NTNU

Norwegian University of Science and Technology

Welcome to TMT4320 Nanomaterials!
August 22th, 2016

- Course information
- Introduction to nanomaterials
- Some basic definitions

Course information

- Lecturers
  - Dr. Carlos Bernuy-Lopez (course responsible)
  - carlos.bernuy-lopez@ntnu.no
  - Associate professor Maria Benelmekki
  - maria.benelmekki@ntnu.no

- Lectures
  - Monday 10:15 -12:00 H1
  - Wednesday 12:15 -14:00 H1

- Student assistants
  - Sandra Karen Tonstad (sandrakt@stud.ntnu.no)
  - Christian Holmvik (chrholm@stud.ntnu.no)

Exercises, mid-term and final exam

- Exercises
  - Thursday at 17:15-19:00 in F6
  - 12 written exercises
  - 50% of the written exercises (6/12) must be approved
  - Must be submitted in the box outside R7 within Friday 14:00
- Mid-term exam
  - October 3rd during regular lecture hours (10:15-12:00)
  - Multiple choice questions
  - Must receive a passing grade in order to be allowed to take the final exam. **Pass = 50% correct answers**
- Final exam (written)
  - November 30th, 2016
  - Counts for 100 % of the final grade
  - Old exams can be found on It's learning (2009-2015)

Learning outcome

- Qualitatively describe how nanoparticle size can affect morphology, crystal structure, reactivity and electronic properties.
- Describe several synthesis methods for producing inorganic nanoparticles, 1D nanostructures (nanotubes, wires and rods), thin films, nanoporous materials, and bulk materials which are built from nanosized building blocks. In addition, you should be able to describe how various types of lithography can be used to produce nanosized structures. You should be able to understand the general theory for the synthesis/production of nanomaterials.
- Perform simple geometrical calculations of surface energy, coordination numbers and volume fraction related to nanoscale properties and synthesis, in addition to simple chemical calculations related to the synthesis.
- Use this knowledge to assess which synthesis methods that might be best suited to produce nanostructured materials from various inorganic compositions (metals, semiconductors, oxides, fullerenes etc.) and combinations of these.
- Identify basic ethical, health and environmental issues related to production and use of nanoparticles and nanomaterials in general.

TMT4320 Nanomaterials

- Learning outcome (in summary)
  - The course will give an introduction to basic chemical and physical principles for the preparation of nanomaterials
  - In addition, several examples of specific structures and synthesis methods will be given
- Recommended previous knowledge
  - Basic courses in chemistry, materials science or solid state physics
- Students
  - Third year Nanotechnology (compulsory)
  - Third year Materials Science (compulsory)
  - Fourth year Chemical Engineering and Biotechnology
  - Various other students

TMT4320 Nanomaterials

- Introduction to nanomaterials
  - Several topics will be covered
  - Not too much details
  - Basic principles and methods
  - Overview of the field
- More details in further courses
  - TKP4190 Fabrication and applications of nanomaterials
    - Nucleation and crystal growth theory
    - Applications and properties (optical, functionalization, drug delivery etc.)
    - More detailed about specific nanoscale structures/particles in NTNU research
  - Materials science courses
  - Physics courses
  - Bio-related courses

Reading list (NEW THIS YEAR)

- Textbook of Nanoscience and Nanotechnology
  - C. Bréchignac, P. Houdy, and M. Lahmani (eds.)
  - Springer, 2013
  - Available at Springer website with NTNU login.
- Nanostructures and Nanomaterials: Synthesis, Properties, and Applications
  - Guozhong Cao, Ying Wang
  - World Scientific, 2011. Provided as additional literature.
- Two journal reviews
- Lecture notes and exercises
- it's learning
  - Written exercises and solutions
  - All lecture notes
  - All relevant information (see course information)

Reading list

- Nanomaterials and Nanochemistry
  - C. Bréchignac, P. Houdy, and M. Lahmani (eds.)
  - Springer, 2007 (or newer edition)
  - Available at Tapir and available as e-book with NTNU login
- Nanoscience
  - C. Dupas, P. Houdy, and M. Lahmani (eds.)
  - Springer, 2007 (or newer edition)
  - Chapters 1, 2 and 8 are available as a compendium at Tapir (also available as e-book with NTNU login)

Lecture plan

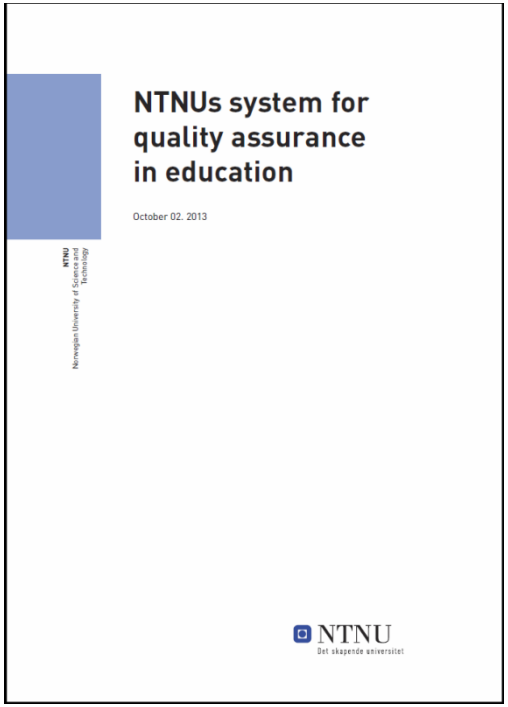
- Duration of course: 22.08.16 to 23.11.16

1. Unique properties
2. Synthesis routes
3. Tools to characterize nanomaterials
4. Applications of nanomaterials
5. Nanostructure materials with High Applications
6. Concerns and challenge of Nanomaterials

- NTNU research on nanomaterials

See info in It's learning for details!

Quality assurance in education at NTNU



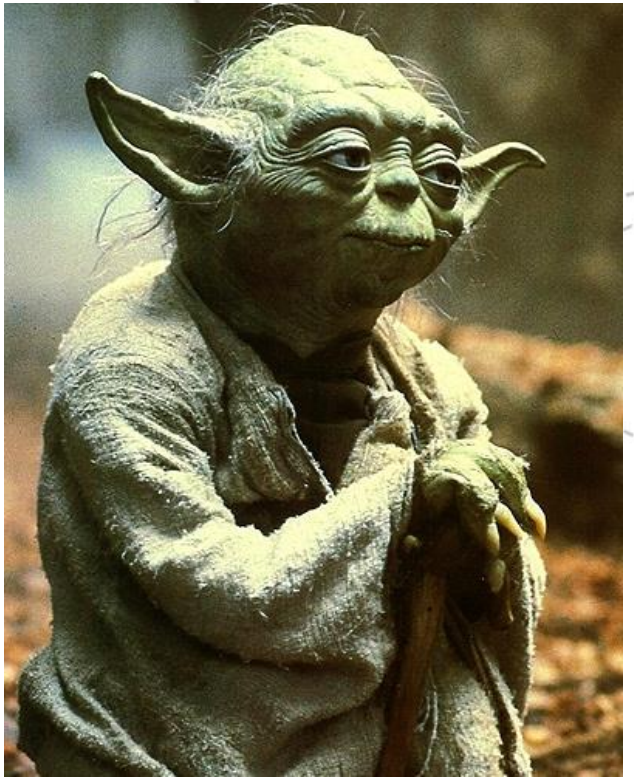
Courtesy of vice dean
Øyvind Weiby Gregersen

NTNU revised the system for quality assurance of education in 2014

- New elements:
  - **Survey** among all students at least each third year.
  - **3 reference group meetings each semester the subject is taught.**
  - The course report and the reports from the reference group meetings are entered into a **database** which is accessible for all students and staff at NTNU.
  - All study programs are evaluated at least each 5th year.
  - Plans of action for development of all programs of study and the teaching of all departments are approved by the dean based on input from the study programs and departments.
  - Report problems – **New problem report page** for students. If you discover that the normal quality assurance system for education does not work as intended, you can report the problem directly.

Roles: The course coordinator

- Establish a **reference group** and arrange three meetings.
- Write a **course report** after the teaching semester and exam are finished.
- Make sure the course report and reference group reports are **available** for the current and next group of students..
- Make sure the program coordinator and head of department obtain the evaluation report.
- Do a **survey** among all the students taking the course at least each third year.
- **Develop** the course on the basis for the evaluation report.



Roles - Students

- Join reference groups, write the reference group report and give input to the members in the reference group.
- Elect student members in program boards, management teams and boards at different levels at NTNU.
- Be updated on the learning objectives of the various courses and the study program you follow as a student.

Student and professor cooperating ?

Roles – The reference group

- The group represents the students in three meetings during the semester.
- Writes an independent report after each meeting which is attached to the course report.
- At least three students take part, but there should be at least one student representative of each study program taking the course.
- In courses with few student, all the students may constitute the reference group.
- The reference group shall be in contact with the rest of the students and represent them in the reference group meetings.
- The students in the reference group write the reference group reports.

