Concepts in Materials Science I

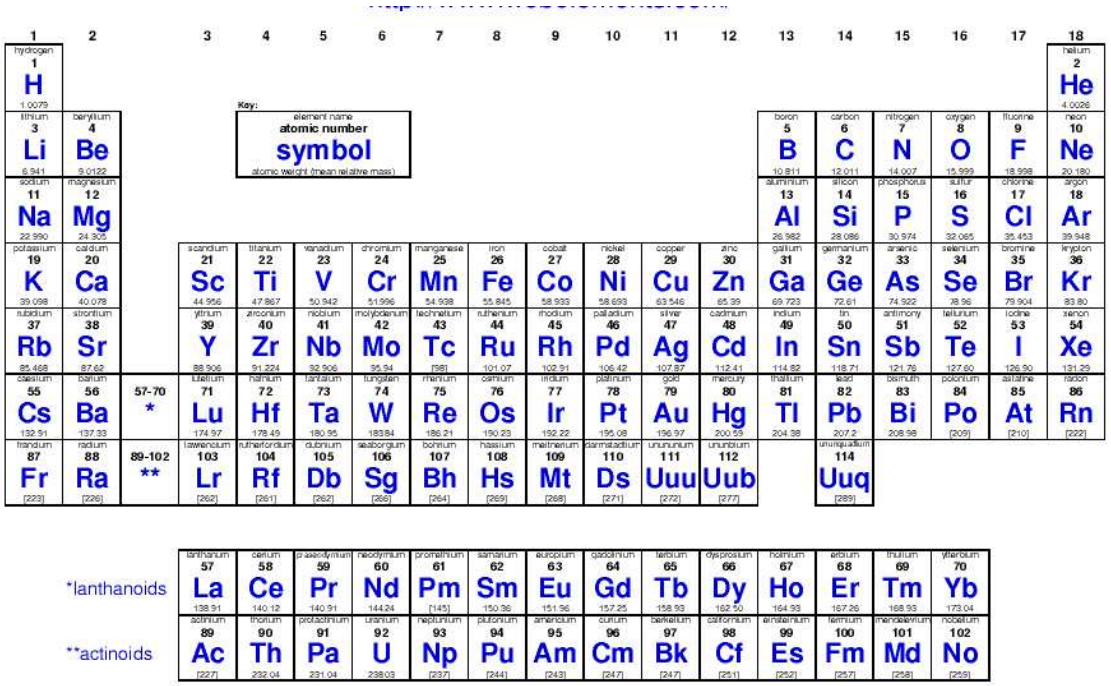
Why Bother?

- **Almost any technology finally boils down to having appropriate materials**
- **Eg. Space, Nuclear Power, Electronics, Medicine etc..**
- **Materials Science is the broad area that deals with design, synthesis, characterization and processing of materials**
- **And, most importantly, its INTERESTING!**

Aim of The Course

- **Understand basic science behind material properties**
- **Quantum and Statistical Mechanics**
- **Strong emphasis on applications to materials**
- **...**
- **Design, make and test materials!**

Raw Materials and Products



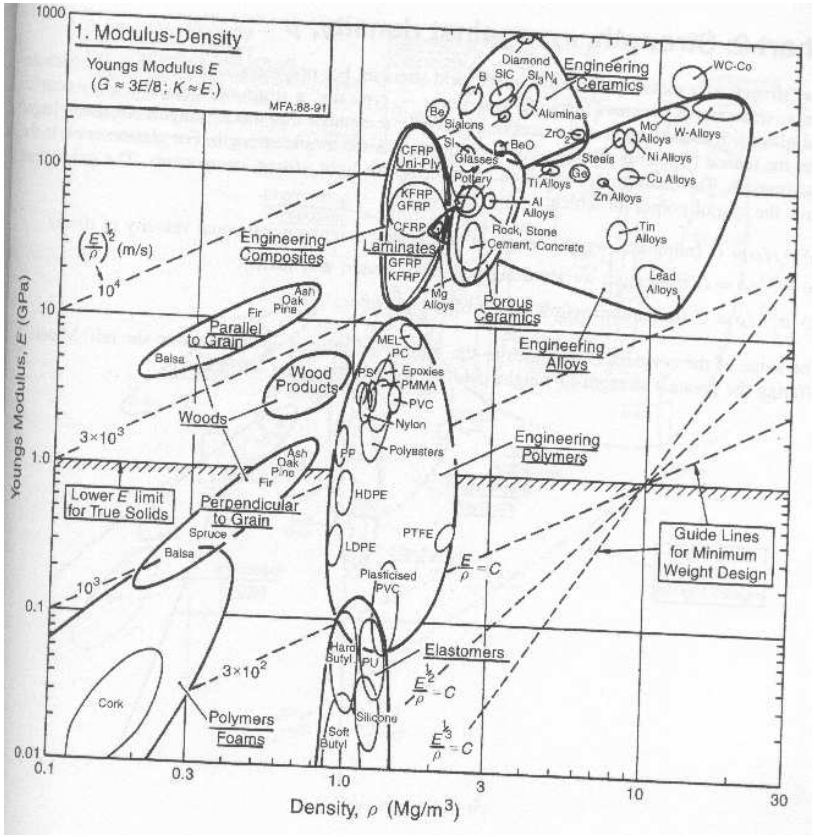
- **Periodic Table – Our "Raw Material".**
- **Material : Atoms arranged in a particular way to achieve desired properties**
- **Material science can otherwise be called as "Atom-Arrangement Science"!!**

