appeared in 2003

Science of the littlest things

Science of very small dimensions has come of age, says, S.Ananthanarayanan.

The early atomic theory was more a philosophical sally, to resolve a semantic deadlock, than insight into the nature of matter.

The Greeks

The philosopher Heraclitus taught that things were constantly changing. Nothing was the same as it was a moment ago. ‘You cannot step into the same river twice”, he said. But the philosopher Parmenides said change was impossible. This was because change implied a split second when a thing was neither one nor the other! This led to the theory that nothing that changes could be real!

Democritus, in the 5th Century BC, found a way out. He said all matter was composed of tiny indestructible units, called atoms. The atoms themselves remained unchanged. But all things were made up of atoms in motion and constantly in change. This took care of both Parmenides and Heraclitus. There was peace, but not science, not as yet.

Dalton does his bit

In the early 1800s, John Dalton noticed that that elements combined in fixed ratios (by weight) to form compounds. This led to the idea that the combinations may be among the same numbers of tiny units of the elements and the atomic theory was reborn, as perhaps the most important discovery of all science.

The atomic theory turned the attention of scientists towards the very small. By using the atomic theory to explain the way gases, liquids and solids behaved, scientists could work out more properties of the atoms. This was through deduction, without conceivable chance of actually seeing atoms!

The scale of atoms

The science of microscopy, with lenses of glass, developed and revealed a universe of life forms behind the curtain of unaided sight. Later, microscopy with special lenses and using ultra-violet light or X Rays opened up an even more microscopic world. But it was clear that these methods could not help see things so small as atoms. The advance of science had otherwise shown that the atom itself consisted of parts thousands of times smaller than itself. And even those parts had minute structure.

Science in the last many decades has consisted to deducing the structure of atoms and their nuclei and the forces that act at the very small distances inside atomic nuclei. At a different level, science could work on materials at nearly the level of groups of atoms.

Electronics spurred the idea of packing massive, room-size assemblies into the dimensions of a postage stamp. This was still not at the ‘atom scale’. Real atom scale work began with creating super-strong materials with the help of ‘giant molecules’. This was again a case of atoms ‘sizing up’, rather than materials ‘sizing down’. A closer step was with using the carbon atom to form ‘nano-tubes’. The carbon atom combines with other atoms using four bonds, unlike most other elements, which use one or two. If carbon is vaporized and allowed to settle under special conditions, millions of carbon atoms form closed patterns, like cylinders. These are the nano-tubes, through which materials or high frequency radio waves can be guided.

How far we have got

UV and X Ray microscopy are effective because they use light of very short wavelength. Even tiny particles can display ‘wave-like’ behaviour. A beam of electrons can work like waves of exceedingly short wavelength. Microscopes using electrons can very nearly image atom-scale deformities in materials. Another method developed is to scan a surface with a very fine electrode, without actually touching the surface. At the points where there are bumps on the surface, there is a tiny fluctuation in the electric current that is able to leak across the gap. The method, which works at low temperatures for now, is able to detect bumps of the order of atoms.