Roles – The reference group

- Nanotechnology: Mette Wirak mettewi@stud.ntnu.no
- Materials Chemistry: Tobias Mohn Werner tobiaswe@stud.ntnu.no
- Industrial Chemistry: Henrik Horten Olavesen henrik.horten.olavesen@gmail.com
- International: Brice Badoux bricebadoux@hotmail.com

Links to the education quality assurance system

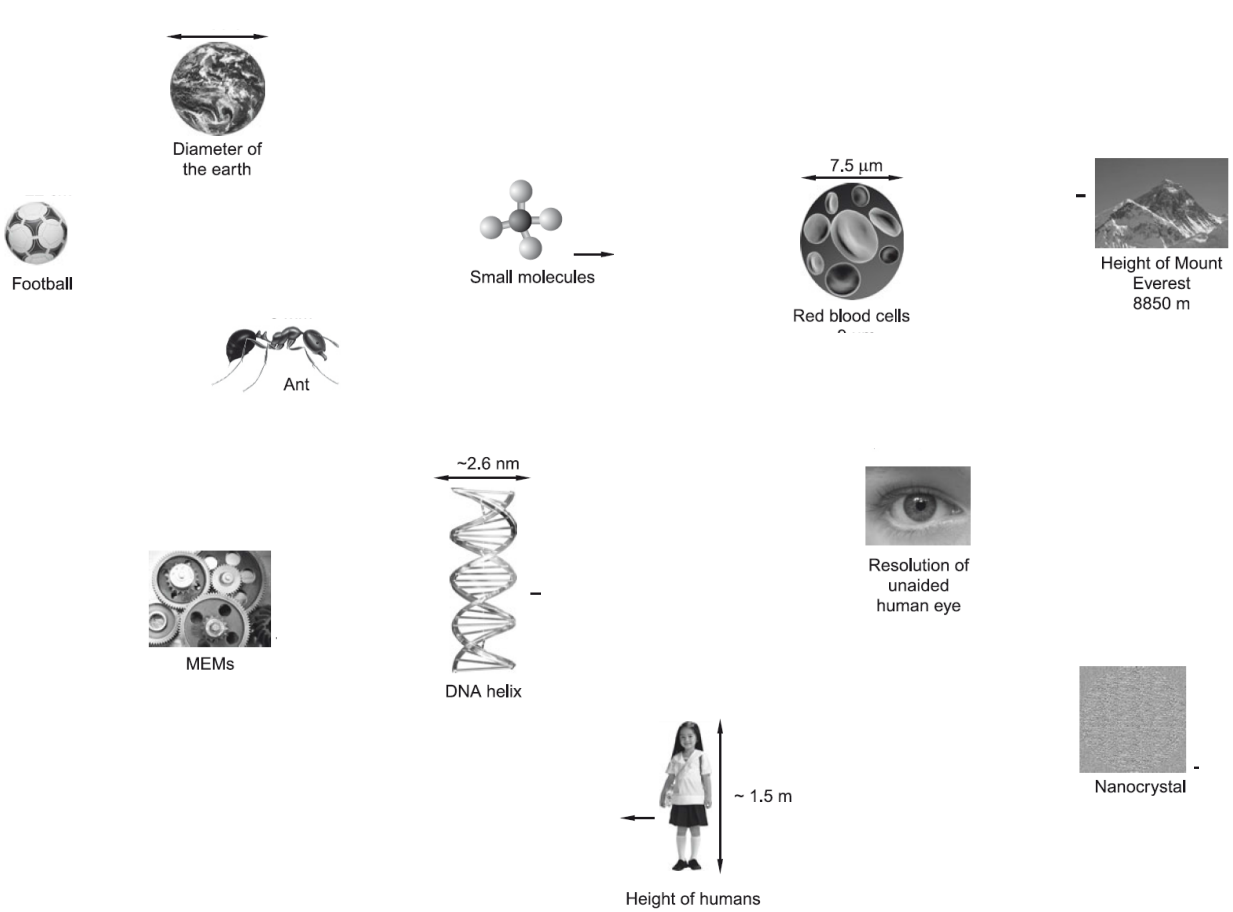
- Description of the system at www: http://www.ntnu.no/utdanningskvalitet/
- All details can be found on the internal pages: https://innsida.ntnu.no/wiki/-/wiki/English/Quality+assurance+of+education
- Page for reporting problems : https://innsida.ntnu.no/avvik
- Database for course reports etc.: https://irom.ivt.ntnu.no/ivt/adm/kvalitetssikring-utdanning/

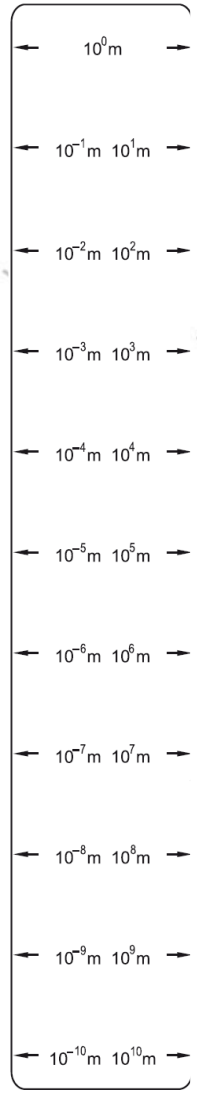
What is a nanomaterial?

What is a nanomaterial?

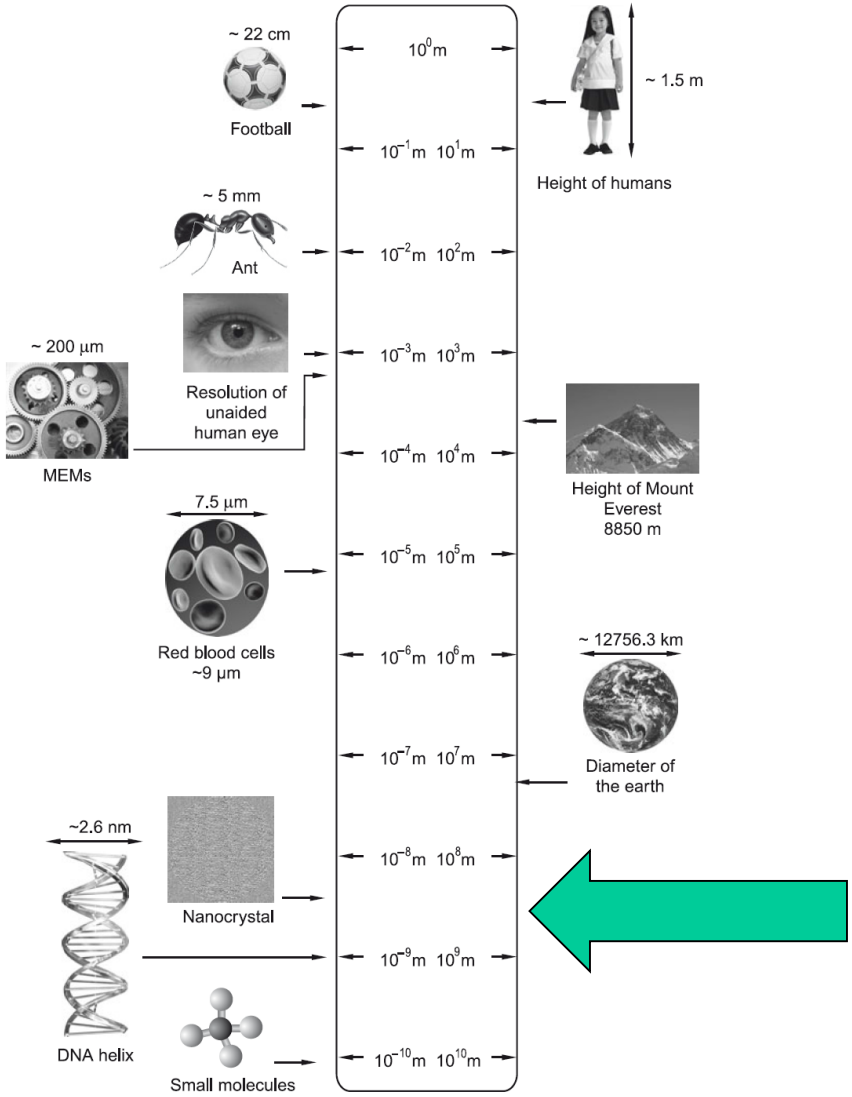
Materials with at least one of their dimensions in the nanometric range (1-100 nm), below which there is significant variation of the properties compared with crystalline materials

What is a nanomaterial?





What is a nanomaterial?



A little bit of history…

When nanoscience was recognised?

-XXth century?
-XXIst century?

A little bit of history…

When nanoscience was recognised?

-XXth century? –Richard Feynman-1959
http://www.zyvex.com/nanotech/feynman.html
-XXIst century?

A little bit of history…

When nanoscience was recognised?

-XXth century? –Richard Feynman-1959
http://www.zyvex.com/nanotech/feynman.html
-XXIst century?

Are nanomaterials so new? From XXth century?

A little bit of history…

When nanoscience was recognised?

-XXth century? –Richard Feynman-1959
http://www.zyvex.com/nanotech/feynman.html
-XXIst century?

Are nanomaterials so new?

- beautiful color of XIth century glass paintings due to Au and Ag nanoparticles

A little bit of history…

Are nanomaterials so new?

- beautiful color of XIth century glass paintings due to Au and Ag nanoparticles

https://en.wikipedia.org/wiki/File:Muzeum_Su%C5%82kowskich_-_Zabytkowy_Witra%C5%BC.jpg

A little bit of history…

Are nanomaterials so new?