Material Properties and Atom Arrangement

- **Material Properties (Rough Classification)**
  - **Electrical Properties**
  - **Magnetic Properties**
  - **Mechanical Properties**
  - **Thermal Properties**
  - **Optical Properties**
- **The central question of Materials Science:**
  Which atoms?
  And, how should they be arranged to obtain desired properties?

Extending the Boundaries....

- **Elastic Stiffness vs. Density**

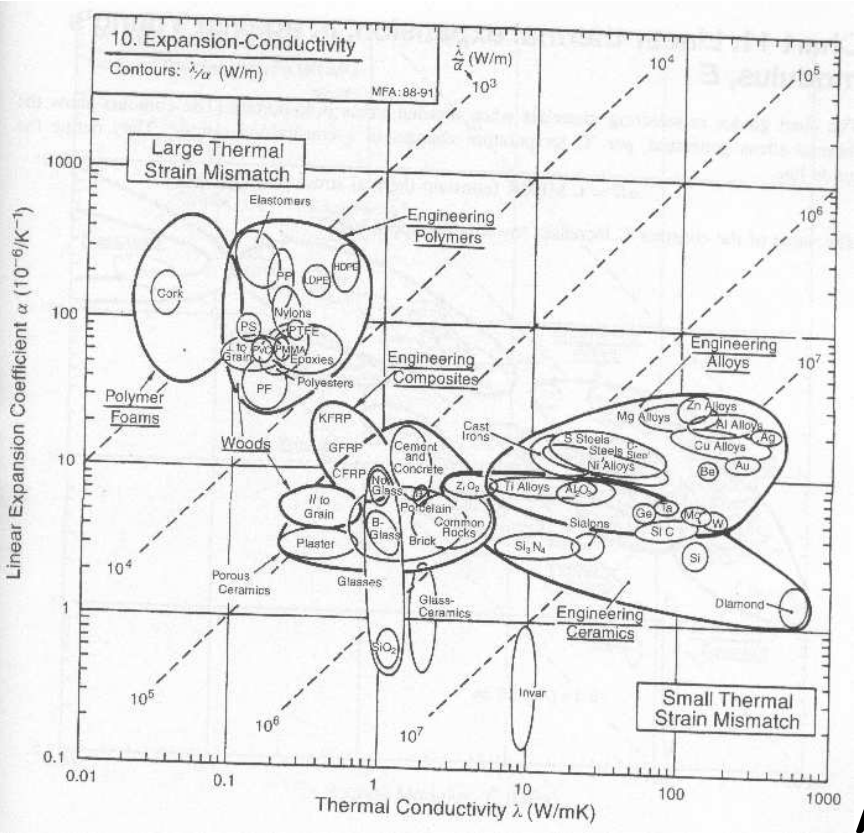


Ashby

- **Materials Question: Design a material with Elastic Stiffness of 10000GPa**

Extending the Boundaries....

- **Thermal Expansion vs. Thermal Conductivity**



Ashby

- **Materials Question: Design a material with Thermal Conductivity greater than 10000 W/mK**

More Materials Questions...

