Nanotechnology and Opportunities in Digital Color Printing

Kock-Yee Law, Xerox Research Center Webster, NY, USA

What is Nanotechnology?

The prefix "nano" originates from Greek. It stands for 10^{-9} of something and can be used with time, dimension, weight, energy, power and so on. The term Nanotechnology is not a descriptor for any branch of technology; rather, it is a frontier for understanding and control of matter at dimensions of roughly 1 to 100 nanometers, where unique phenomena enable novel applications. Nanotechnology encompasses nano scale science, engineering and technology, involving imaging, measuring, modeling and manipulation of matter at the nanometer scale. At this level, due to quantum confinement effect and the extraordinary aspect ratio and surface area, the physical, chemical, and biological properties of materials differ in fundamental and valuable ways from the properties of individual atoms or bulk matter.

History of Nanotechnology

The concept of possible unique phenomenon in the nano scale can be traced back to a lecture delivered by Richard P. Feynman in the annual meeting for the American Physical Society in 1959 at California Institute of Technology [1]. He asserted that "the principles of physics, as far as I can see, do not speak against the possibility of maneuvering things atom by atom. It is not an attempt to violate any laws; it is something, in principle, that can be done; but in practice, it has not been done because we are too big". In fact, he went on and asked, "…… can we not write the entire 24 volumes of the Encyclopedia Britannica on the head of a pin?" He proceeded to calculate that there was actually plenty of room on the pin if one can use dots made of 32 atoms across. In my opinion, this has to be the first description of marking in the nano scale!

The challenge of knowing whether you are reaching down to the nano scale or not lie in your ability of seeing and measuring things in that scale. This technical barrier started to come down in 1982 with the invention of the scanning tunneling microscope (STM) by Gerd Binnig and Heinrich Rohrer at the IBM Zurich Research Laboratory [2]. STM revolutionized our ability to image and subsequently manipulate atoms on a solid surface. This along with the advent of a variety of force microscopes, high resolution scanning & transmission electron microscopes, and high-speed data processing in the last twenty years have allowed detecting and seeing atoms routinely and contribute greatly to the rapidly development of Nanotechnology.

The discovery of C60 (Buckminsterfullerene, Bulky ball) in 1985 also contributed to some excitement of the early Nanotechnology movement [3]. In the early 90s, the attention switched to carbon nanotubes shortly after it was discovered (or re-discovered) [4,5]. The field just took off when larger amount of "pure" carbon nanotube became available for investigations. Carbon nanotube has been a subject of a few reviews and books since. To date, the unique properties of carbon nanotubes, being strong mechanically, electrically and thermally conductive while possessing novel magnetic, field emitting and optical & electronic properties, have been validated experimentally. A variety of applications, ranging from fillers in sporting goods and automobiles to high-tech devices like transistors, display, to nanoelectronic devices, have been reported. Concurrently, a variety of nanomaterials/nanostructures, such as quantum dots, nanowires, dendrimers, organic-inorganic hybrid (sol gel) materials, various metal & metal oxide nanoparticles and polymeric nanocomposites with molecular tailoring structure and morphology, have been maturing. This along with the miniaturization of the transistor from micron-scale down to 65 – 32 nm scale, where the application of Nanotechnology in transistor design, architecture and manufacturing, is essential, and the merging with biotechnology have created a multi dimensional, gigantic R&D arena called Nanotechnology. In a sense, Nanotechnology is the frontier for science, engineering and technology without border and with a lot of cross-talks. Some economists/politicians/scientists hypothesize that Nanotechnology is in the process of triggering the next industrial revolution since the computer.

Recognizing the importance and potential impact of Nanotechnology to future society and economy, the US federal government had convened a small group of researchers to plot out a long term strategy for what eventually became known as the National Nanotechnology Initiative (NNI) [6]. The R&D funding from the US government in the last decade is plotted in Figure 1.

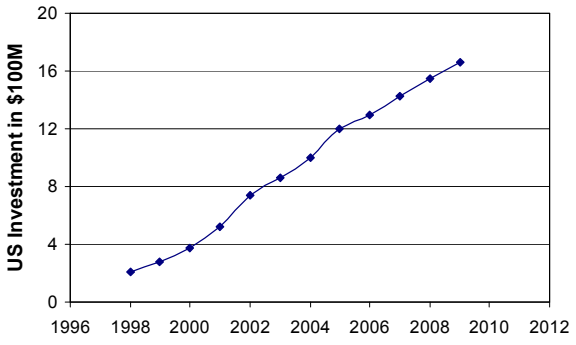
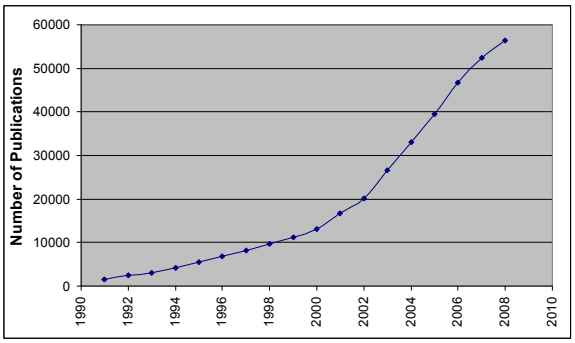


***Figure 1**. Plot of US federal government R&D funding in the last decade (source: www.nano.gov/)*

Globally, many countries have followed the US lead and invest heavily in Nanotechnology, particularly Japan and Western Europe countries. Expectedly, private industries also invest enthusiastically and this global R&D investments have resulted in a tremendous growth in intellectual properties and technical capability worldwide. Figure 2 plots the number of English publications and US patents (granted and applications filed) during this period and the growth has been exponential in the last decade.

