From: McCauley, Brendan

Sent: 8/18/2014 8:13:57 PM

To: TTAB EFiling

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Subject: U.S. TRADEMARK APPLICATION NO. 79129484 - GRAPHENE TUBE - 130376 - Request for Reconsideration Denied - Return to TTAB - Message 1 of 6

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Attachment Information:

Count: 12

Files: AH Science- Nanotube.jpg, AH Science- Title.jpg, AH Science- Verso.jpg, Credo- American Heritage- Carbon Nanotube.jpg, Credo- American Heritage- Nanotube.jpg, Credo- Penguin Dict of Sci- Nanotechnology & Nanotubes.jpg, Encyclopedia Britannica- Carbon nanotubes, graphene and tubes1.jpg, Encyclopedia Britannica- Carbon nanotubes, graphene and tubes2.jpg, Encyclopedia Britannica- Graphene1.jpg, Encyclopedia Britannica- Graphene2.jpg, Encyclopedia Britannica- nanotechnology1.jpg, 79129484.doc

UNITED STATES PATENT AND TRADEMARK OFFICE (USPTO)
OFFICE ACTION (OFFICIAL LETTER) ABOUT APPLICANT'S TRADEMARK APPLICATION

U.S. APPLICATION SERIAL NO. 79129484 **MARK:** GRAPHENE TUBE	
CORRESPONDENT ADDRESS: DARREN CREW KRATZ QUINTOS & HANSON LLP 1420 K STREET NW 4TH FLOOR WASHINGTON, DC 20005	**GENERAL TRADEMARK INFORMATION:** http://www.uspto.gov/trademarks/index.jsp
APPLICANT: INCUBATION ALLIANCE, INC.	
CORRESPONDENT'S REFERENCE/DOCKET NO: 130376 **CORRESPONDENT E-MAIL ADDRESS:**	

REQUEST FOR RECONSIDERATION DENIED

ISSUE/MAILING DATE:

INTERNATIONAL REGISTRATION NO. 1158571

The trademark examining attorney has carefully reviewed applicant's request for reconsideration. The amended identification of goods set forth in the request for reconsideration is accepted and the requirement related thereto set forth in the final Office action dated January 29, 2014 is withdrawn. However, the trademark examining attorney has carefully reviewed applicant's request for reconsideration in relation to the final Section 2(e)(1) refusal and is denying the request related to the Section 2(e)(1) refusal for the reasons stated below. *See* 37 C.F.R. §2.64(b); TMEP §§715.03(a)(2)(B), (a)(2)(E), 715.04(a). Thus, the Section 2(e)(1) refusal made final in the Office action dated January 29, 2014 is maintained and continue to be final. *See* TMEP §§715.03(a)(2)(B), (a)(2)(E), 715.04(a).

In the present case, applicant's request related to the Section 2(e)(1) refusal has not resolved all the outstanding issue(s), nor does it raise a new issue or provide any new or compelling evidence with regard to the outstanding issue(s) in the final Office action. In addition, applicant's analysis and arguments related thereto are not persuasive nor do they shed new light on the issues. Accordingly, the request related to the Section 2(e)(1) refusal is denied.

The filing of a request for reconsideration does not extend the time for filing a proper response to a final Office action or an appeal with the Trademark Trial and Appeal Board (Board), which runs from the date the final Office action was issued/mailed. *See* 37 C.F.R. §2.64(b); TMEP §715.03, (a)(2)(B), (a)(2)(E), (c).

If time remains in the six-month response period to the final Office action, applicant has the remainder of the response period to comply with and/or overcome any outstanding final requirement(s) and/or refusal(s) and/or to file an appeal with the Board. TMEP §715.03(a)(2)(B), (c). However, if applicant has already filed a timely notice of appeal with the Board, the Board will be notified to resume the appeal. *See* TMEP §715.04(a). Applicant filed an appeal on July 28, 2014.

SECTION 2(E)(1) REFUSAL - MERELY DESCRIPTIVE

The trademark examining attorney has carefully reviewed applicant's request for reconsideration in relation to the final Section 2(e)(1) refusal and is denying the request related to the Section 2(e)(1) refusal for the reasons stated below. *See* 37 C.F.R. §2.64(b); TMEP §§715.03(a)(2)(B), (a)(2)(E), 715.04(a). Therefore, the Section 2(e)(1) refusal made final in the Office action dated January 29, 2014 is maintained and continue to be final. *See* TMEP §§715.03(a)(2)(B), (a)(2)(E), 715.04(a).

Registration is refused because the applied-for mark merely describes a feature or characteristic of applicant's goods and/or services. Trademark Act Section 2(e)(1), 15 U.S.C. §1052(e)(1); *see* TMEP §§1209.01(b), 1209.03 *et seq.*

A mark is merely descriptive if it describes an ingredient, quality, characteristic, function, feature, purpose, or use of an applicant's goods and/or services. TMEP §1209.01(b); *see, e.g.*, *DuoProSS Meditech Corp. v. Inviro Med. Devices, Ltd.*, 695 F.3d 1247, 1251, 103 USPQ2d 1753, 1755 (Fed. Cir. 2012) (quoting *In re Oppedahl & Larson LLP*, 373 F.3d 1171, 1173, 71 USPQ2d 1370, 1371 (Fed. Cir. 2004)); *In re Steelbuilding.com*, 415 F.3d 1293, 1297, 75 USPQ2d 1420, 1421 (Fed. Cir. 2005) (citing *Estate of P.D. Beckwith, Inc. v. Comm'r of Patents*, 252 U.S. 538, 543 (1920)).

The determination of whether a mark is merely descriptive is made in relation to an applicant's goods and/or services, not in the abstract. *DuoProSS Meditech Corp. v. Inviro Med. Devices, Ltd.*, 695 F.3d 1247, 1254, 103 USPQ2d 1753, 1757 (Fed. Cir. 2012); *In re The Chamber of Commerce of the U.S.*, 675 F.3d 1297, 1300, 102 USPQ2d 1217, 1219 (Fed. Cir. 2012); TMEP §1209.01(b); *see, e.g.*, *In re Polo Int'l Inc.*, 51 USPQ2d 1061, 1062-63 (TTAB 1999) (finding DOC in DOC-CONTROL would refer to the "documents" managed by applicant's software rather than the term "doctor" shown in a dictionary definition); *In re Digital Research Inc.*, 4 USPQ2d 1242, 1243-44 (TTAB 1987) (finding CONCURRENT PC-DOS and CONCURRENT DOS merely descriptive of "computer programs recorded on disk" where the relevant trade used the denomination "concurrent" as a descriptor of a particular type of operating system).

"Whether consumers could guess what the product [or service] is from consideration of the mark alone is not the test." *In re Am. Greetings Corp.*, 226 USPQ 365, 366 (TTAB 1985).

Applicant's mark is GRAPHENE TUBE for goods set forth in the application as carbon nanotubes and currently described as carbon nanotubes having a cross section of a flat circle and not a cylindrical shape, namely, carbon with thin walls and a large external diameter, in powder or particulate material form, or in a dispersion.

Applicant's goods are clearly set forth in the identification as being carbon. Graphene is carbon, namely, an allotrope of carbon. The term is also defined as: 1.(organic chemistry) Any polycyclic aromatic hydrocarbon having the structure of part of a layer of graphite. 2. (inorganic chemistry) An arbitrarily large-scale, one-atom-thick layer of graphite, an allotrope of carbon, that has remarkable electric characteristics. See attached information from http://en.wikipedia.org/wiki/Graphene and http://en.wiktionary.org/wiki/graphene provided in the Office action dated June 20, 2013 and incorporated into this Office action by reference.

In addition, as previously noted, the term graphene is defined as a fullerene consisting of bonded carbon atoms in sheet form one atom thick. See attached definition from http://www.oxforddictionaries.com/us/definition/american_english/graphene provided in the final Office action dated January 29, 2014 and incorporated into this Office action by reference. Graphene is also referenced as a highly conductive allotrope of carbon whose atoms are arranged in a mesh-like form a single atom thick on the web page WhatIs.Com, namely, http://whatis.techtarget.com/definition/graphene. See attached web page provided in the final Office action dated January 29, 2014 and incorporated into this Office action by reference.

The attached web pages from *Britannica Academic Edition* reference the nature of graphene in connection with nanotubes which may be represented as scrolls of graphene. In the attached pages from *Nanotechnology for Dummies*, graphene is defined as molecules composed of carbon atoms in a pattern of hexagons that seen in buckyballs, arranged in a planar sheet one atom thick.

Thus, in relation to the goods, the term GRAPHENE in the mark describes a characteristic or feature of the goods which are made of carbon in the nature of graphene. Moreover, as noted in applicant's response dated December 16, 2013, applicant has indicated that the goods do or will contain graphene. Thus, in relation to the goods the term graphene in the mark clearly describes a feature or characteristic of the goods being made with graphene. The examining attorney notes that there seems to be no disagreement that the term graphene in the applied-for mark is descriptive in relation to the goods.

On the contrary, applicant argues that the term tube in the mark is not descriptive of applicant's goods. However, the term tube in the mark also describes a feature or characteristic of applicant's goods. The term tube is defined as any of various usually cylindrical structures or devices. See attached definition from *Merriam-Webster* provided in the Office action dated June 20, 2013 and incorporated into this Office action by reference.