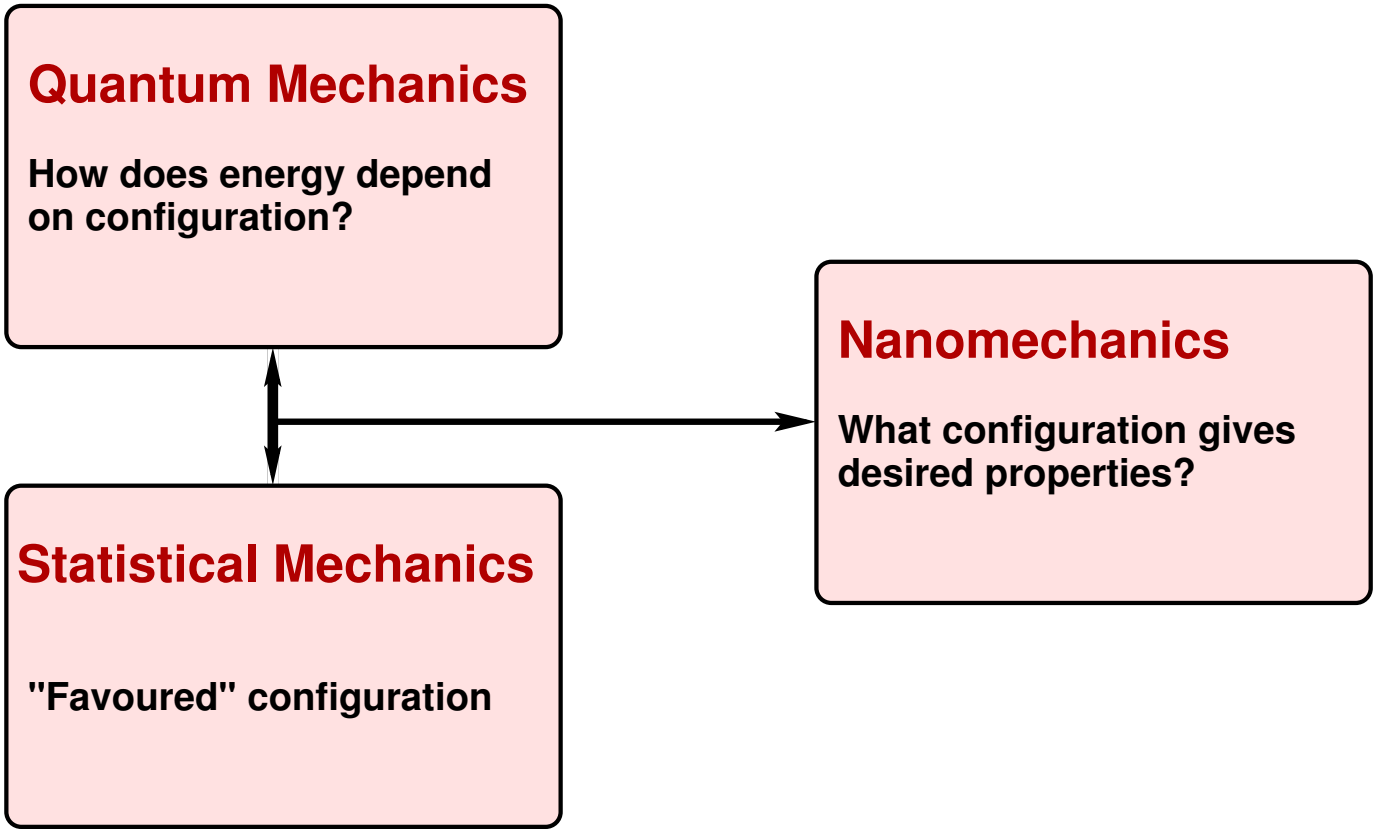
- **Transparent Ferromagnet**
- **Ferromagnetic and Ferroelectric Material (Multiferroics!)**
- **Biofriendly Materials**
- **Self Cleaning Adhesives**
- **...**
- **What is your question?**

Why Quantum Mech.? And Stat. Mech.?