- beautiful color of XIth century glass paintings due to Au and Ag nanoparticles

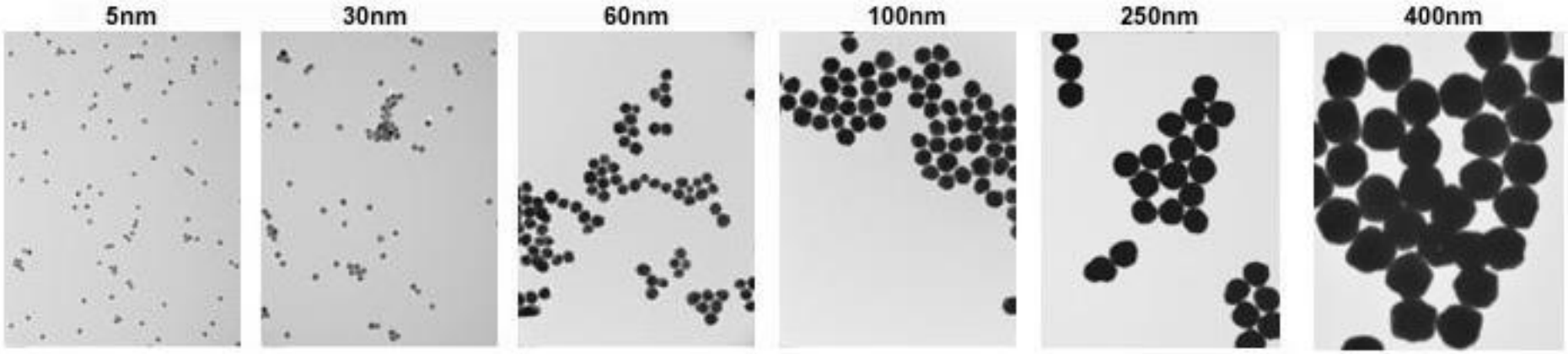
Different collors depending of particle sizes.

https://en.wikipedia.org/wiki/File:Muzeum_Su%C5%82kowskich_-_Zabytkowy_Witra%C5%BC.jpg

A little bit of history…

Are nanomaterials so new?

- beautiful color of XIth century glass paintings due to Au and Ag nanoparticles



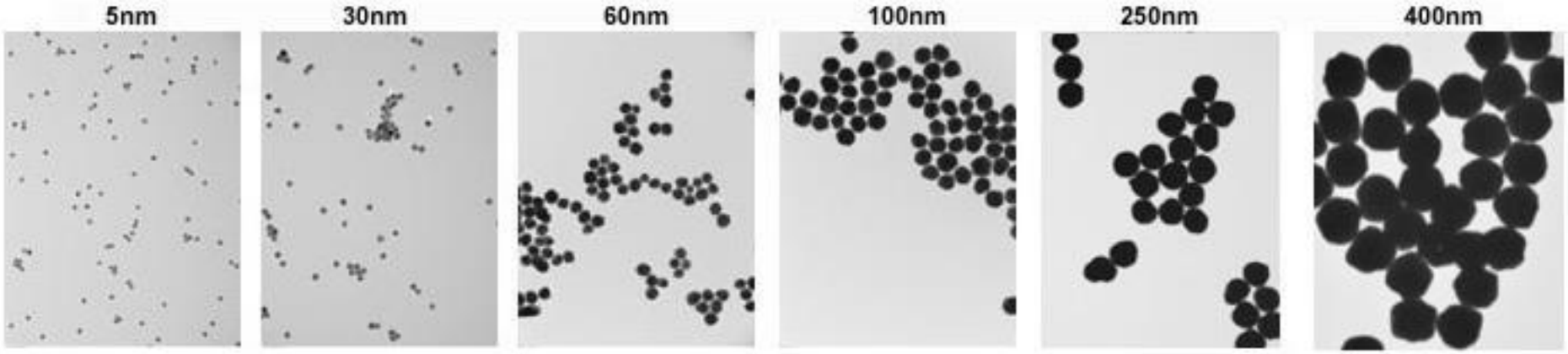
TEM pictures of Au nanoparticles

https://en.wikipedia.org/wiki/File:Muzeum_Su%C5%82kowskich_-_Zabytkowy_Witra%C5%BC.jpg

A little bit of history…

Are nanomaterials so new?

- beautiful color of XIth century glass paintings due to Au and Ag nanoparticles



TEM pictures of Au nanoparticles

https://en.wikipedia.org/wiki/File:Muzeum_Su%C5%82kowskich_-_Zabytkowy_Witra%C5%BC.jpg

A little bit of history…

When nanoscience was recognised?

-XXth century? –Richard Feynman-1959
http://www.zyvex.com/nanotech/feynman.html
-XXIst century?

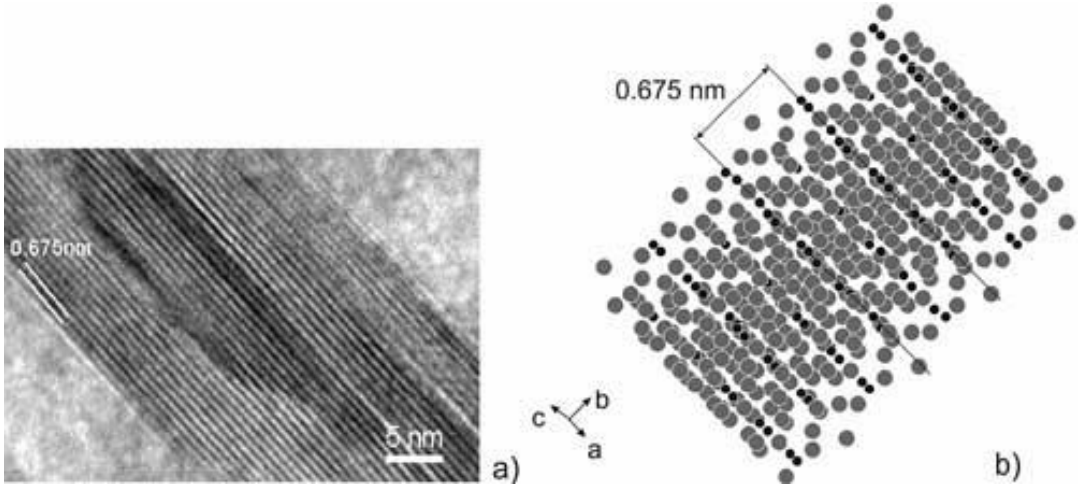
Are nanomaterials so new?

- beautiful color of XIth century glass paintings due to Au and Ag nanoparticles
-carbon nanotube in swords made in India 1500 years ago!

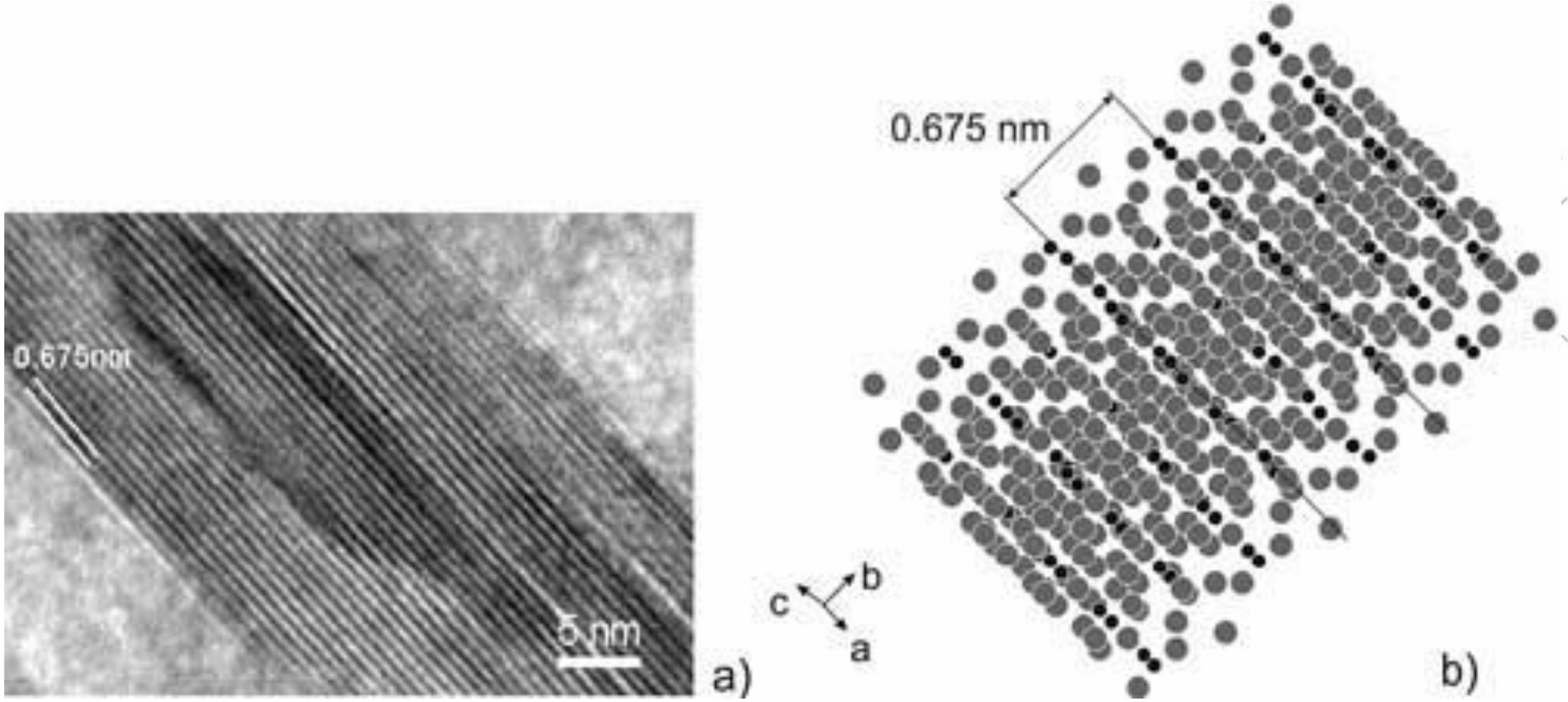
A little bit of history…

Wootz steel (Fe and C alloy)

HRTEM image of an iron carbide nanowire encapsulated in carbon nanotubes(a).