Applicant's goods as set forth in the identification of record are carbon nanotubes. According to the attached definition from *The American Heritage Science Dictionary*, a nanotube is defined as a hollow cylindrical or toroidal molecule made of one element, usually carbon. The attached CREDO web pages define a carbon nanotube as the most common form of nanotube, composed entirely of carbon atoms or cylindrical fullerenes, with numerous applications in nanotechnology. The nanotube is noted in these web pages as a hollow cylindrical or toroidal tube measuring nanometers in diameter, composed of atoms of a singly element, typically carbon. The CREDO web pages related to nanotechnology indicate that the carbon nanotube can be imagined as constructed by splitting a buckyball into two and then adding a cylindrical section to join the two hemispheres together.

In addition, the attached web pages from *How Stuff Works* on the subject of nanotechnology indicate that a carbon nanotube is a nano-size cylinder of carbon atoms. The attached nanocyl web page indicates that a carbon nanotube is a tube-shaped material, made of carbon, having a diameter measuring on a nonometer scale. The attached web pages from Nanotechnology Now notes that: Strictly speaking, any tube with nanoscale dimensions, but generally used to refer to carbon nanotubes, which are sheets of graphite rolled up to make a tube.

The attached *Nanotechnology for Dummies* web pages define carbon nanotubes as molecules composed of carbon atoms arranged on the surface of a cylindrical shape in a pattern of hexagons as seen in buckyballs. The attached pages from VAN NOSTRAND'S SCIENTIFIC ENCYCLOPEDIA indicate that a nanotube is cylindrical and the name is derived from their size since the diameter of a nanotube is on the order of a few nanometers while they can be up to several centimeters in length. Lastly, but not least, the attached webopedia web pages defines carbon nanotube technology or carbon nanotubes as tubes of carbon atoms less than a nonometer (one billionth of a meter) in diameter.

The attached web pages from *Britannica Academic Edition* covering carbon nanotubes note:

> In 1991 Iijima Sumio of NEC Corporation’s Fundamental Research Laboratory, Tsukuba Science City, Japan, investigated material extracted from solids that grew on the tips of carbon electrodes after being discharged under C60 formation conditions. Iijima found that the solids consisted of tiny tubes made up of numerous concentric “graphene” cylinders, each cylinder wall consisting of a sheet of carbon atoms arranged in hexagonal rings. The cylinders usually had closed-off ends and ranged from 2 to 10 micrometres (millionths of a metre) in length and 5 to 40 nanometres (billionths of a metre) in diameter.

The attached web pages from *Britannica Academic Edition* relating to nanotechnology note that carbon atoms can be bonded together in a tube geometry. The web pages also indicate that 1991 carbon nanotubes that were discovered were carbon ringlike structures extended from spheres into long tubes of varying diameter. Moreover, the article notes that carbon nanotubes have remarkable properties and that depending on their specific diameter and bonding arrangement of their carbon atoms, nanotubes exhibit either metallic or semiconducting behavior.

In light of the various definitions of carbon nanotubes and the information noted above regarding nanotubes and nontechnology, a nanotube is cylindrical or tube shape. The nanotube has a diameter by definition which will always make it tube in shape or form per se. Applicant's identification of goods indicates that the cross section of the goods are a flat circle which would be consistent with a cross section of a tube. Thus, consistent with the many definitions of nanotube which clearly define it as either cylindrical or a tube, the term tube in the mark describes a feature or characteristic of applicant's goods related to the shape of the goods regardless of applicant's description of the cross section portion of the goods as a flat circle and not a cylindrical shape. As noted in the description, applicant's goods have thin walls a large external diameter creating the tube or cylindrical shape which by definition is the nature of a carbon nanotube.

For the foregoing reasons, in connection with applicant's goods, the wording tube in the mark indicates the exact nature of the goods as carbon nanotubes made with graphene which have a cylindrical or tube shape.

In support of the descriptive nature of the wording in the mark as used in the nanotube industry to indicate a type of nanotube, the examining attorney notes the following:

1. The attached web pages from ACS PUBLICATIONS regarding an article entitled "Large-Diameter Graphene Nanotubes Synthesized Using Ni Nanowire Templates".
2. The attached web pages related to the Cornell University Library for the article entitled *Electrical conductivity of collapsed multilayer graphene tubes*.
3. The attached web pages for a search in ProQuest Dialog with the associated web pages showing 43 abstracts for articles related to graphene tubes.
4. The attached web pages from SprinerLink related to a discussion of Carbon Nanofiber-Based Nanocomposites for Biosensing that discusses that multiwalled carbon nanotubes are composed of coaxial, multilayer graphene tubes with an interlayer space of 0.34 nm.
5. The attached web pages from *Nanotechnology Now* with an article related to Zyvex Technologies joining OCSiAl to create World's Largest Nanotechnology Company and which references OCSiAl as being known for developing the world's largest low cost an scalable production of graphene tubes under the brand name TUBALL®.
6. The attached web pages from *Nanotechnology Now* with another attached article referencing Graphene tubes as the future of manufacturing.
7. The attached web pages from Pubmed.gov related to the abstract for the article Graphene/graphene-tube nanocomposites template from cage-containing metal-organic frameworks for oxygen reduction in Li-O2 batteries.
8. Attached below a full length article related to a global sampling campaign handled by OCSiAl right after the first presentation of a unique technology for graphene tubes synthesis brought significant results.
9. Attached below a full length article indicating Ocsial was founded in 2009 as the first low-cost mass producer of graphene tubes.

As previously discussed in the January 29, 2014 final Office action, applicant's materials and evidence of record do not support the term tube in the mark is suggestive.

Furthermore, applicant's arguments as set forth in applicant's request for reconsideration on July 29, 2014 are equally unpersuasive on the issue of whether the term tube in the mark is suggestive of applicant's goods. Even with the amended identification of record which describe the nature of applicant's goods, applicant's goods are still set forth as nanotubes which by definition are tubal or cylindrical in nature despite applicant's description thereof such that the term tube is descriptive in relation to the goods. This is clearly supported by the multiple definitions of nanotube of record.

In addition, the materials provided by applicant with the December 16, 2013 response to Office action do not clearly contradict the tube like nature of applicant's goods as the materials show the circular or oval nature or string or hair like nature of the goods which is consistent with a tube like shape. As noted by applicant, in "Document 2" entitled <u>Graphene TubeTM Introduction</u>, applicant describes the nature of the goods as a string-like shape which is also tubular and cylindrical in form. Applicant's emphasis on the cross section of the goods which applicant claims is to be similar to that of a bicycle inner tube seemingly support the tube shape of the good as such an analogy references tubes too. Furthermore, applicant's arguments that this shape is flattened to have a shape as shown in the top center drawing related thereto, and then is flattened even more with the result being the applicant's goods as shown in the top right drawing referenced is a thin strip with a string-like shape does not obviate that the ultimate shape for the goods as being tubular in shape because even a string-like shape is cylindrical or tubal in form consistent with a definition of a nanotube.

Applicant's explanations provided in the request for reconsideration regarding the apparent inconsistency related to the use of the phrases "thin strip and tube shape" and "tubular form" in Documents 3 and 4 entitled <u>Graphene TubeTM</u> provided in the response to Office action on December 16, 2013 are unpersuasive. According to the applicant, the information and wording used relates to the original technology developed by the applicant and not to explain all the intricate details of the goods associated with applicant's applied-for trademark. Even if such information is found not to reference the goods per se, the applicant's goods are defined as nanotubes such that by definition the goods have a cylindrical or tube shape which would make the use of the term tube in the mark descriptive.

Furthermore, the use of the entire wording in the mark as set forth by the evidence above seemingly describes a type, class or genre of nanotube such that the wording in applicant's mark is descriptive in the relevant nanotube industry. With respect to number 9 above, applicant notes in the July 28, 2014 request for reconsideration that Oscial uses the wording graphene tubes to reference SWCNTs which are not applicant's goods. While these might not be the exact type of nanotube as applicant's per se, the goods in general would still be composed of graphene and consistent with the definition of nanotube have a tube or cylindrical shape such that competitors would need the wording in applicant's mark to also describe the nature of such goods. Thus, applicant's attempt to distinguish the goods is unpersuasive.

Thus, upon reflection, investigation, and lengthy discussions with applicant's counsel, the examining attorney is unpersuaded that the mark is suggestive. In light of applicant's identification of goods inclusive of the word nanotubes, the definition of the term nanotube, the evidence related to the use of the wording graphene tube in the nanotube industry, the examining attorney concludes that the term tube in the mark is not suggestive in connection with applicant's goods which are a nanotube which is defined as cylindrical or tube in shape. As applicant has admitted for the record the goods are made with graphene. Therefore, the entire wording in the mark describes the nature of applicant's goods.

/Brendan McCauley/

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Time of Request: Tuesday, August 05, 2014 09:35:05 EST

Client ID/Project Name:

Number of Lines: 851

Job Number: 1826:474831259

Research Information

Service: Terms and Connectors Search

Print Request: All Documents 1-22

Source: All English Language News

Search Terms: Ocsial

1 of 22 DOCUMENTS

PR Newswire

July 14, 2014 Monday 12:07 PM EST

LENGTH: 538 words

HEADLINE: OCSiAl opens dealership program for the cheapest single wall carbon nanotubes in the world;

World's largest manufacturer of single wall carbon nanotubes introduces dealership program for TUBALL worldwide.

