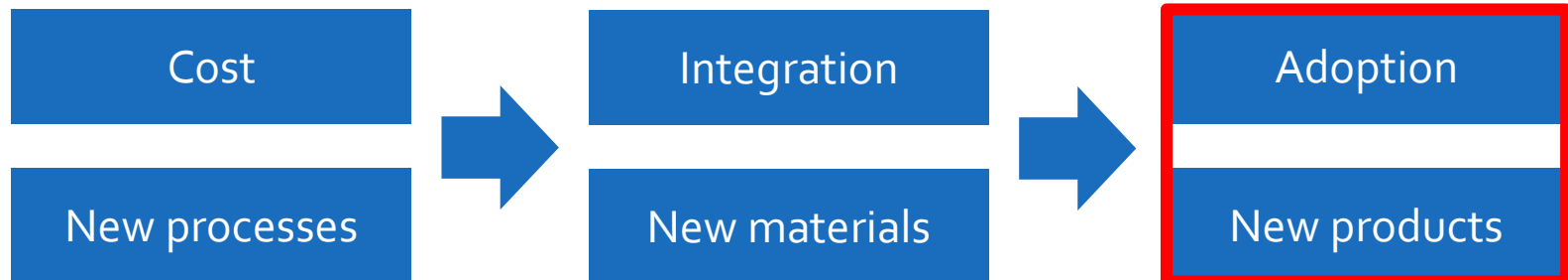
Garmor's novel GO material enhances dispersion while maintaining properties

- Employs a milling process to produce graphene oxide (GO) nanoplatelets from graphite using a mild oxidant; GO is oxidized on the edges and retains conductivity
- Has made strides in cost reduction and new application development in the past year
- Dispersion properties make Garmor's GO compelling



Imagine IM hits big with product innovation

- Manufactures bulk graphene nanoplatelets (GNPs) from graphite for use in geosynthetic textiles
- Graphene-enabled geosynthetic textiles have increased conductivity at a lower production and installation cost
- First customer is Geosynthetic Australasia, a textile manufacturer in Australia



Outlook: Graphene at the crossroads

- › Graphene commercialization efforts have struggled up to this point
- › Major innovations are continuing to occur globally in response to key challenges
- › Graphene can overtake its carbon cousin if it can accelerate adoption as additives while developing new products

Questions?