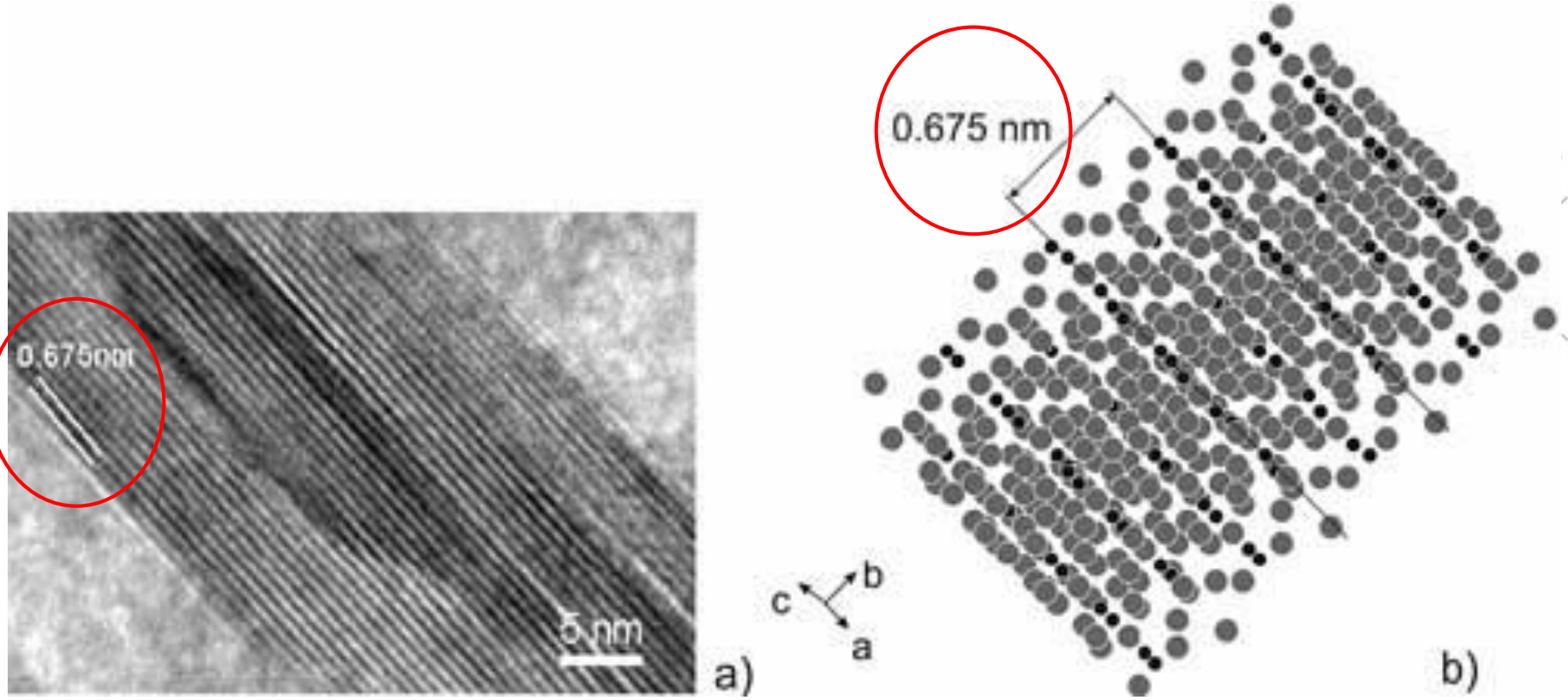


A little bit of history…



HRTEM image of an iron carbide nanowire encapsulated in carbon nanotubes(a).

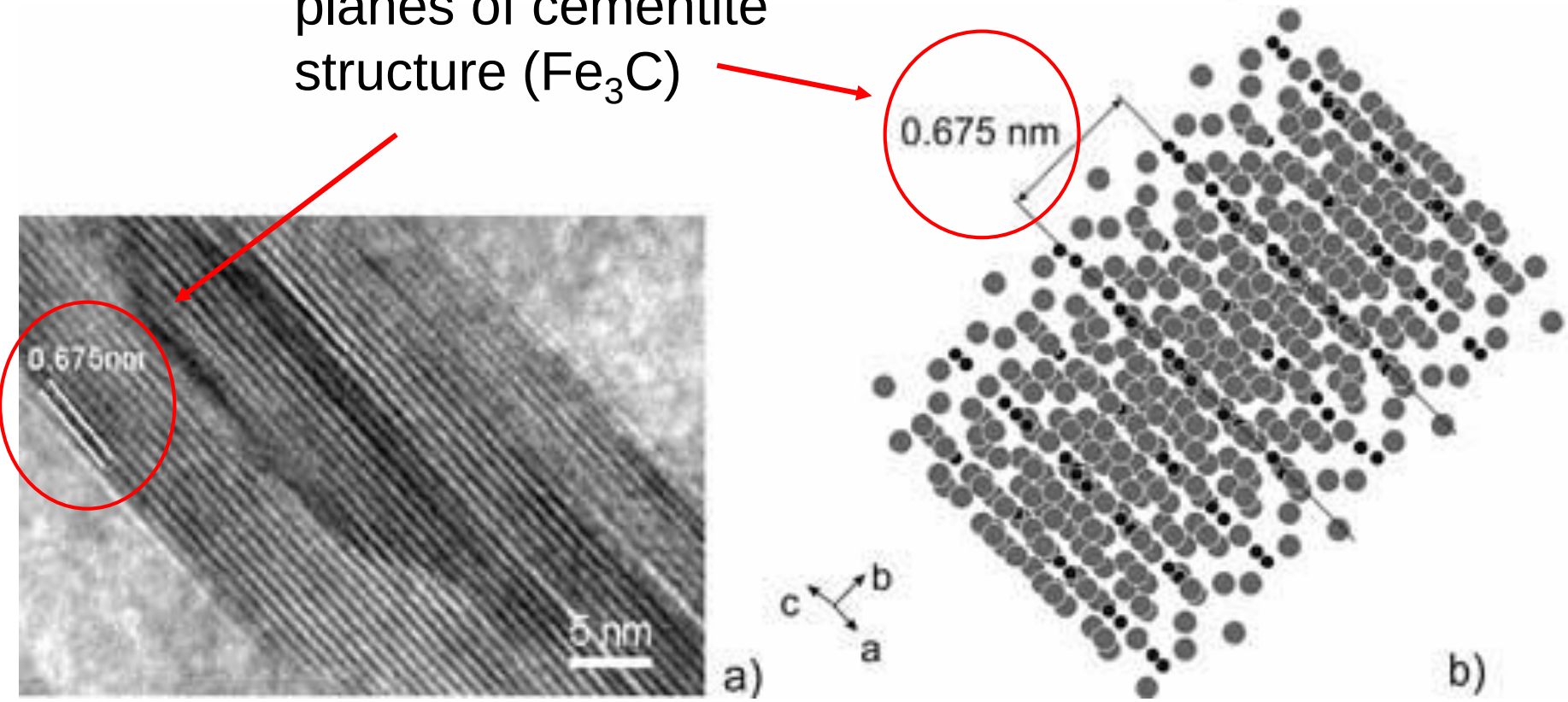
A little bit of history…



HRTEM image of an iron carbide nanowire encapsulated in carbon nanotubes(a).