DATELINE: PALO ALTO, Calif., July 14, 2014

BODY:

Global sampling campaign handled by OCSiAl right after the first presentation of a unique technology for graphene tubes synthesis brought significant results. "We have been receiving numerous requests for partnership lately," - says Grigory Gurevich, first vice-president. "OCSiAl, - nanomaterial producers and sellers from worldwide ask for possibility to stock TUBALL for further distribution. We have thoroughly considered all the requests and came to strategic decision to open the dealership prospective for those who are genuinely interested in developing business with TUBALL. Growing demand for TUBALL and TUBALL-based masterbatches urged the company to offer dealership as an effective option to satisfy the needs of world's market".

By now OCSiAl has formed general conditions of the dealership program; details are not disclosed and subject to negotiate with potential partners. Basic requirements for future dealers set the purchase volumes of TUBALL for the year of 2014 and 2015. To join the program the initial purchase of 10 kg will be enough. "Conditions are both reasonably strict and flexible," - continues Grigory Gurevich. - "On the one hand, we do require substantial commitments in terms of size of ...

...encourage our partners with technical and marketing support, including sampling actions".

The first strategic dealership agreement with Shanghai Evermore Additives Corp (EVERMORE Group) was achieved a week ago during the exhibition NANOKOREA 2014. Along with TUBALL Evermore is going to sell different masterbatches including those for composites, made on the base of Zyvex Technologies' products. "We have great expectations for further prosperity of our business in cooperation with **OCSiAl**", - says Managing Director Wu Lu-Hao. "We hope not only to attract new clients via highly sought TUBALL product, but to advance existing partnerships through offering new opportunities for development of our client's products".

According to analytical forecasts, the global nanomaterial market will increase by 6 times in the next 3-4 years. Given the unique technology and versatility of applications TUBALL will speed up market growth by introducing class new products. **OCSiAl** itself will also contribute to dealers' success - the company is actively investing in development and is planning to expand production facilities during the upcoming year. In the nearest future together with SWCNT **OCSiAl** will also offer to its dealers universal TUBALL-based additives to enhance different materials including polymer composites, rubber products, conductive inks and others, facilitating wide adoption of SWCNT by many industries.

http://www.**ocsial**.com

SOURCE **OCSiAl**

Max Atanassov, max@**ocsial.**com; or Ksenia Kulgaeva, kulgaeva.km@**ocsial.**com, +1 415 906 5271

PUB-COMPANY:

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Time of Request: Tuesday, August 05, 2014 09:35:05 EST

Client ID/Project Name:

Number of Lines: 851

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Research Information

Service: Terms and Connectors Search

Print Request: All Documents 1-22

Source: All English Language News

Search Terms: Ocsial

108B8C

Time of Request: Friday, August 15, 2014 13:40:48 EST

Client ID/Project Name:

Number of Lines: 45

Job Number: 1827:476276143

Research Information

Service: Terms and Connectors Search

Print Request: Current Document: 1

Source: US Newspapers

Search Terms: graphene tube

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1 of 1 DOCUMENT

Columbus Business First (Ohio)

June 16, 2014 Monday

LENGTH: 361 words

HEADLINE: Nanotechnology firm Zyvex acquired by Luxembourg's Ocsial

BYLINE: Carrie Ghose

BODY:

Columbus' Zyvex Technologies has been acquired by Luxembourg-based Ocsial, which says the combination forms the world's largest nanotechnology company.

Zyvex will stay on the SciTech campus and expand in Columbus, said a statement from Mike Nemeth, vice president of business development, in response to questions from Columbus Business First.

"Zyvex will be expanding operations in the future as we scale to target new markets and industries with an improved product line," he wrote. "We see this as an opportunity to grow."

Financial terms of the merger were not disclosed. Zyvex keeps its brands and products, using carbon nanotubes in advanced coatings for aerospace, sporting goods and other industries. The companies planned an online news conference Monday afternoon.

Ocsial was founded in 2009 as the first low-cost mass producer of **graphene tubes** - pure carbon engineered to be the thickness of a single atom.

The companies said combining mass production with Zyvex's research and product development should lead to higher quality and more durable consumer goods, longer-lasting batteries and lighter materials for construction and vehicles.

"With support from Ocsial, Zyvex will be in an even better position to bring the potential of nanotechnology into powerful commercial reality," said a statement from Zyvex President Lance Criscuolo.

Zyvex Performance Materials Inc. was spun out from Texas-based Zyvex Corp. and moved to Columbus in 2007; it adopted the trade name Zyvex Technologies in 2010.

Zyvex received $5.7 million in Ohio Third Frontier grants for relocation and product commercialization, according to the 2013 annual report of the state Development Services Agency. It employed 19 workers at the end of 2012, the most recent figure available.

The combined company has 160 employees.

Ocsial's name is the combined symbols for the elements oxygen, carbon, silicon and aluminum. Its U.S. headquarters is in Palo Alto, California, with operations in England, Germany, Russia and South Korea.

LOAD-DATE: June 16, 2014

108B8C

********** Print Completed **********

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as well as changes in the quantum states of particles, for new engineering purposes. The development of nanotechnology holds out great promise of improvements in the quality of life, including new treatments for disease and greater efficiency in computer data storage and processing. For example, tiny autonomous robots, or nanobots, may one day be sent into human bodies to repair cells and cure cancers, perhaps even extending the human life span by many years. The simple devices created by nanotechnology so far have not yet approached the complexity of the envisioned nanomachines and nanobots. Some scientists even see a dark side to the technology, emphasizing the need for caution in its development, particularly in attempts to create nanobots that can replicate themselves like living organisms.

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nanotube (năn′ə-to͞ob′) A hollow cylindrical or toroidal molecule made of one element, usually carbon. Nanotubes are being investigated as semiconductors and for uses in nanotechnology. See also **fullerene.**

nanotube

computer graphic of a nanotube

Nansen bottle (năn′sən, nän′-) An ocean-water sampling bottle with spring-loaded valves at both ends that are closed at an appropriate depth by a messenger device sent down the wire connecting the bottle to the surface. The Nansen bottle has been replaced by the **Niskin bottle**, which is made of plastic and thus does not corrode like Nansen's metal bottle. These plastic bottles, however, are frequently referred to as Nansen bottles because their basic design is the same. The Nansen bottle was named for its inventor, Norwegian explorer Fridtjof Nansen (1861–1930).

napalm (nā′päm′) A firm jelly made by mixing gasoline with aluminum salts (made of fatty acids). It is used in some bombs and in flamethrowers. Napalm was developed during World War II.

naphtha (năf′thə) Any of several liquid mixtures of hydrocarbons made by refining petroleum or by breaking down coal tar. Naphtha is usually flammable, and is used as a solvent and as an ingredient in gasoline. It is also used to make plastics.

naphthalene (năf′thə-lēn′) A white crystalline compound made from coal tar or petroleum and used to make dyes, mothballs, explosives, and solvents. Naphthalene consists of two benzene rings fused together. *Chemical formula:* $C_{10}H_8$.

naphthene (năf′thēn′, năp′-) See **cycloalkane.**

naphthol (năf′thôl′, -thōl′, năp′-) A poisonous organic compound occurring in two isomeric forms. Both isomers are important in the manufacture of dyes, and also in making antiseptics, insecticides, and tanning agents. Naphthol consists of a hydroxyl group (OH) attached to naphthalene. *Chemical formula:* $C_{10}H_8O$.

Napierian logarithm (nə-pîr′ē-ən, nā-) See **natural logarithm.**

narcotic (när-kŏt′ĭk) Any of a group of highly addictive analgesic drugs derived from opium or opiumlike compounds. Narcotics can cause drowsiness and significant alterations of mood and behavior.

nasal (nā′zəl) Relating to or involving the nose.