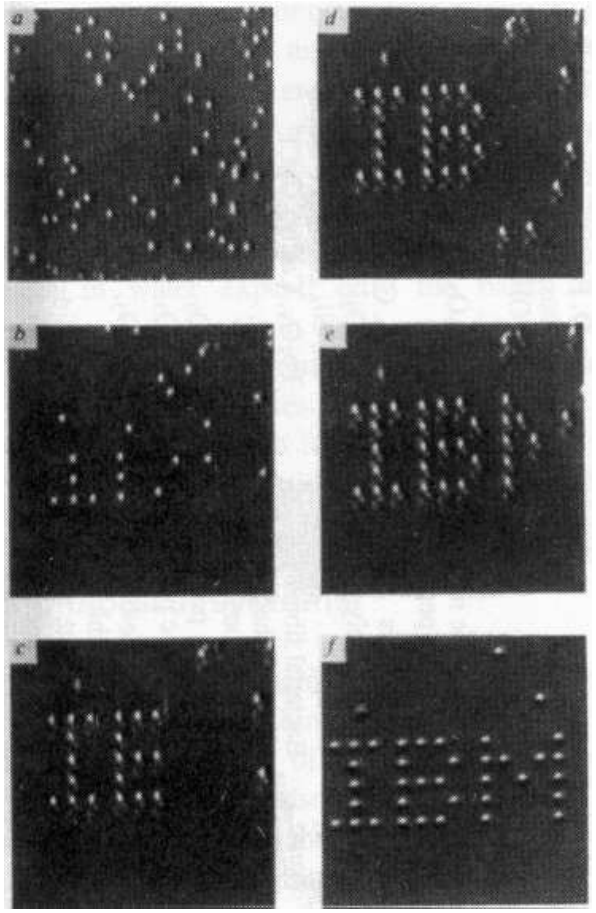
- **Thats what Nature does!**
- **Most(All) material properties can be traced to electrons**
- **Much of 20th century technology exploits quantum mechanics**
- **...**
- **To know when to be astonished with a purpose in view!**
- **And, because accident favours the prepared mind!**

The Grand Scheme!

- Material: Atoms in a particular configuration
- Properties: Which atoms? What configuration?
- The Scheme of Materials Design



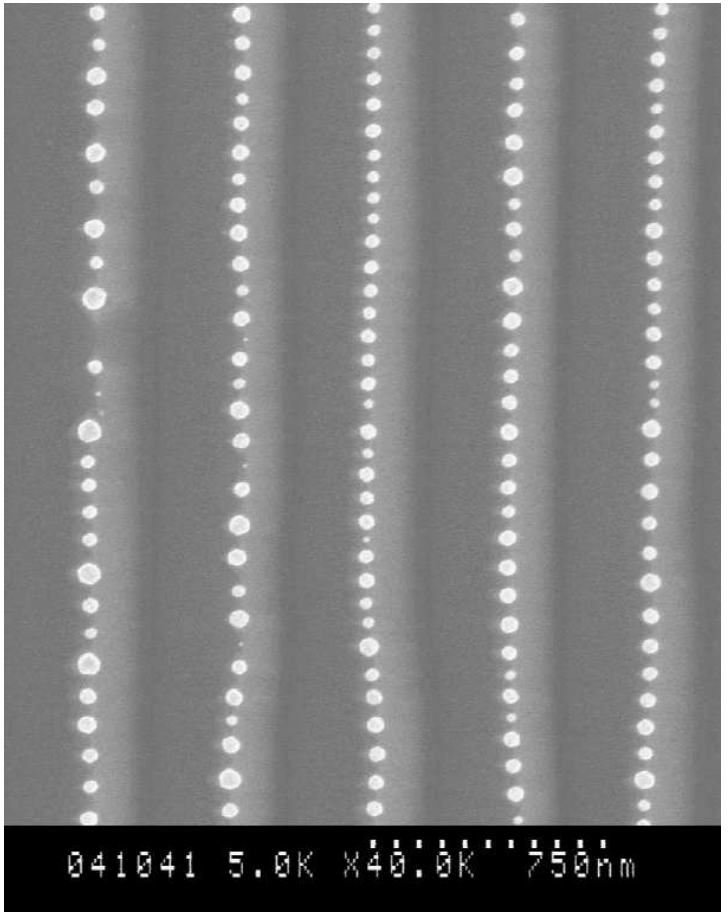
So, Where are we now?



Eigler et al.