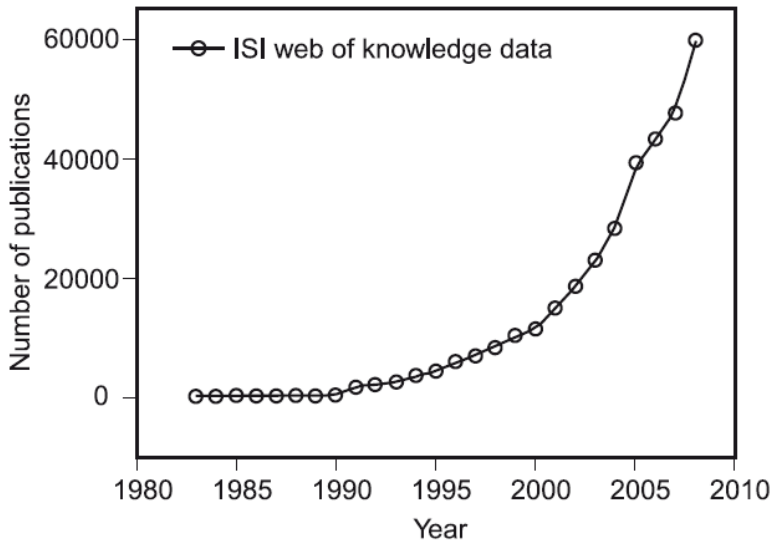
A little bit of history…

Lattice spacing of (010) planes of cementite structure (Fe_3C)

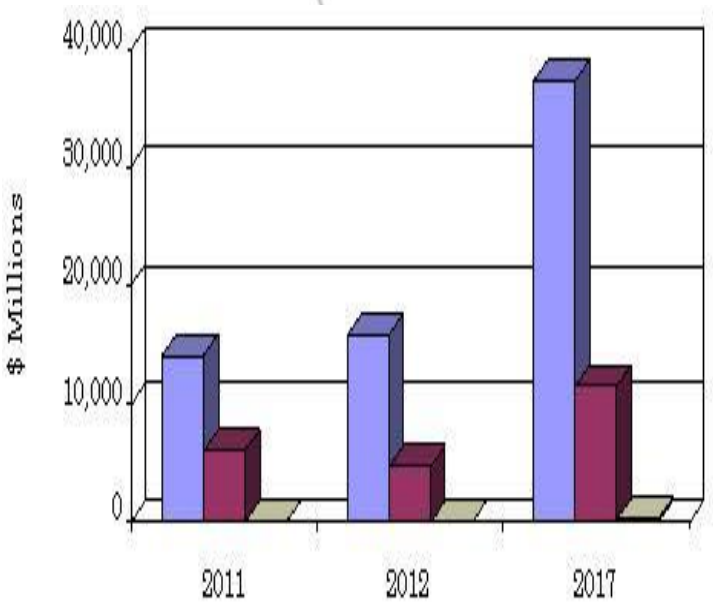


HRTEM image of an iron carbide nanowire encapsulated in carbon nanotubes(a).

And future…

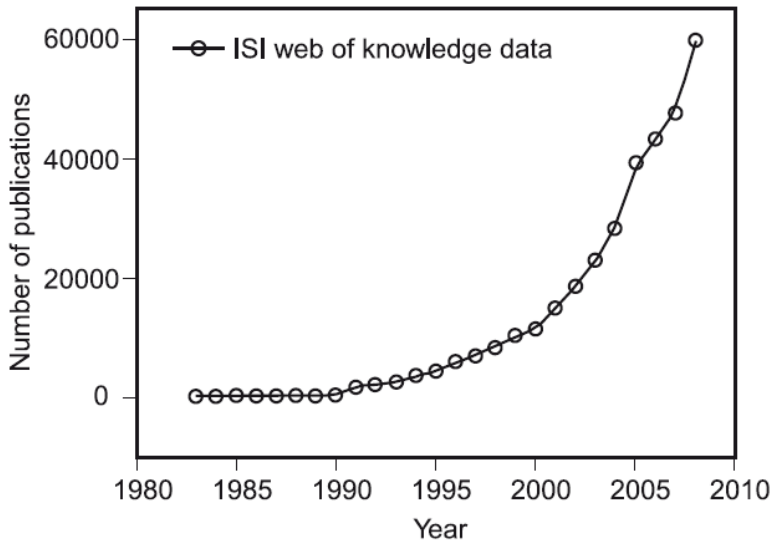


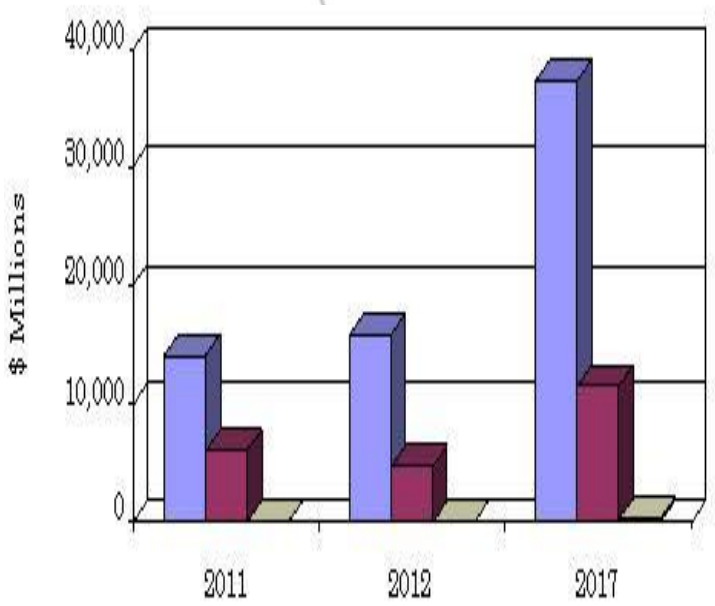
Scientific articles



Market

And future…





Scientific articles

Market

«Nano Age» generation → You

Problem A

Imagine that you are visiting your grandparents and that they are asking what you are studying these days. When you tell them the awesome subject of nanomaterials they look at you very surprised: they don't know at all what you are talking about.

a) How can you explain them what nanotechnology is in a manner that they can understand?
b) After this, they look very exciting but they tell you that this is something that they are not going to see because it seems to far in the future. What would you tell them?
c) Is it nanotechnology around us right now? Where?

Solution to problem A

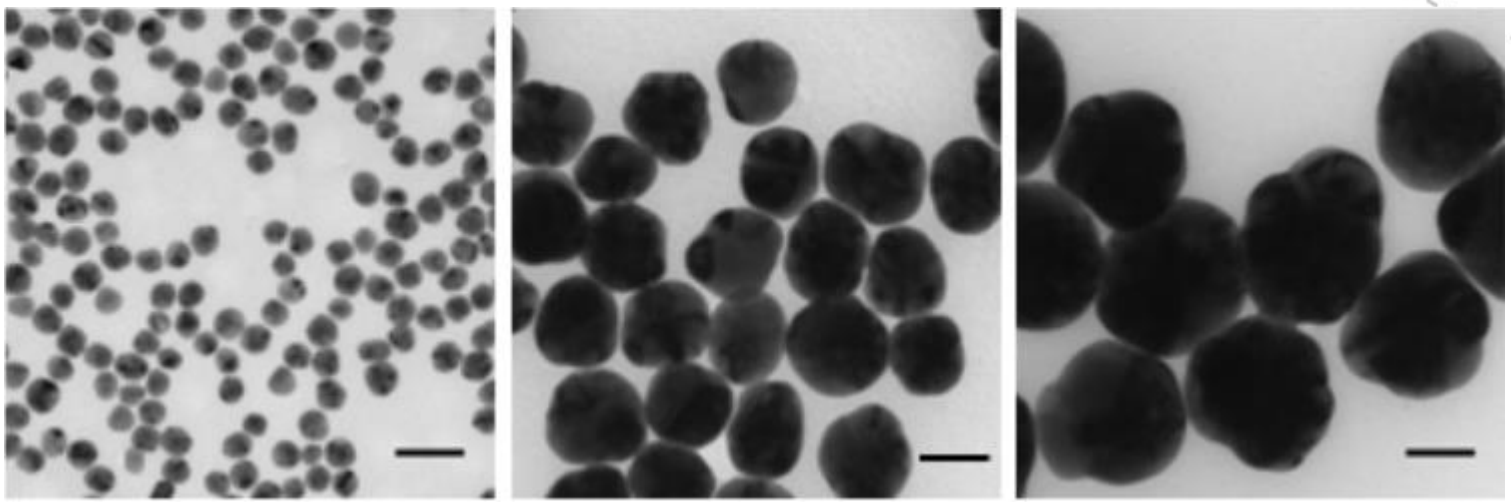
a) Something very, very, very tiny.
«Small» things in nanometers:
An ant measures 5,000,000 nm
A single hair measures 80,000 nm of diameter.
A bacterium measures 2,000 nm of diameter.
http://www.htwins.net/scale2/
b) Noooo!! It's already here!!
c) http://product.statnano.com/
A washing machine with Ag nanoparticles:
http://product.statnano.com/product/1497
Cremes made of nanoparticles:
http://product.statnano.com/industry/skin_care/product
Raquets made of carbon nanotubes.
http://product.statnano.com/industry/tennis/product

Solution to problem A

A washing machine with Ag nanoparticles:
http://product.statnano.com/product/1497