Nathans (nā′thənz), **Daniel** 1928–1999. American microbiologist who pioneered the use of *restriction enzymes*—enzymes that break DNA molecules down into manageable fragments—to create the first genetic map on which the location of specific genes on the DNA could be identified. For this work, which revolutionized genetic engineering, Nathans shared the 1978 Nobel Prize for physiology or medicine with Werner Arber and Hamilton Smith.

native (nā′tĭv) **1.** Living or growing naturally in a particular place or region; indigenous. **2.** Occurring in nature on its own, uncombined with other substances. Copper and gold are often found in native form. **3.** Of or relating to the naturally occurring conformation of a macromolecule, such as a protein.

natural gas (năch′ər-əl) A mixture of hydrocarbon gases that occurs naturally beneath the

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dic·tion·ar·y

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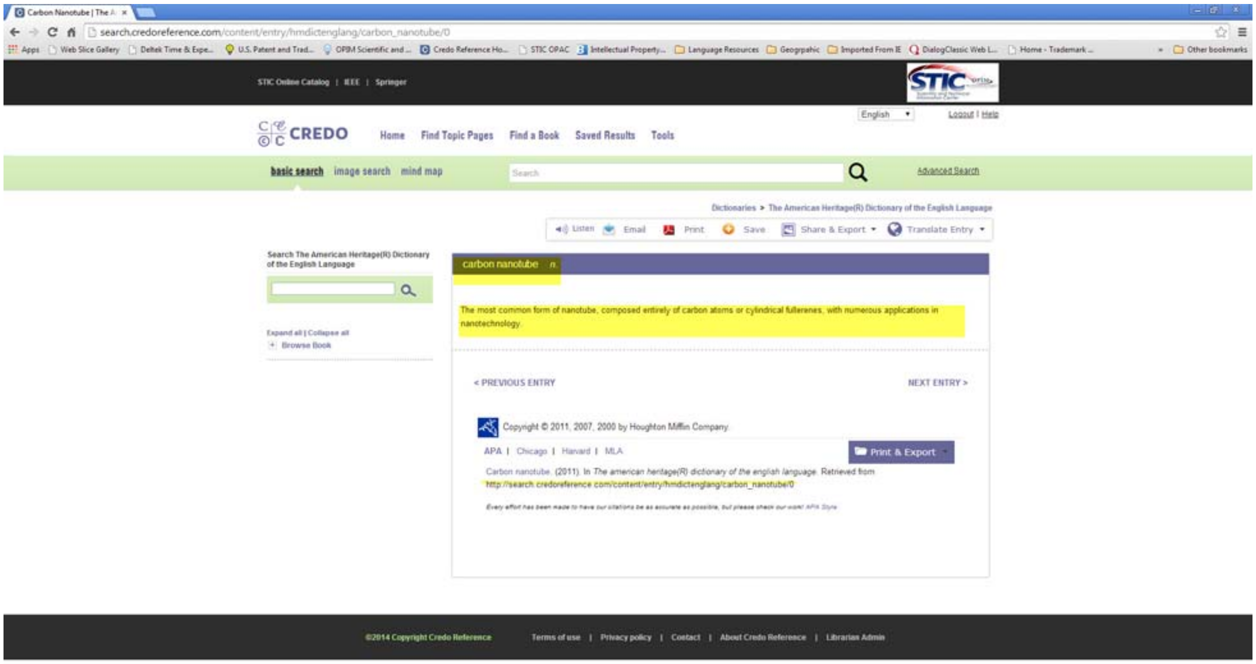

carbon nanotube *n.*

The most common form of nanotube, composed entirely of carbon atoms or cylindrical fullerenes, with numerous applications in nanotechnology.

Carbon nanotube. (2011). In *The american heritage(R) dictionary of the english language*. Retrieved from http://search.credoreference.com/content/entry/hmdictenglang/carbon_nanotube/0

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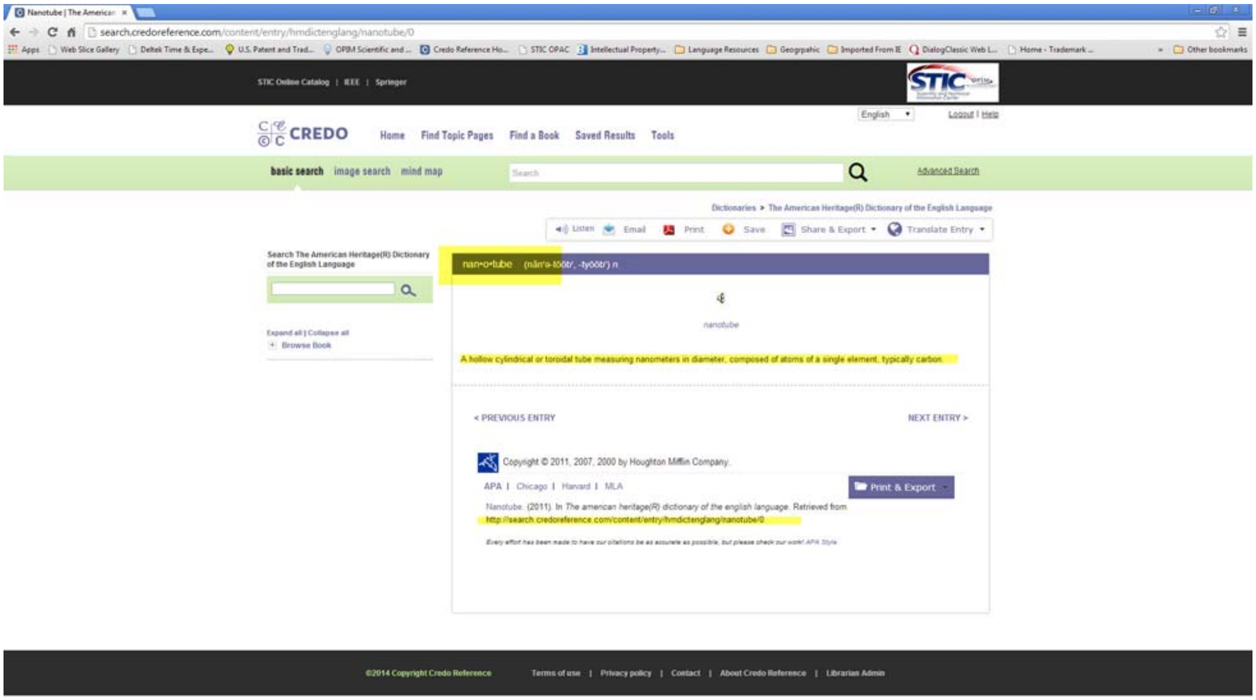

nan•o•tube (năn′ə-to͞ot′, -tyo͞ot′) *n*

nanotube

A hollow cylindrical or toroidal tube measuring nanometers in diameter, composed of atoms of a single element, typically carbon.

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Nanotube. (2011). In *The american heritage(R) dictionary of the english language*. Retrieved from http://search.credoreference.com/content/entry/hmdictenglang/nanotube/0

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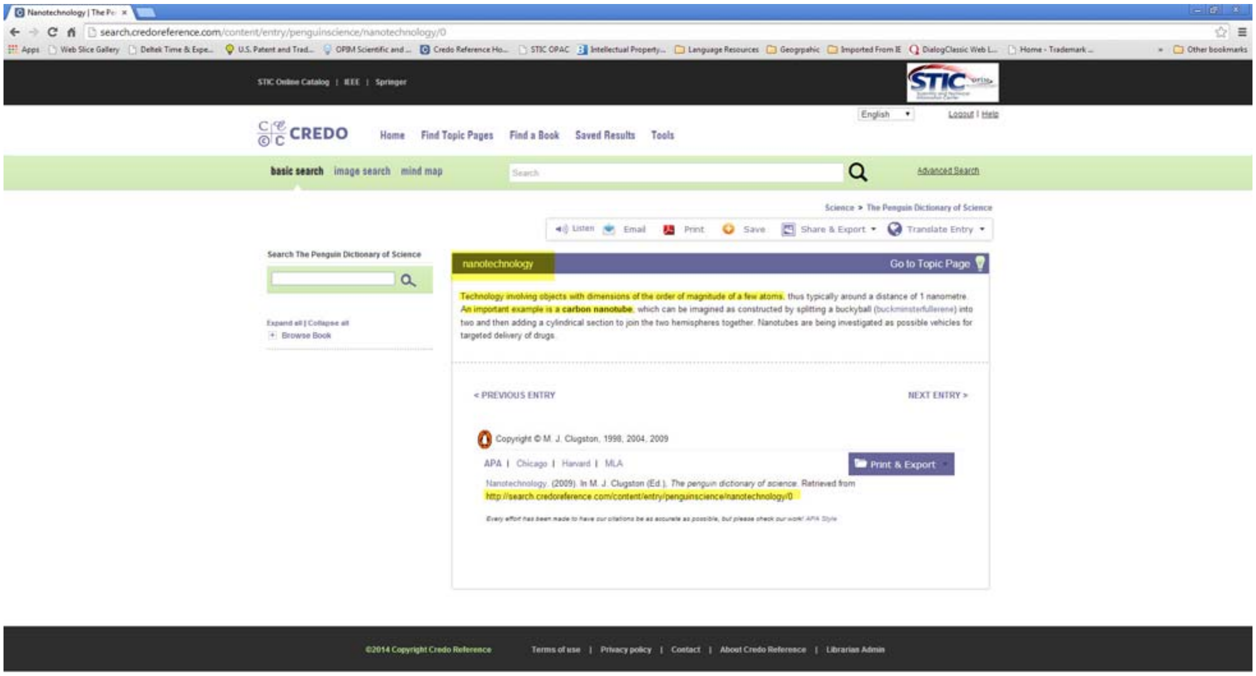

nanotechnology

Technology involving objects with dimensions of the order of magnitude of a few atoms, thus typically around a distance of 1 nanometre. An important example is a **carbon nanotube**, which can be imagined as constructed by splitting a buckyball (buckminsterfullerene) into two and then adding a cylindrical section to join the two hemispheres together. Nanotubes are being investigated as possible vehicles for targeted delivery of drugs.