- **Individual atoms can be manipulated**

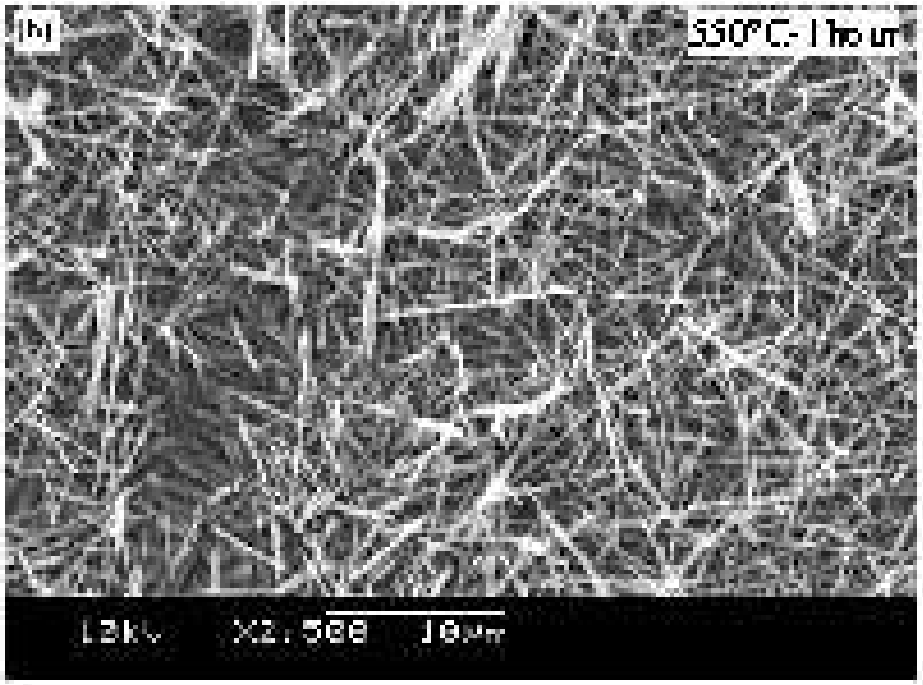
So, Where are we now?

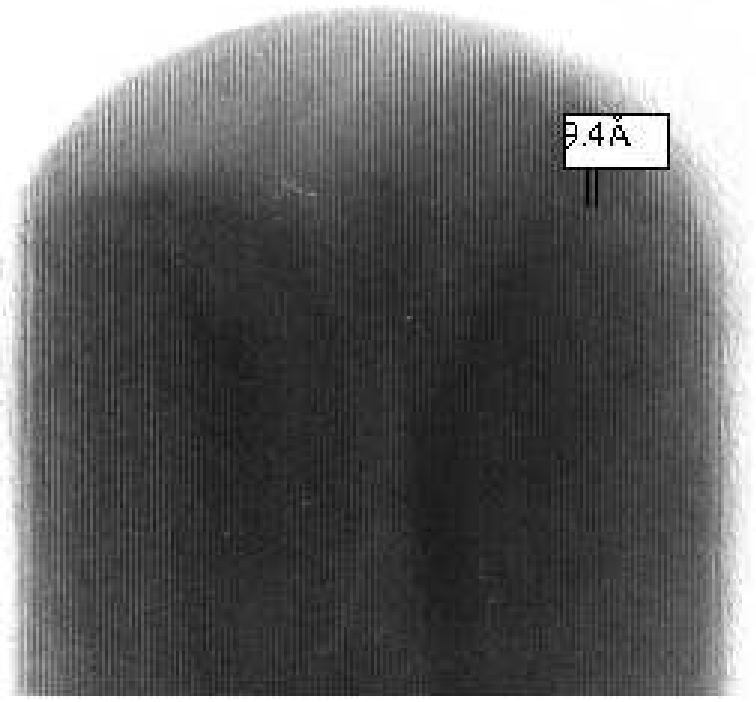


Ravishankar and Carter

- **Clumps of atoms can be manipulated**

So, Where are we now?





Sahana and Shivashankar

- **Nanowires can be grown!**

Well, How did all this start?

- India has a rich tradition in materials – Chandra Pillar
- First department of "Materials Science" – Northwestern University, Illinois, USA, 1957
- Early Encouragement:
  - "I consider it harmful when younger physicists become accustomed to order-of-magnitude physics. The residual resistivity is a dirt effect, and one shouldn't wallow in dirt!" – Pauli 1933
  - "The physics department at Columbia University will never occupy itself with the physics of dirt" – Rabi 1940
- MRC started in 1977

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And a thought for the day...and years...

उद्यमेन हि सिध्यन्ति कर्याणि न मनोरथै ।
न हि सुप्तस्य सिंहस्य प्रविशन्ति मुखे मृगाः ॥

Happy Atom Arrangement! (HAA...)