Solution to problem A

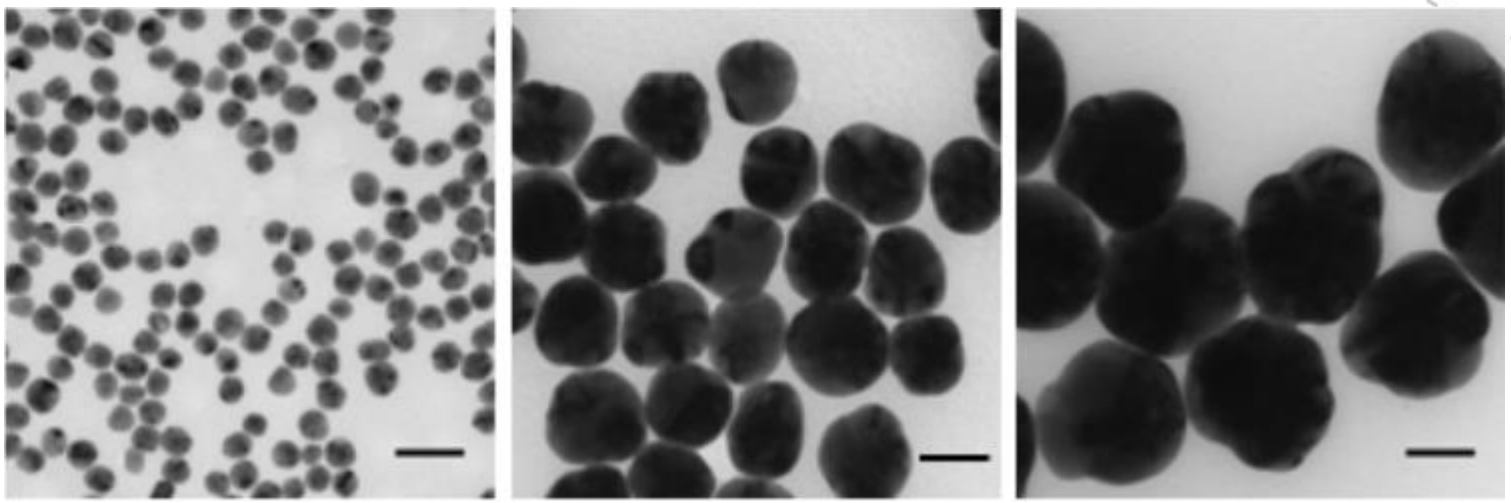
A washing machine with Ag nanoparticles:
http://product.statnano.com/product/1497



Transmission electron microscopy (TEM) images of silver nanoparticles

Solution to problem A

A washing machine with Ag nanoparticles:
http://product.statnano.com/product/1497



20 nm 60 nm 100 nm

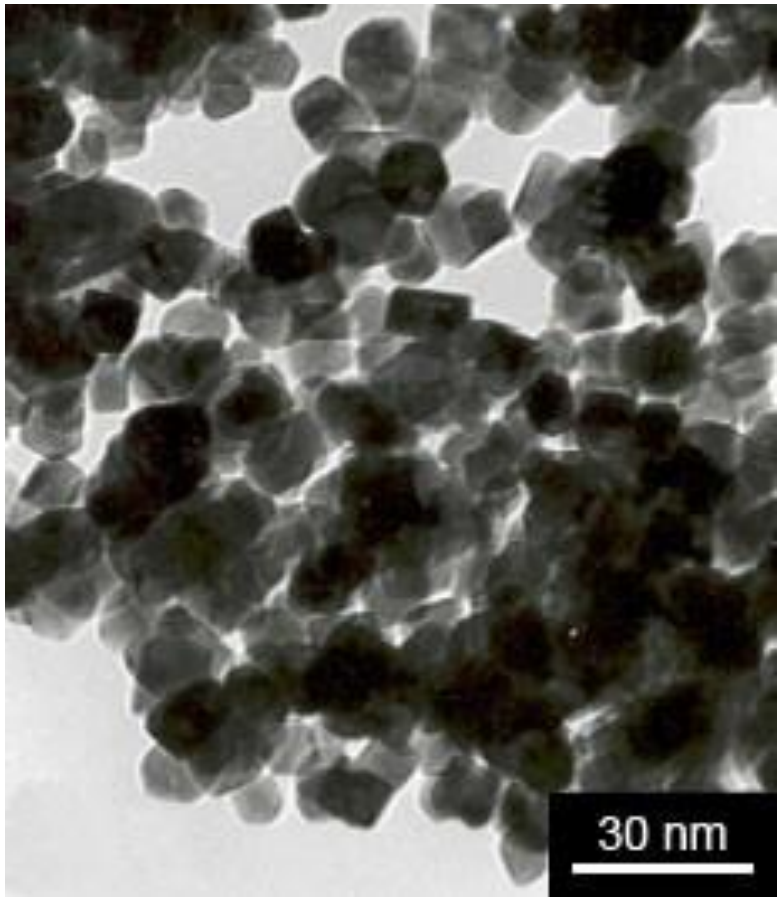
Transmission electron microscopy (TEM) images of silver nanoparticles. Scale bars are 50 nm.

Solution to problem A

Cremes made of nanoparticles:
http://product.statnano.com/industry/skin_care/product

Solution to problem A

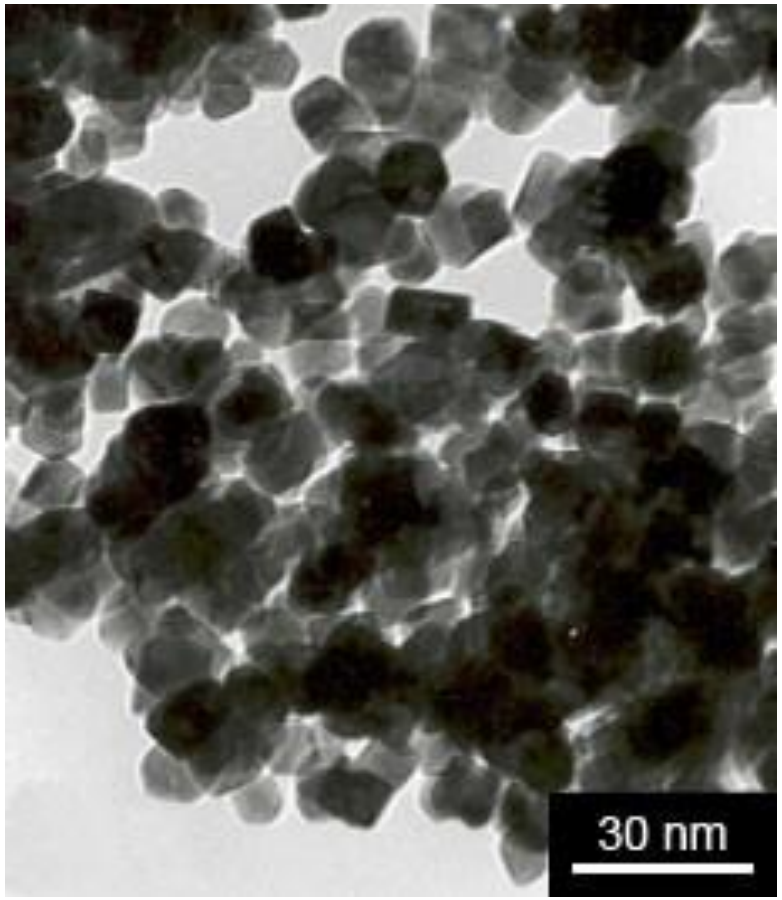
Cremes made of nanoparticles:
http://product.statnano.com/industry/skin_care/product



TiO_2
Nanoparticles

Solution to problem A

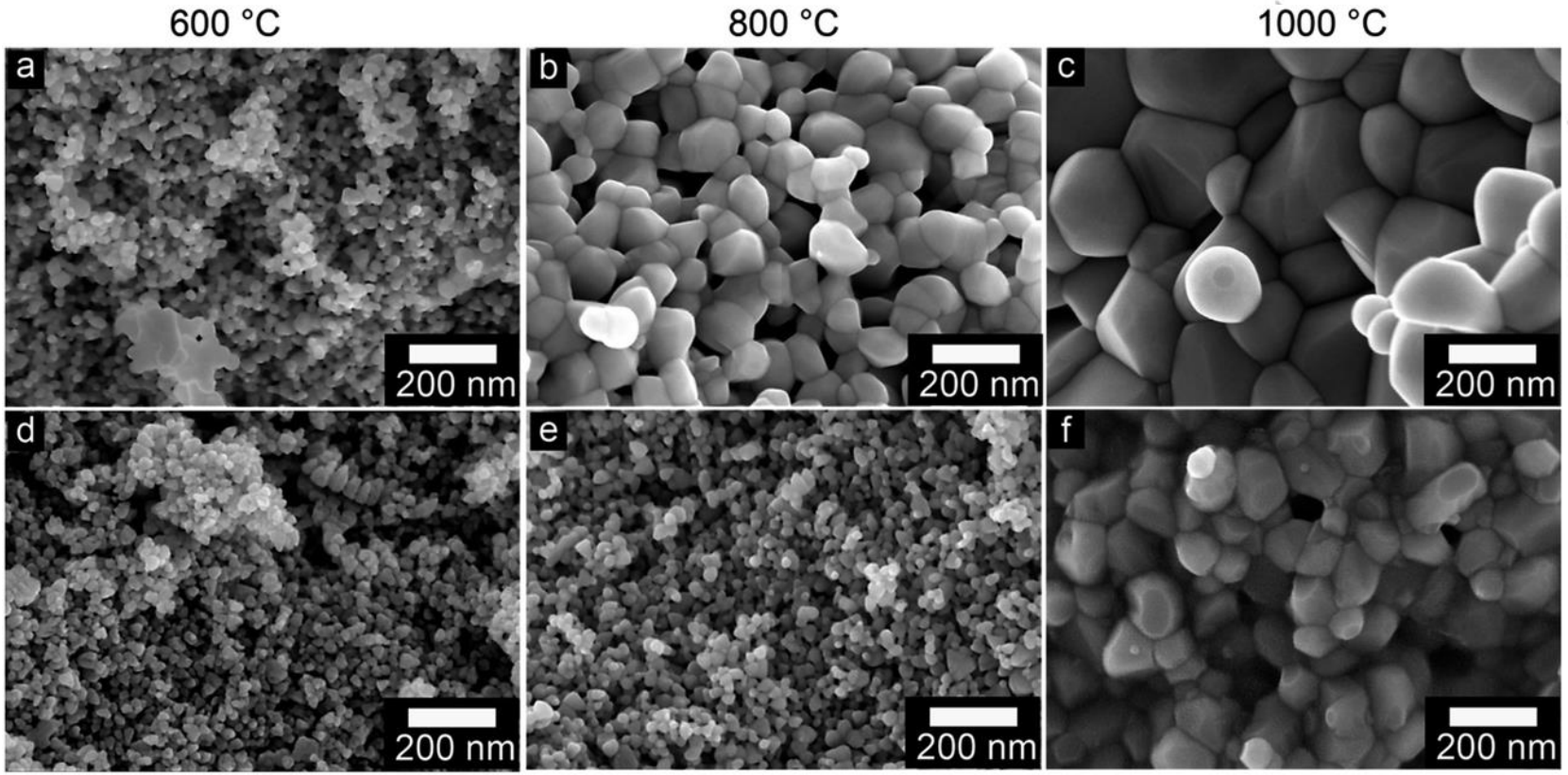
Cremes made of nanoparticles:
http://product.statnano.com/industry/skin_care/product