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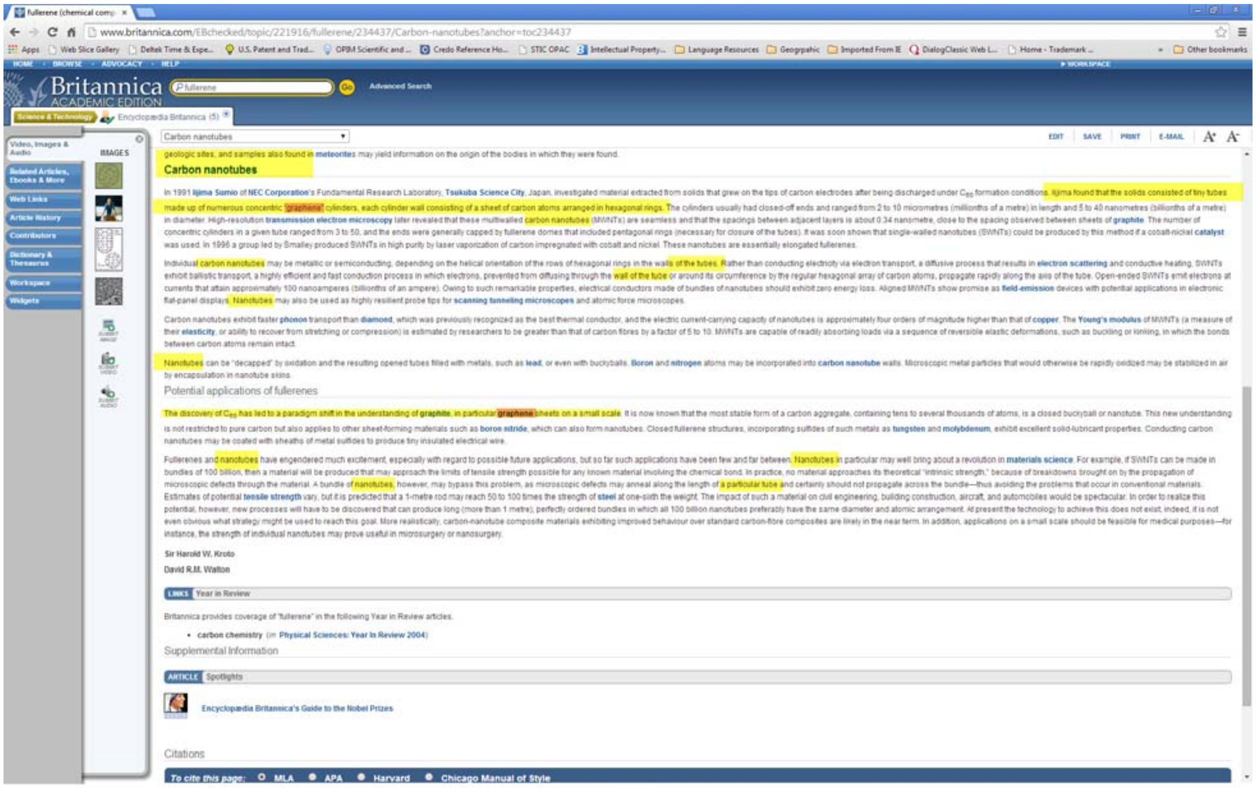

geologic sites, and samples also found in **meteorites** may yield information on the origin of the bodies in which they were found.

Carbon nanotubes

In 1991 **Iijima Sumio** of **NEC Corporation**'s Fundamental Research Laboratory, **Tsukuba Science City**, Japan, investigated material extracted from solids that grew on the tips of carbon electrodes after being discharged under C_{60} formation conditions. Iijima found that the solids consisted of tiny tubes made up of numerous concentric "graphene" cylinders, each cylinder wall consisting of a sheet of carbon atoms arranged in hexagonal rings. The cylinders usually had closed-off ends and ranged from 2 to 10 micrometres (millionths of a metre) in length and 5 to 40 nanometres (billionths of a metre) in diameter. High-resolution **transmission electron microscopy** later revealed that these multiwalled carbon nanotubes (MWNTs) are seamless and that the spacings between adjacent layers is about 0.34 nanometre, close to the spacing observed between sheets of **graphite**. The number of concentric cylinders in a given tube ranged from 3 to 50, and the ends were generally capped by fullerene domes that included pentagonal rings (necessary for closure of the tubes). It was soon shown that single-walled nanotubes (SWNTs) could be produced by this method if a cobalt-nickel **catalyst** was used. In 1996 a group led by Smalley produced SWNTs in high purity by laser vaporization of carbon impregnated with cobalt and nickel. These nanotubes are essentially elongated fullerenes.

Individual carbon nanotubes may be metallic or semiconducting, depending on the helical orientation of the rows of hexagonal rings in the walls of the tubes. Rather than conducting electricity via electron transport, a diffusive process that results in **electron scattering** and conductive heating, SWNTs exhibit ballistic transport, a highly efficient and fast conduction process in which electrons, prevented from diffusing through the wall of the tube or around its circumference by the regular hexagonal array of carbon atoms, propagate rapidly along the axis of the tube. Open-ended SWNTs emit electrons at currents that attain approximately 100 nanoamperes (billionths of an ampere). Owing to such remarkable properties, electrical conductors made of bundles of nanotubes should exhibit zero energy loss. Aligned MWNTs show promise as **field-emission** devices with potential applications in electronic flat-panel displays. Nanotubes may also be used as highly resilient probe tips for **scanning tunneling microscopes** and atomic force microscopes.

Carbon nanotubes exhibit faster **phonon** transport than **diamond**, which was previously recognized as the best thermal conductor, and the electric current-carrying capacity of nanotubes is approximately four orders of magnitude higher than that of **copper**. The **Young's modulus** of MWNTs (a measure of their **elasticity**, or ability to recover from stretching or compression) is estimated by researchers to be greater than that of carbon fibres by a factor of 5 to 10. MWNTs are capable of readily absorbing loads via a sequence of reversible elastic deformations, such as buckling or kinking, in which the bonds between carbon atoms remain intact.

Nanotubes can be "decapped" by oxidation and the resulting opened tubes filled with metals, such as **lead**, or even with buckyballs. **Boron** and **nitrogen** atoms may be incorporated into **carbon nanotube** walls. Microscopic metal particles that would otherwise be rapidly oxidized may be stabilized in air by encapsulation in nanotube skins.

Potential applications of fullerenes

The discovery of C_{60} has led to a paradigm shift in the understanding of **graphite**, in particular graphene sheets on a small scale. It is now known that the most stable form of a carbon aggregate, containing tens to several thousands of atoms, is a closed buckyball or nanotube. This new understanding is not restricted to pure carbon but also applies to other sheet-forming materials such as **boron nitride**, which can also form nanotubes. Closed fullerene structures, incorporating sulfides of such metals as **tungsten** and **molybdenum**, exhibit excellent solid-lubricant properties. Conducting carbon nanotubes may be coated with sheaths of metal sulfides to produce tiny insulated electrical wire.

Fullerenes and nanotubes have engendered much excitement, especially with regard to possible future applications, but so far such applications have been few and far between. Nanotubes in particular may well bring about a revolution in **materials science**. For example, if SWNTs can be made in bundles of 100 billion, then a material will be produced that may approach the limits of tensile strength possible for any known material involving the chemical bond. In practice, no material approaches its theoretical "intrinsic strength," because of breakdowns brought on by the propagation of microscopic defects through the material. A bundle of nanotubes, however, may bypass this problem, as microscopic defects may anneal along the length of a particular tube and certainly should not propagate across the bundle—thus avoiding the problems that occur in conventional materials. Estimates of potential **tensile strength** vary, but it is predicted that a 1-metre rod may reach 50 to 100 times the strength of **steel** at one-sixth the weight. The impact of such a material on civil engineering, building construction, aircraft, and automobiles would be spectacular. In order to realize this potential, however, new processes will have to be discovered that can produce long (more than 1 metre), perfectly ordered bundles in which all 100 billion nanotubes preferably have the same diameter and atomic arrangement. At present the technology to achieve this does not exist; indeed, it is not even obvious what strategy might be used to reach this goal. More realistically, carbon-nanotube composite materials exhibiting improved behaviour over standard carbon-fibre composites are likely in the near term. In addition, applications on a small scale should be feasible for medical purposes—for instance, the strength of individual nanotubes may prove useful in microsurgery or nanosurgery.

Sir Harold W. Kroto

David R.M. Walton

LINKS Year in Review

Britannica provides coverage of "fullerene" in the following Year in Review articles.