(a)



(b)

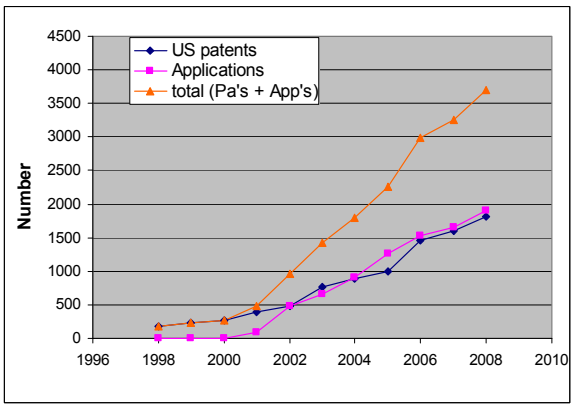


***Figure 2**. Plots of (a) English publications and (b) US patents granted and filed in Nanotechnology in the last decade.*

Opportunities for the Printing Industry

It is generally recognized that people print less and less and the key question we ask ourselves is "will the market still out there in the next 10 years?". Figure 3 shows a plot from a market study by the Caslon & Company. Their study revealed that, although the number of printing pages is declining steadily, the color digital printing market will grow healthy in the next decade.

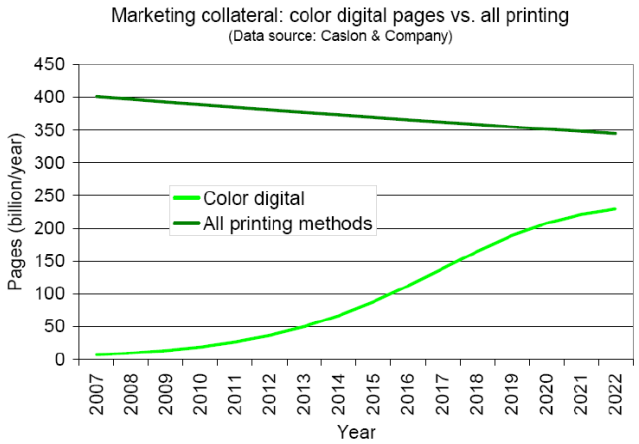


***Figure 3**. Plot of printing pages market forecast in the next decade.*

Now when we assessing the capability, the following is a summary of opportunities for Nanotechnology:

Nanomaterials and nanocomposites
- stronger and lighter
- multi functional
- beyond conventional

Nano surfaces & coatings
- easy clean, self clean
- offset free release

Green
- beyond energy star
- sustainability (long life & recyclability)

Smart devices
- self healing
- self maintain & self help
- security

Tools and modeling

In this presentation, a specific example is given around model nanostructured surfaces that are created by the photolithographic technique [8]. These nanostructured surfaces are superoleophobic, specifically they repel both water and oil with extremely high contact angles (~ 160°). Both toner and ink were found to have extremely high contact angles too. The tremendous performance advantage in using this kind of nanostructured surface in fusing is discussed.

References

[1] R. Feynman, "Plenty of Room at the Bottom", Engineering and Science, California Institute of Technology, February (1960).

[2] G. Binnig, H. Rohrer, Ch. Gerber, and E. Weibel, Appl. Phys. Lett., Vol. 40, 178 (1982); and Phys. Rev. Lett., Vol. 49 57 (1982).

[3] H. W. Kroto, J. R. Heath, S. C. O'Brien, R. F. Curl, and R. E. Smalley, Nature, Vol. 318, 162 (1985).

[4] S. Iijima and co-workers in the NEC lab have been generally credited for the discovery of the singe-walled and multi-walled carbon nanotubes due to their excellent characterization of these materials [5]. However, prior to the Iijima studies, carbon tubes that are in the "nanometer" dimensions have been reported in the literature.

[5] S. Iijima, Nature, Vol. 354, 56 (1991); and S. Iijima and T. Ichlhashi, Nature, Vol. 363, 603 (1993).

[6] The URL for all the NNIs, including the "NNI Supplement to the President's 2010 Budget" can be found at: http://www.nano.gov/.

[7] Forecast 2006: The North American Production Digital Printing Market, Caslon & Company.

[8] K.Y. Law and H. Zhao, Design and properties of micro/ nanostructured surfaces for digital color printing, invited presentation at the 237th ACS National Meeting, Salt Lake City, UT, March 22-26, 2009.

Author Biography

Kock-Yee Law received his BS in chemistry from The Chinese University of Hong Kong (1974) and his PhD in photo-organic chemistry from The University of Western Ontario (1978). He has been at Xerox Webster for over 28 years and he is currently a technical manager in the Xerox Innovation Group responsible for the development and delivery of Nanotechnology for the future.