TiO_2
Nanoparticles
15 nm diameter

Solution to problem A

Cremes made of nanoparticles:
http://product.statnano.com/industry/skin_care/product



ZnO Nanoparticles

Solution to problem A

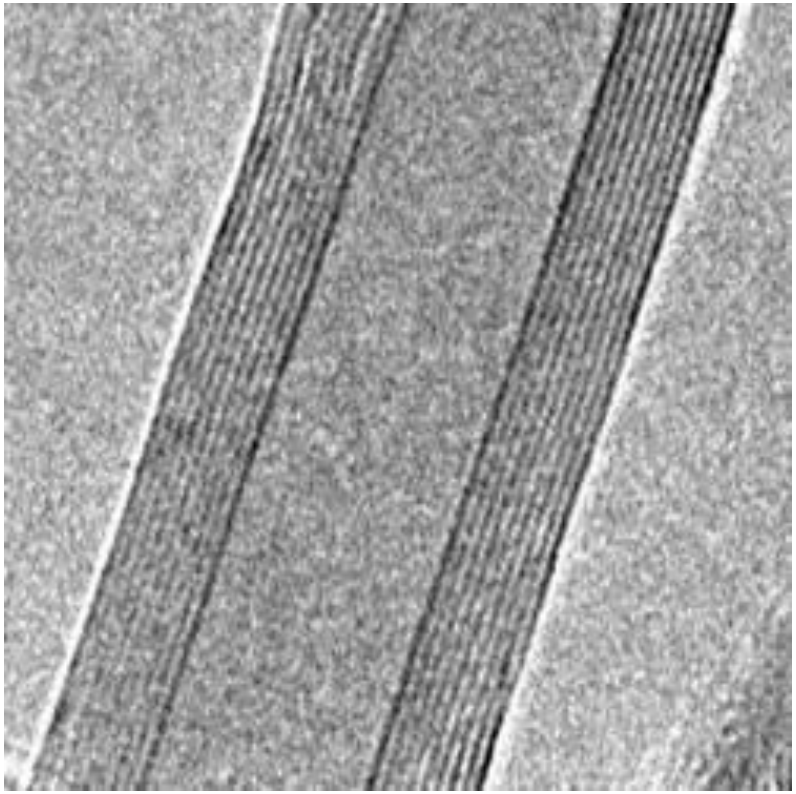
Raquets made of carbon nanotubes.
http://product.statnano.com/industry/tennis/product

Solution to problem A

Raquets made of carbon nanotubes.
http://product.statnano.com/industry/tennis/product

Solution to problem A

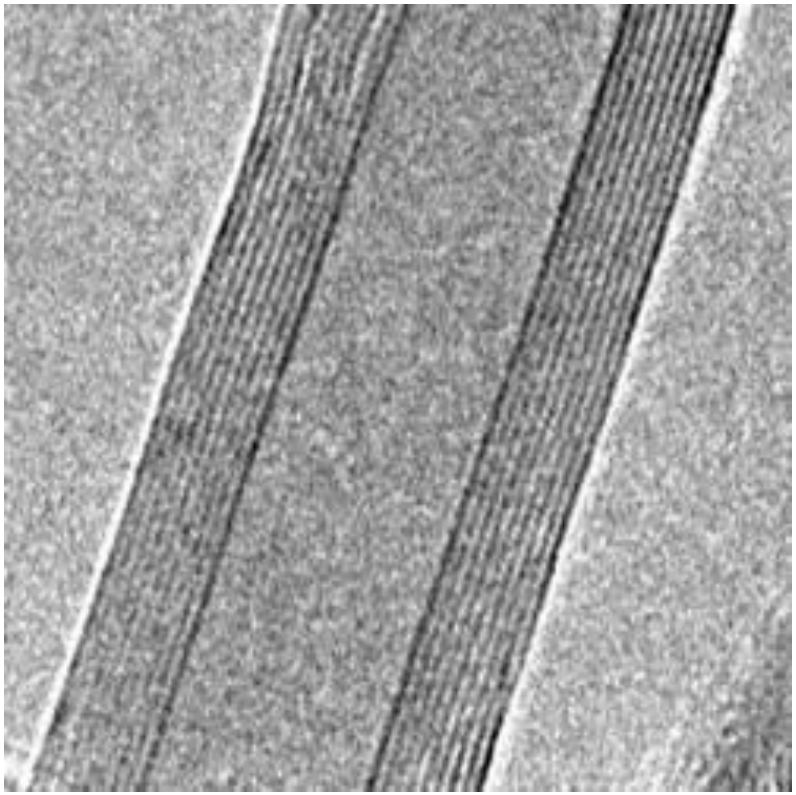
Raquets made of carbon nanotubes.
http://product.statnano.com/industry/tennis/product



Carbon nanotube.

Solution to problem A

Raquets made of carbon nanotubes.
http://product.statnano.com/industry/tennis/product



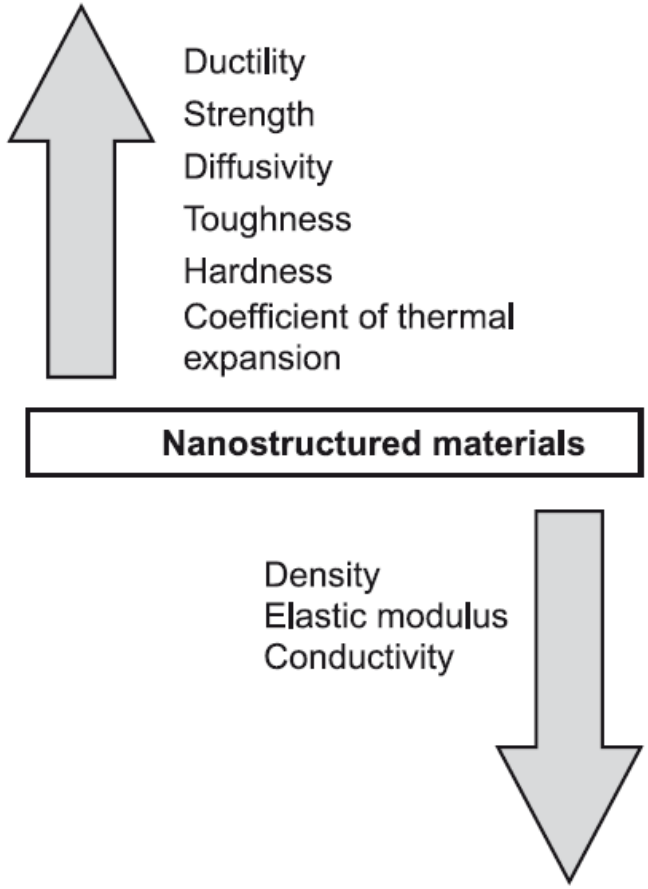
Carbon nanotube. 10 nm inner diameter, 9 concentric walls, and a clear inner channel.

Properties:nano makes a difference?