- **carbon chemistry** (in **Physical Sciences: Year In Review 2004**)

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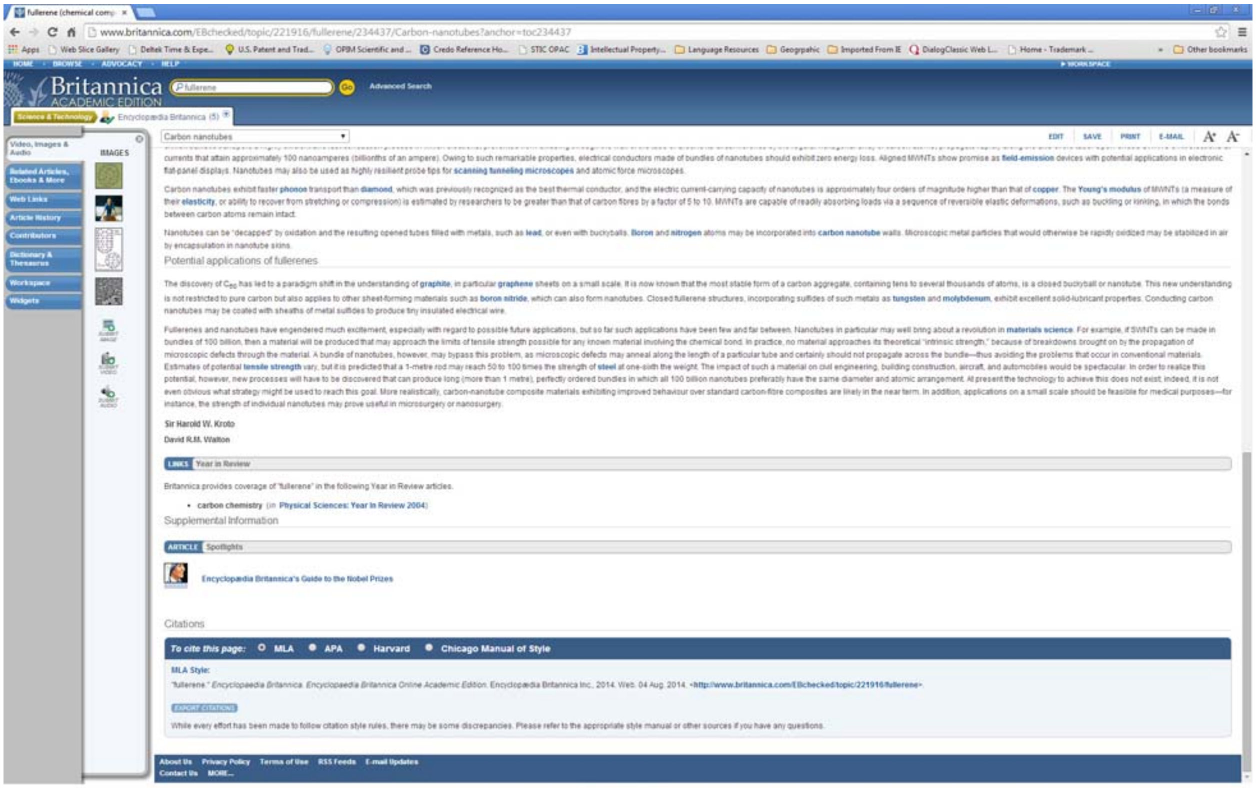

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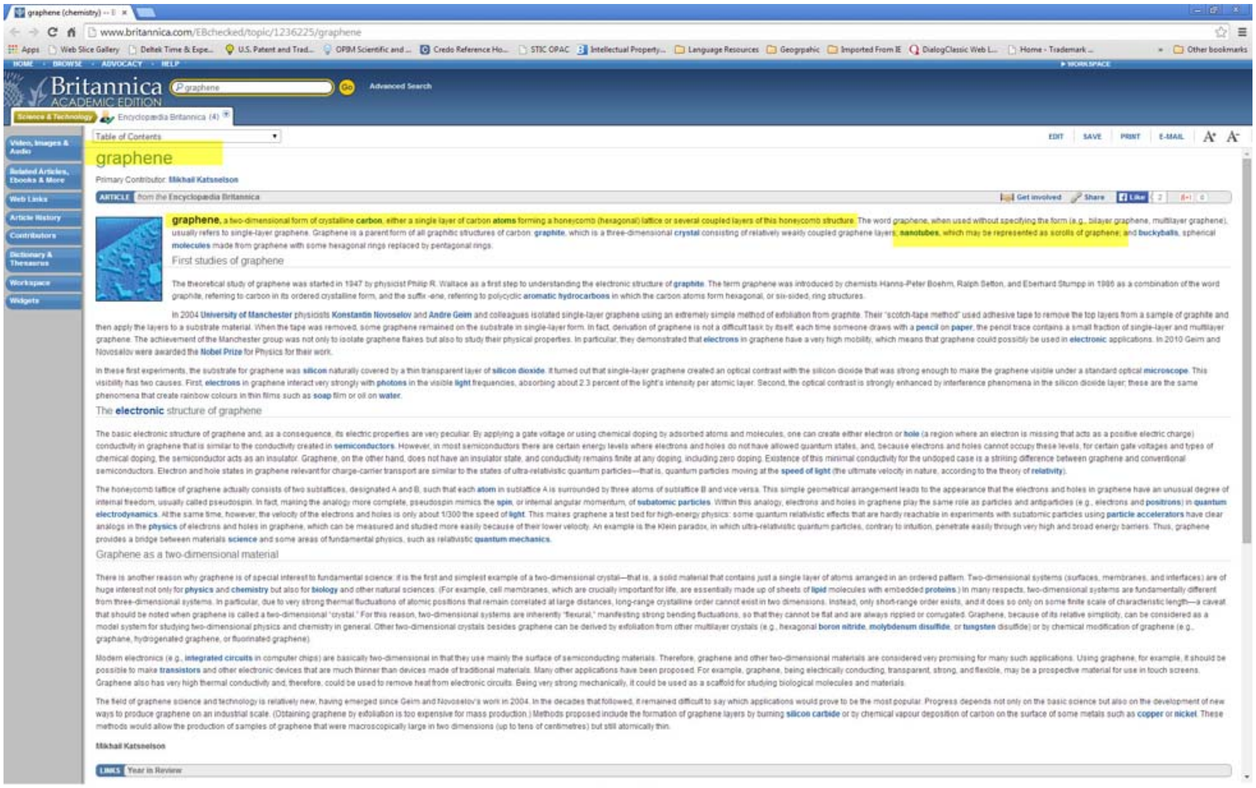

graphene

Primary Contributor: **Mikhail Katsnelson**

graphene, a two-dimensional form of crystalline **carbon**, either a single layer of carbon **atoms** forming a honeycomb (hexagonal) lattice or several coupled layers of this honeycomb structure. The word graphene, when used without specifying the form (e.g., bilayer graphene, multilayer graphene), usually refers to single-layer graphene. Graphene is a parent form of all graphitic structures of carbon: **graphite**, which is a three-dimensional **crystal** consisting of relatively weakly coupled graphene layers; **nanotubes**, which may be represented as scrolls of graphene; and **buckyballs**, spherical **molecules** made from graphene with some hexagonal rings replaced by pentagonal rings.

First studies of graphene

The theoretical study of graphene was started in 1947 by physicist Philip R. Wallace as a first step to understanding the electronic structure of **graphite**. The term graphene was introduced by chemists Hanns-Peter Boehm, Ralph Setton, and Eberhard Stumpp in 1986 as a combination of the word graphite, referring to carbon in its ordered crystalline form, and the suffix -ene, referring to polycyclic **aromatic hydrocarbons** in which the carbon atoms form hexagonal, or six-sided, ring structures.

In 2004 **University of Manchester** physicists **Konstantin Novoselov** and **Andre Geim** and colleagues isolated single-layer graphene using an extremely simple method of exfoliation from graphite. Their "scotch-tape method" used adhesive tape to remove the top layers from a sample of graphite and then apply the layers to a substrate material. When the tape was removed, some graphene remained on the substrate in single-layer form. In fact, derivation of graphene is not a difficult task by itself; each time someone draws with a **pencil** on **paper**, the pencil trace contains a small fraction of single-layer and multilayer graphene. The achievement of the Manchester group was not only to isolate graphene flakes but also to study their physical properties. In particular, they demonstrated that **electrons** in graphene have a very high mobility, which means that graphene could possibly be used in **electronic** applications. In 2010 Geim and Novoselov were awarded the **Nobel Prize** for Physics for their work.

In these first experiments, the substrate for graphene was **silicon** naturally covered by a thin transparent layer of **silicon dioxide**. It turned out that single-layer graphene created an optical contrast with the silicon dioxide that was strong enough to make the graphene visible under a standard optical **microscope**. This visibility has two causes. First, **electrons** in graphene interact very strongly with **photons** in the visible **light** frequencies, absorbing about 2.3 percent of the light's intensity per atomic layer. Second, the optical contrast is strongly enhanced by interference phenomena in the silicon dioxide layer; these are the same phenomena that create rainbow colours in thin films such as **soap** film or oil on **water**.

The **electronic** structure of graphene

The basic electronic structure of graphene and, as a consequence, its electric properties are very peculiar. By applying a gate voltage or using chemical doping by adsorbed atoms and molecules, one can create either electron or **hole** (a region where an electron is missing that acts as a positive electric charge) conductivity in graphene that is similar to the conductivity created in **semiconductors**. However, in most semiconductors there are certain energy levels where electrons and holes do not have allowed quantum states, and, because electrons and holes cannot occupy these levels, for certain gate voltages and types of chemical doping, the semiconductor acts as an insulator. Graphene, on the other hand, does not have an insulator state, and conductivity remains finite at any doping, including zero doping. Existence of this minimal conductivity for the undoped case is a striking difference between graphene and conventional semiconductors. Electron and hole states in graphene relevant for charge-carrier transport are similar to the states of ultra-relativistic quantum particles—that is, quantum particles moving at the **speed of light** (the ultimate velocity in nature, according to the theory of **relativity**).

