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Nanopatenting patterns in relation to product life cycle

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Abstract

This paper compares the positions of national nanotechnology development efforts based on analyses of patenting from 1994 to 2005. Searching Derwent world patent index files, 19,351 unique patents are collected based on a composite search algorithm. These abstract records are categorized multiple ways — by top patent assignees, by International Patent Classifications, and through content analyses of the "Use" subfield. We classify the R&D activities by using a 3-stage, life cycle, value chain of nano-raw materials, nanointermediates, and nano-products. Profiles of Japanese, American (US), and European (German) emphases show notable differences in concentration and value chain niche. Such characterizations offer significant research management and policy implications.

Keywords: Nanotechnology; Foresight; Patent analysis; Value chain; Innovation management; Text mining; Technical intelligence; Future-oriented technology analyses

1. Introduction

Nanotechnology involves the construction and use of functional structures designed on a molecular scale, with at least one dimension measured in nanometers. On this scale, due mainly to quantum[1] or

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[1] Also called quantum confinement, this refers to the effect caused by the small numbers of atoms which limits the movement of electrons, generating new physical properties in the material.

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surface[2] effects, the physical, chemical, and biological properties of the materials are significantly altered.

From an economic perspective, nanotechnology is currently one of the major foci of research, development, and innovation activities in all industrialized countries [1]. Over the last 8 years, according to Roco [2], global government investment in this area has increased nine-fold: from $432 million in 1997 to about $4.1 billion in 2005. The United States, Japan, and the European Union are investing comparable annual amounts of about $1 billion US (2005) for nanotechnology R&D. The rapid pace at which nanotechnology is moving forward is probably the main reason that it has come to the attention of almost every policy maker and senior manager [3,4].

Although some nanotechnology products have been on the market for several years, it is evident that the society-wide discussion of the advantages and risks of nanotechnology is still at the initial stage. Nonetheless it is clear that the technology draws upon multiple research domains and will affect multiple sectors. Nanotechnology is both "enabling" and "horizontal." According to Grupp [5], enabling technologies are prerequisites for other technologies, products, and processes. Nanotechnology is also a horizontal technology, as it makes possible applications in a number of sectors.

Some authors discuss the disruptive nature of nanotechnology — *e.g*. Walsh and Linston [6] and Kostoff et al. [7]. According to Bower and Christensen [8] when the use of a technology creates products with different performance attributes that may not have been valued by existing customers, it could be called disruptive. Some scientific discoveries alter a technological paradigm to a new competitive one [9–11]. In recent literature, some authors propose methods to identify the development of disruptive technologies. Kostoff et al. [7] state text mine of scientific literature for knowledge discovery to further commercial and governmental uses. Walsh [12] state suggests a model for disruptive technology roadmapping and Fleischer et al. [13] present a methodology to combine technology assessment with roadmapping.

We offer a three-stage, life-cycle framework to provide new perspectives on nano-development. It is based on the notion of a nanotechnology production chain proposed by Lux Research [14], a nanotechnology research and consulting company.[3] This chain is formed on the basis of the value added by the so-called "nano-raw materials," passing through "nanointermediates" and generating "nano-products." Nano-raw materials are any raw material whose nanometric scale confers specific properties to this dimension. Nanointermediates incorporate nano-raw materials, but are not yet aimed at the final user. Nano-products are products available in the market. This classification scheme will be further discussed in reference to the construction of a taxonomy (Section 6). As nanotechnology is "transverse" – involving different economic sectors – this approach seems appropriate. The use of three stages allows us to analyze the nanotechnology *via* a wide screen, without involving details specific to particular businesses.

Future-oriented technology analyses (technology foresight) model the future of a given object of study — *e.g*., a technology in this case. Such studies manipulate information derived using qualitative and/or quantitative techniques [15,16]. The present study was achieved by generating innovation indicators obtained through data and text mining [7,17,18].

The use of technological analyses to help understand the stages of nanotechnology's trajectory is of fundamental importance because the diverse actors involved – researchers, governments, companies and

[2] The surface effects are caused by the larger surface/volume ratio in nanoparticles interfering in chemical properties, as, for example, in reactivity.

[3] The concept of production chain, usual in business management, was introduced to the nanotechnology area by Lux Research. We adopt this construct for our nano analyses as well.