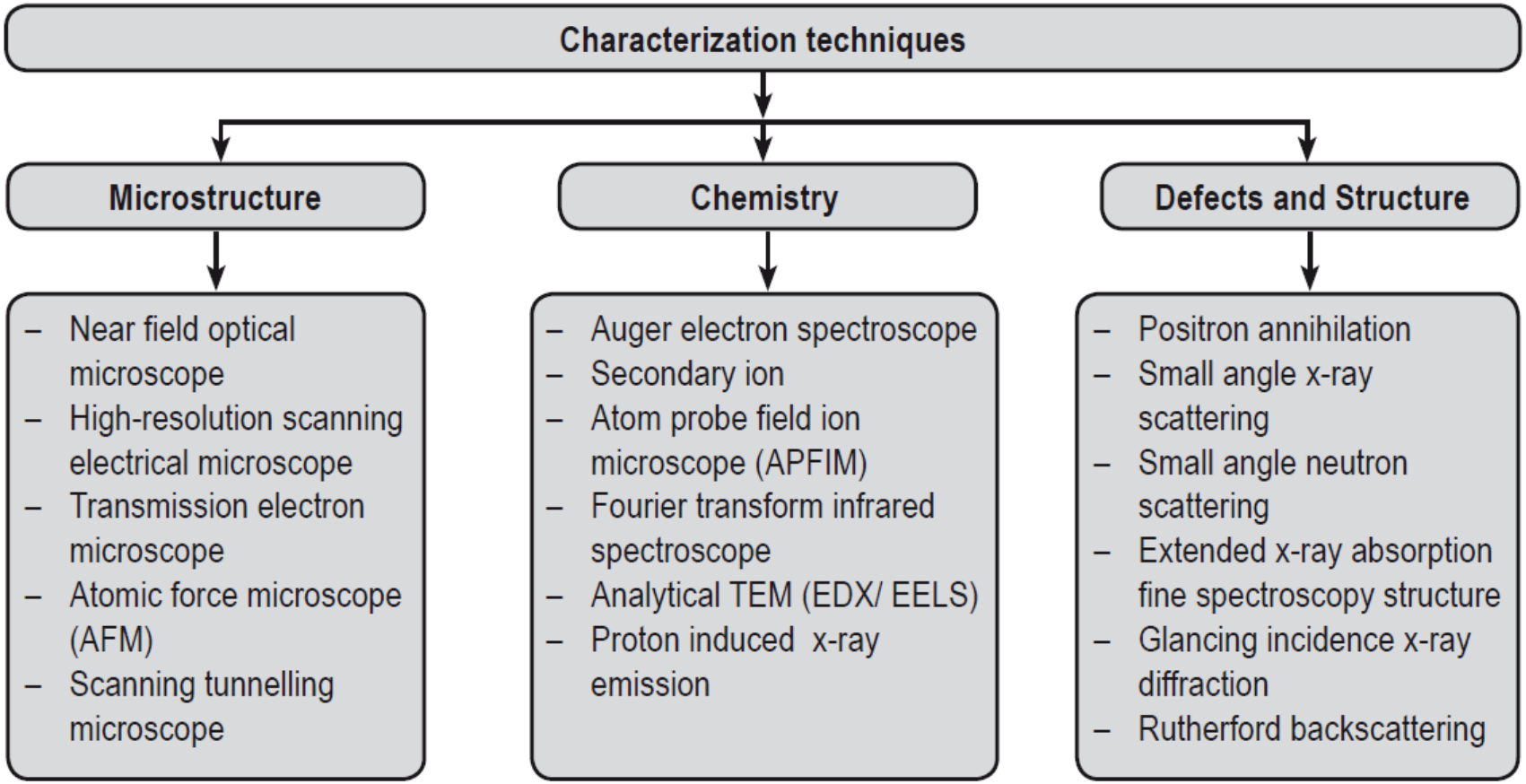
Table 1.2 Change in properties of Ni as grain size is changed from 10 μm to 10 nm

Property	Change in property in comparison to bulk
Hardness	5 times increase
Strength	3–10 times increase
Wear resistance	170 times increase
Frictional coefficient	Reduced to half
Corrosion resistance	Reduced or localised corrosion is stopped
Magnetic properties	Lower coercivity, saturation magnetisation reduced by 5%
Electrical properties	Resistivity increased by 3 times
Hydrogen diffusion	Higher
Electrocatalytic properties	Improved electrocatalytic activities for hydrogen evolution

Properties:nano makes a difference?



How do we characterize nanomaterials?



Applications of nanomaterials

- Electronic devices
- Renewable energy
- Catalysis
- Medicine
- Sports
- Food

Nature: the best Nanotechnologist

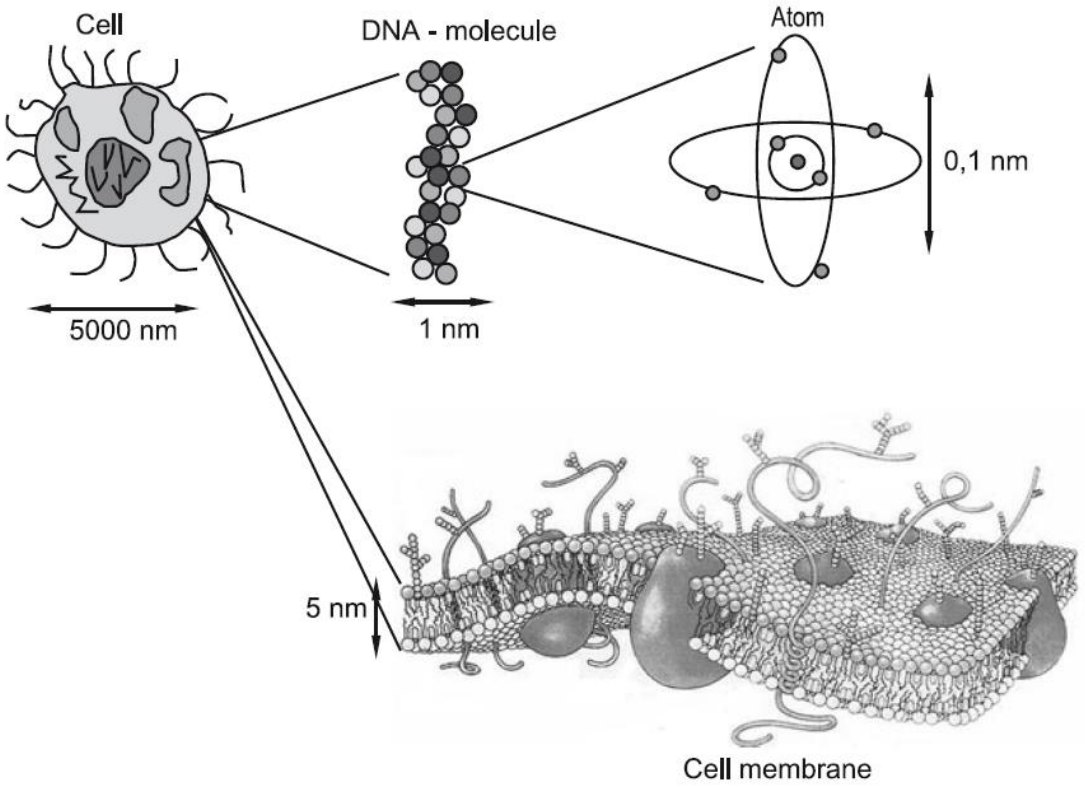


Fig. 1.19 Nanotechnology in nature. Biological features such as DNA, cells and membranes are of nanoscale.

Nature: the best Nanotechnologist

Fig. 1.20 Spider's web: It is not only aesthetically pleasing but is also a biological wonder as the fibres of the web are the strongest known fibres—until the carbon nanotubes were discovered. (*Source:* http://commons.wikimedia.org/wiki/File: SpiderWeb.jpg).

Concerns and challenges of Nanotechnology

Table 7.1 Possible diseases that can affect different parts of the body owing to nanoparticles

Brain	Alzheimers & Parkinson's disease
Lungs	Cancer, asthma, bronchitis
Gastrointestinal system	Colon cancer
Circulation	Blood pressure, thrombus, vasoconstriction
Skin	Dermatitis, auto-immune disease
Lymphatic system	Sarcoma

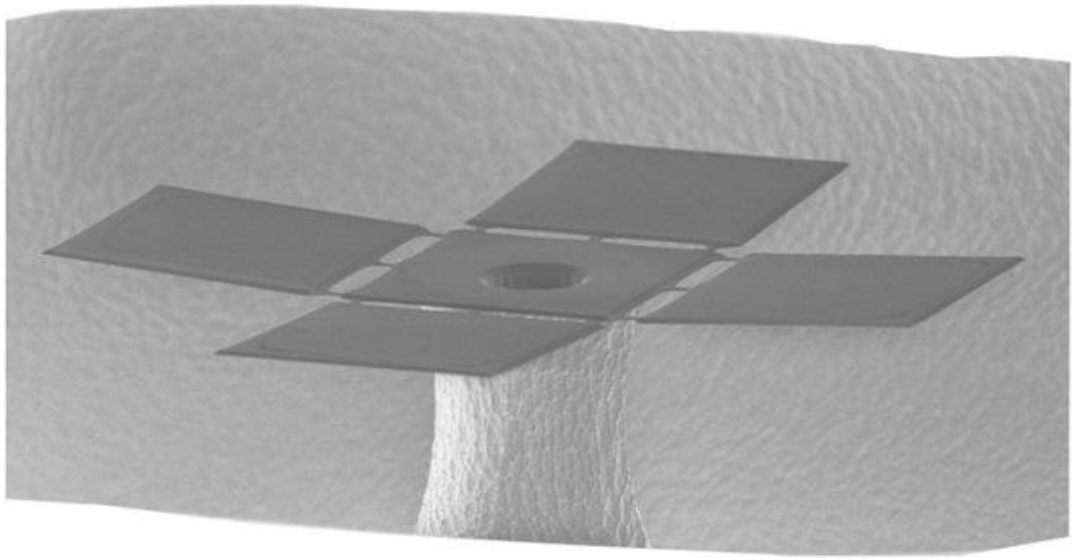
RRI and ELSA: Responsible Research and Inovation (RRI) and ethical, legal, and social aspects (ELSA)

Ecological aspects

Will a superelastic battery that can stretch up to 600 percent someday power our pants?

- https://www.youtube.com/watch?v=g2P57NreeSI

Silicon nitride origami—making self-assembling 3D microstructures using water



- https://www.youtube.com/watch?v=W53lyLH1Upg

Next time:

- Starting chapter 2 in “Textbook of Nanoscience and Nanotechnology”:

Unique properties of Nanomaterials