The honeycomb lattice of graphene actually consists of two sublattices, designated A and B, such that each **atom** in sublattice A is surrounded by three atoms of sublattice B and vice versa. This simple geometrical arrangement leads to the appearance that the electrons and holes in graphene have an unusual degree of internal freedom, usually called pseudospin. In fact, making the analogy more complete, pseudospin mimics the **spin**, or internal angular momentum, of **subatomic particles**. Within this analogy, electrons and holes in graphene play the same role as particles and antiparticles (e.g., electrons and **positrons**) in **quantum electrodynamics**. At the same time, however, the velocity of the electrons and holes is only about 1/300 the speed of **light**. This makes graphene a test bed for high-energy physics: some quantum relativistic effects that are hardly reachable in experiments with subatomic particles using **particle accelerators** have clear analogs in the **physics** of electrons and holes in graphene, which can be measured and studied more easily because of their lower velocity. An example is the Klein paradox, in which ultra-relativistic quantum particles, contrary to intuition, penetrate easily through very high and broad energy barriers. Thus, graphene provides a bridge between materials **science** and some areas of fundamental physics, such as relativistic **quantum mechanics**.

Graphene as a two-dimensional material

There is another reason why graphene is of special interest to fundamental science: it is the first and simplest example of a two-dimensional crystal—that is, a solid material that contains just a single layer of atoms arranged in an ordered pattern. Two-dimensional systems (surfaces, membranes, and interfaces) are of huge interest not only for **physics** and **chemistry** but also for **biology** and other natural sciences. (For example, cell membranes, which are crucially important for life, are essentially made up of sheets of **lipid** molecules with embedded **proteins**.) In many respects, two-dimensional systems are fundamentally different from three-dimensional systems. In particular, due to very strong thermal fluctuations of atomic positions that remain correlated at large distances, long-range crystalline order cannot exist in two dimensions. Instead, only short-range order exists, and it does so only on some finite scale of characteristic length—a caveat that should be noted when graphene is called a two-dimensional "crystal." For this reason, two-dimensional systems are inherently "flexural," manifesting strong bending fluctuations, so that they cannot be flat and are always rippled or corrugated. Graphene, because of its relative simplicity, can be considered as a model system for studying two-dimensional physics and chemistry in general. Other two-dimensional crystals besides graphene can be derived by exfoliation from other multilayer crystals (e.g., hexagonal **boron nitride**, **molybdenum disulfide**, or **tungsten** disulfide) or by chemical modification of graphene (e.g., graphane, hydrogenated graphene, or fluorinated graphene).

Modern electronics (e.g., **integrated circuits** in computer chips) are basically two-dimensional in that they use mainly the surface of semiconducting materials. Therefore, graphene and other two-dimensional materials are considered very promising for many such applications. Using graphene, for example, it should be possible to make **transistors** and other electronic devices that are much thinner than devices made of traditional materials. Many other applications have been proposed. For example, graphene, being electrically conducting, transparent, strong, and flexible, may be a prospective material for use in touch screens. Graphene also has very high thermal conductivity and, therefore, could be used to remove heat from electronic circuits. Being very strong mechanically, it could be used as a scaffold for studying biological molecules and materials.

The field of graphene science and technology is relatively new, having emerged since Geim and Novoselov's work in 2004. In the decades that followed, it remained difficult to say which applications would prove to be the most popular. Progress depends not only on the basic science but also on the development of new ways to produce graphene on an industrial scale. (Obtaining graphene by exfoliation is too expensive for mass production.) Methods proposed include the formation of graphene layers by burning **silicon carbide** or by chemical vapour deposition of carbon on the surface of some metals such as **copper** or **nickel**. These methods would allow the production of samples of graphene that were macroscopically large in two dimensions (up to tens of centimetres) but still atomically thin.

Mikhail Katsnelson

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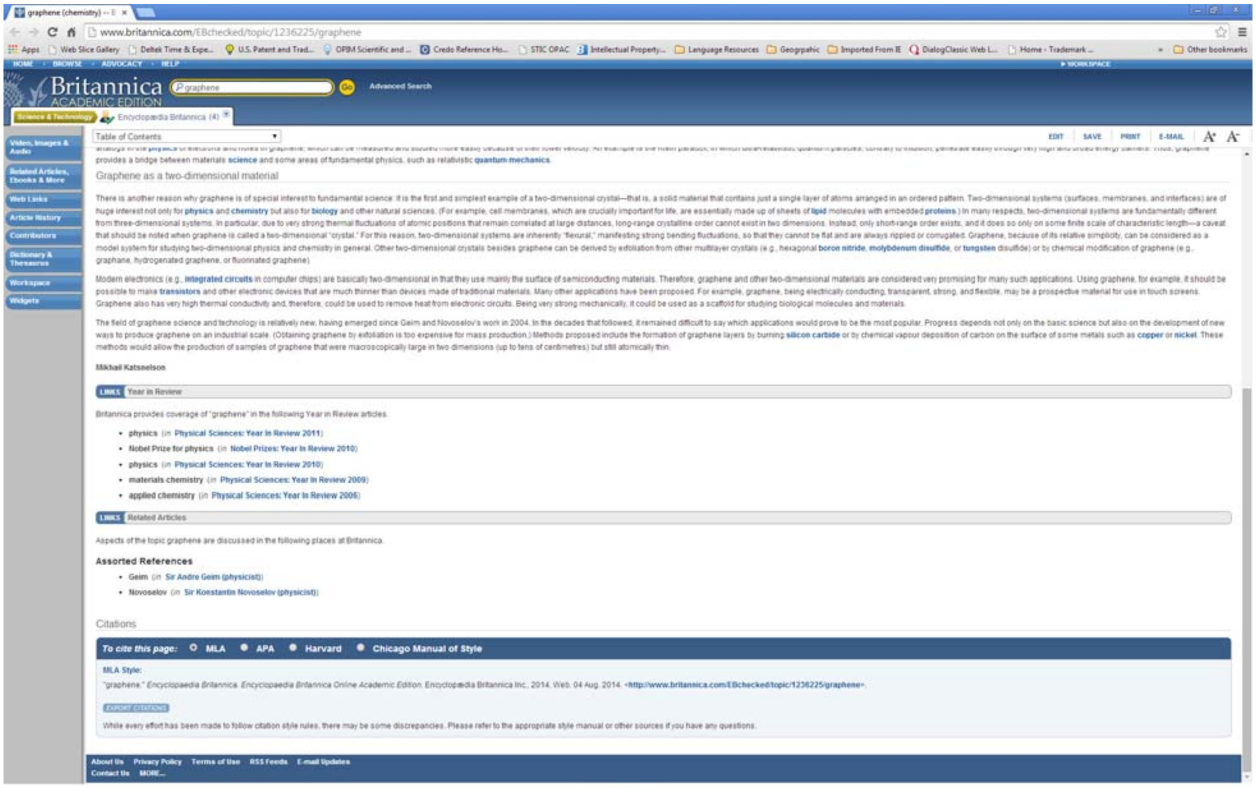

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- **physics** (*in* **Physical Sciences: Year In Review 2011**)
- **Nobel Prize for physics** (*in* **Nobel Prizes: Year In Review 2010**)
- **physics** (*in* **Physical Sciences: Year In Review 2010**)
- **materials chemistry** (*in* **Physical Sciences: Year In Review 2009**)
- **applied chemistry** (*in* **Physical Sciences: Year In Review 2006**)

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Aspects of the topic graphene are discussed in the following places at Britannica.

Assorted References

- **Geim** (*in* **Sir Andre Geim (physicist)**)
- **Novoselov** (*in* **Sir Konstantin Novoselov (physicist)**)

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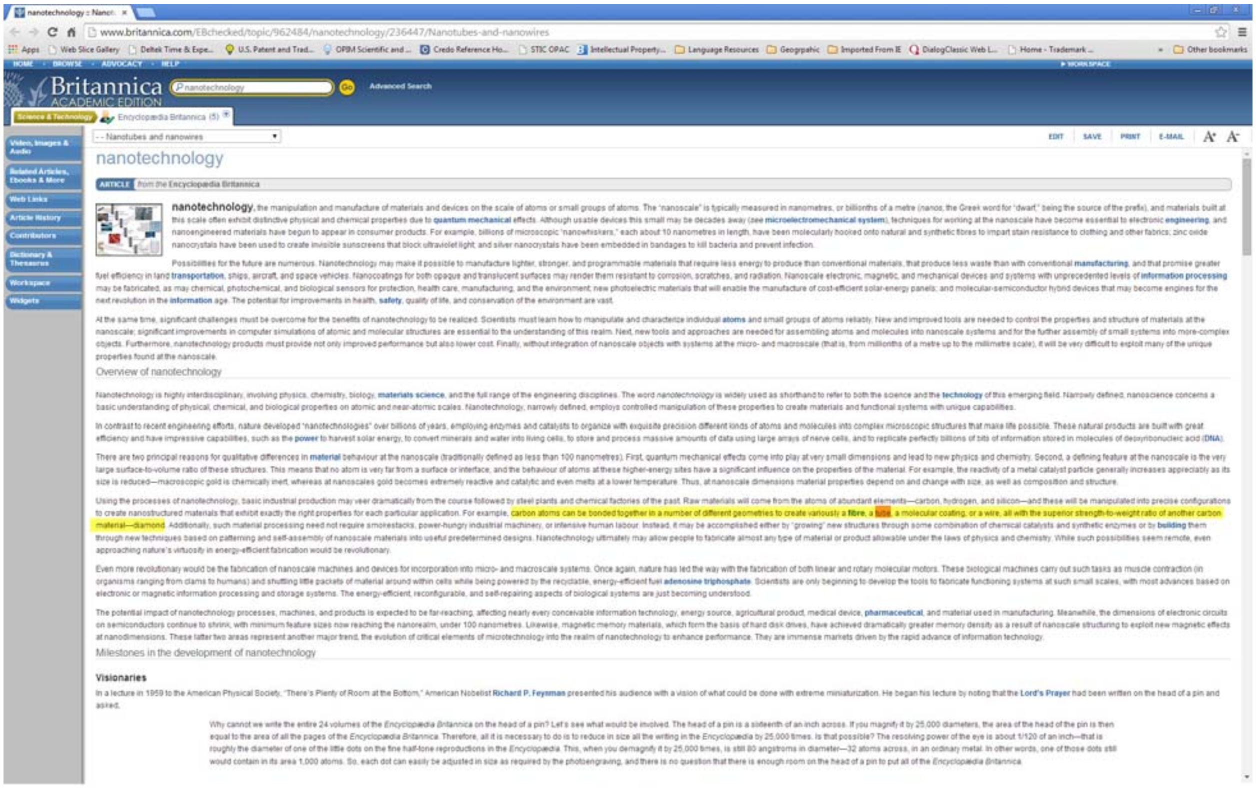

