

## *How Nanotech Is It? (Draft)*

### (1) Assembly Method

This is probably the single most important attribute that we can use to measure whether a technology, product, or process is nanotechnology. Nanotechnology is not just the design and manufacture of small structure, but the assembly of those structures from the *bottom up*. The main inspiration here is from biological systems. We want to build small structures as DNA is used to build proteins: component by component.

Though the direction from which we assemble seems to now be a well-defined notion, there are many situations where a technology is neither clearly TOP-DOWN or BOTTOM-UP. For example, modern photolithography may at first seem like a BOTTOM-UP procedure, since we built our integrated circuit layer by layer. However, even though there is a layering/depositing of materials, this only takes place after a strong light source has *broken away* the unwanted parts of the wafer. Since this “breaking away” is the primary means by which the circuit structure is created, we must place photolithography in the TOP-DOWN category.

### (2) Dimensions Controlled

Just because a process assembles small structures, there must be a minimum of one dimension controlled. We can make suspensions of gold particles or buckeyballs in a fluid, but this is, by itself, is not nanotechnology. We must create at least a wire (or cylindrical structure) to have true nanotechnology.

The actual manufacturing process for this need not be deterministically precise. We don't need a deterministic enzyme to walk along a strand of DNA and attach an amino acids at each step. We can have a randomized method of manufacturing where we sift out the successes from the failures. For example, for carbon nanotubes, we use a laser and a graphite substrate to create a mesh of different sized tubes. Note that even though we cannot control the formation of each tube individually, the formation is still BOTTOM-UP. Each carbon nanotube is constructed from individual atoms.

### (3) Homogeneity

Unlike the above two, this attribute was selected because it matches so well with the popular vision of nanotechnology. No specific homogeneity index is required for a component to nanotechnology, but a “more heterogeneous” structure can be regarded as “more nanotech.”

We can measure the homogeneity index as a number from 0 (perfectly homogeneous, like a carbon nanotube) to 1 (a living cell). Most technologies being developed today try to focus on regularly structured arrays, where each component can be two or three types of atoms. The best illustration of this is the DRAM memory chip. We have a regular array of dynamic memory cells, each of which is non-homogeneous. This type of structure should be given a homogeneity index between 0 and 1, where the index gets larger as the number of atom-types per unit increases.