nanotechnology

nanotechnology, the manipulation and manufacture of materials and devices on the scale of atoms or small groups of atoms. The "nanoscale" is typically measured in nanometres, or billionths of a metre (nanos, the Greek word for "dwarf," being the source of the prefix), and materials built at this scale often exhibit distinctive physical and chemical properties due to **quantum mechanical** effects. Although usable devices this small may be decades away (see **microelectromechanical system**), techniques for working at the nanoscale have become essential to electronic **engineering**, and nanoengineered materials have begun to appear in consumer products. For example, billions of microscopic "nanowhiskers," each about 10 nanometres in length, have been molecularly hooked onto natural and synthetic fibres to impart stain resistance to clothing and other fabrics; zinc oxide nanocrystals have been used to create invisible sunscreens that block ultraviolet light; and silver nanocrystals have been embedded in bandages to kill bacteria and prevent infection.

Possibilities for the future are numerous. Nanotechnology may make it possible to manufacture lighter, stronger, and programmable materials that require less energy to produce than conventional materials, that produce less waste than with conventional **manufacturing**, and that promise greater fuel efficiency in land **transportation**, ships, aircraft, and space vehicles. Nanocoatings for both opaque and translucent surfaces may render them resistant to corrosion, scratches, and radiation. Nanoscale electronic, magnetic, and mechanical devices and systems with unprecedented levels of **information processing** may be fabricated, as may chemical, photochemical, and biological sensors for protection, health care, manufacturing, and the environment; new photoelectric materials that will enable the manufacture of cost-efficient solar-energy panels; and molecular-semiconductor hybrid devices that may become engines for the next revolution in the **information** age. The potential for improvements in health, **safety**, quality of life, and conservation of the environment are vast.

At the same time, significant challenges must be overcome for the benefits of nanotechnology to be realized. Scientists must learn how to manipulate and characterize individual **atoms** and small groups of atoms reliably. New and improved tools are needed to control the properties and structure of materials at the nanoscale; significant improvements in computer simulations of atomic and molecular structures are essential to the understanding of this realm. Next, new tools and approaches are needed for assembling atoms and molecules into nanoscale systems and for the further assembly of small systems into more-complex objects. Furthermore, nanotechnology products must provide not only improved performance but also lower cost. Finally, without integration of nanoscale objects with systems at the micro- and macroscale (that is, from millionths of a metre up to the millimetre scale), it will be very difficult to exploit many of the unique properties found at the nanoscale.

Overview of nanotechnology

Nanotechnology is highly interdisciplinary, involving physics, chemistry, biology, **materials science**, and the full range of the engineering disciplines. The word *nanotechnology* is widely used as shorthand to refer to both the science and the **technology** of this emerging field. Narrowly defined, nanoscience concerns a basic understanding of physical, chemical, and biological properties on atomic and near-atomic scales. Nanotechnology, narrowly defined, employs controlled manipulation of these properties to create materials and functional systems with unique capabilities.

In contrast to recent engineering efforts, nature developed "nanotechnologies" over billions of years, employing enzymes and catalysts to organize with exquisite precision different kinds of atoms and molecules into complex microscopic structures that make life possible. These natural products are built with great efficiency and have impressive capabilities, such as the **power** to harvest solar energy, to convert minerals and water into living cells, to store and process massive amounts of data using large arrays of nerve cells, and to replicate perfectly billions of bits of information stored in molecules of deoxyribonucleic acid (**DNA**).

There are two principal reasons for qualitative differences in **material** behaviour at the nanoscale (traditionally defined as less than 100 nanometres). First, quantum mechanical effects come into play at very small dimensions and lead to new physics and chemistry. Second, a defining feature at the nanoscale is the very large surface-to-volume ratio of these structures. This means that no atom is very far from a surface or interface, and the behaviour of atoms at these higher-energy sites have a significant influence on the properties of the material. For example, the reactivity of a metal catalyst particle generally increases appreciably as its size is reduced—macroscopic gold is chemically inert, whereas at nanoscales gold becomes extremely reactive and catalytic and even melts at a lower temperature. Thus, at nanoscale dimensions material properties depend on and change with size, as well as composition and structure.

Using the processes of nanotechnology, basic industrial production may veer dramatically from the course followed by steel plants and chemical factories of the past. Raw materials will come from the atoms of abundant elements—carbon, hydrogen, and silicon—and these will be manipulated into precise configurations to create nanostructured materials that exhibit exactly the right properties for each particular application. For example, carbon atoms can be bonded together in a number of different geometries to create variously a **fibre**, a tube, a molecular coating, or a wire, all with the superior strength-to-weight ratio of another carbon material—diamond. Additionally, such material processing need not require smokestacks, power-hungry industrial machinery, or intensive human labour. Instead, it may be accomplished either by "growing" new structures through some combination of chemical catalysts and synthetic enzymes or by **building** them through new techniques based on patterning and self-assembly of nanoscale materials into useful predetermined designs. Nanotechnology ultimately may allow people to fabricate almost any type of material or product allowable under the laws of physics and chemistry. While such possibilities seem remote, even approaching nature's virtuosity in energy-efficient fabrication would be revolutionary.

Even more revolutionary would be the fabrication of nanoscale machines and devices for incorporation into micro- and macroscale systems. Once again, nature has led the way with the fabrication of both linear and rotary molecular motors. These biological machines carry out such tasks as muscle contraction (in organisms ranging from clams to humans) and shuttling little packets of material around within cells while being powered by the recyclable, energy-efficient fuel **adenosine triphosphate**. Scientists are only beginning to develop the tools to fabricate functioning systems at such small scales, with most advances based on electronic or magnetic information processing and storage systems. The energy-efficient, reconfigurable, and self-repairing aspects of biological systems are just becoming understood.

The potential impact of nanotechnology processes, machines, and products is expected to be far-reaching, affecting nearly every conceivable information technology, energy source, agricultural product, medical device, **pharmaceutical**, and material used in manufacturing. Meanwhile, the dimensions of electronic circuits on semiconductors continue to shrink, with minimum feature sizes now reaching the nanorealm, under 100 nanometres. Likewise, magnetic memory materials, which form the basis of hard disk drives, have achieved dramatically greater memory density as a result of nanoscale structuring to exploit new magnetic effects at nanodimensions. These latter two areas represent another major trend, the evolution of critical elements of microtechnology into the realm of nanotechnology to enhance performance. They are immense markets driven by the rapid advance of information technology.

Milestones in the development of nanotechnology

Visionaries

In a lecture in 1959 to the American Physical Society, "There's Plenty of Room at the Bottom," American Nobelist **Richard P. Feynman** presented his audience with a vision of what could be done with extreme miniaturization. He began his lecture by noting that the **Lord's Prayer** had been written on the head of a pin and asked,

> Why cannot we write the entire 24 volumes of the *Encyclopædia Britannica* on the head of a pin? Let's see what would be involved. The head of a pin is a sixteenth of an inch across. If you magnify it by 25,000 diameters, the area of the head of the pin is then equal to the area of all the pages of the *Encyclopædia Britannica*. Therefore, all it is necessary to do is to reduce in size all the writing in the *Encyclopædia* by 25,000 times. Is that possible? The resolving power of the eye is about 1/120 of an inch—that is roughly the diameter of one of the little dots on the fine half-tone reproductions in the *Encyclopædia*. This, when you demagnify it by 25,000 times, is still 80 angstroms in diameter—32 atoms across, in an ordinary metal. In other words, one of those dots still would contain in its area 1,000 atoms. So, each dot can easily be adjusted in size as required by the photoengraving, and there is no question that there is enough room on the head of a pin to put all of the *Encyclopædia Britannica*.