# From bench to business

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The process of transferring a laboratory discovery to the marketplace can sometimes seem like a black art. It doesn't have to be.

So you have a hot discovery, the paper has been published, and the patent has been filed. You may even have discussed setting up a business venture to exploit this advance with your University's technology-transfer office. But what are the chances of commercial success? The odds are seemingly stacked against you. Even in biomaterials — a field with a long history in technology transfer — less than 2% of new scientific ideas make the transition from the bench to profitable business. Can you hope to buck this trend? A better understanding of the many paths to commercialization is one step in the right direction. This is not a formula for predicting success — far from it — but taking a critical look at your innovation and understanding its most likely route to the marketplace is essential before you seek investment.

Academe, government and industry are under increasing pressures globally to justify their expenditures on research by linking scientific findings and technological advances with the generation of products leading to social benefits and economic growth. Consequently, there has been an increase in studies into the seemingly random process that leads from scientific discovery to commercialization. This has resulted in a realization that there are multiple paths from science to product. In the case of materials science, some of these paths are different from other fields. With the advent of wider public and industrial interest in nanotechnology, it is even more important to understand and categorize different types of innovations or advances to enable a more robust and swifter commercialization process.

## TYPES OF INNOVATION

Innovations can either involve new products or new processes to produce new (or existing) products. In the case of the service industry, it was suggested by Barras[1] in 1986 that process innovation, a change in the way a service is provided, occurs first, and only later are new products produced, and that these new

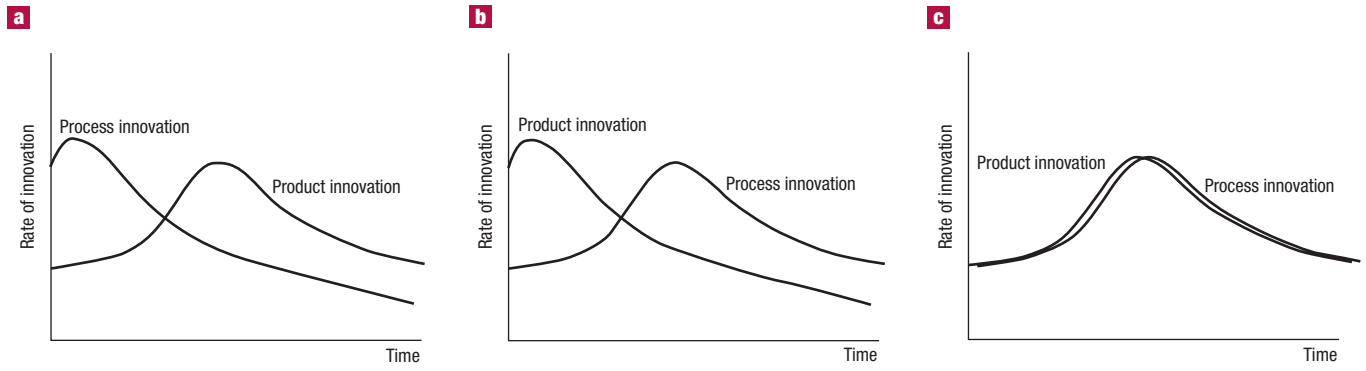


Figure 1 **Types and rates of innovation. a, Relationship between product and process innovation for services. b, Relationship between product and process innovation for products based on fabrication and assembly. c, Relationship between product and process innovation for materials-based products.**

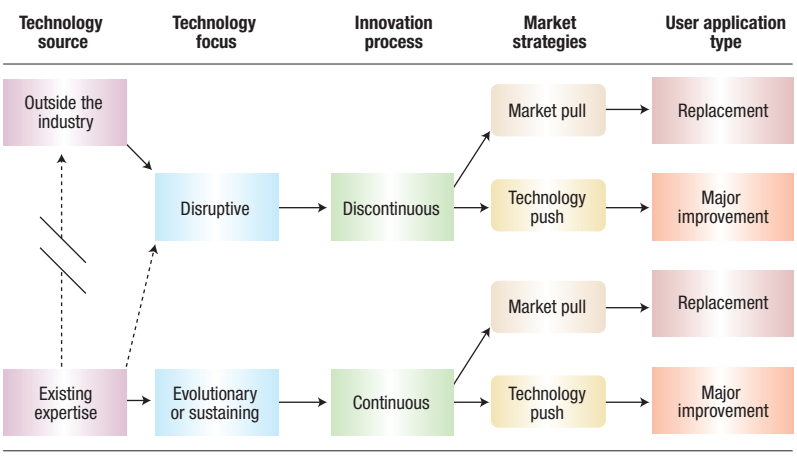


Figure 2 **Different paths for innovations to reach the marketplace. An important consideration for any commercialization process is understanding the role of market-pull and technology-push on new product introductions. (Figure based on ref. 4)**

products are dependent on the earlier process innovation (Fig. 1a). By contrast, for manufactured goods it has been suggested that product innovation typically leads to a mature design standard, and once this occurs the rate of innovation in product rapidly declines[2]. However, in this case, innovation in process design increases, as manufacturers attempt to reduce the cost of manufacture of the product (Fig. 1b). This is clearly the case for fabrication and assembly-based products, such as automobiles and computers.

For materials-based products, the relationship between process and product is different[3]. Product and process innovation are often simultaneous and interdependent, because the design of the material is inherent in the process that produces it. A change in process typically modifies at least some of the properties of the product as well as the cost of production (Fig. 1c). There are many examples from industry. We will briefly consider three of these; sheet glass made by the tin-float process, the continuous casting of steel, and semiconductor silicon wafers.

The manufacture of sheet glass was expensive until the tin-float process was developed. This process allowed for the production of glass with a very flat surface, and it immediately became possible to create new products that were not feasible with earlier processes.

## Box 1: A Case in Commercialization

Applying the market-pull/technology-push analysis to current materials products can lead to interesting observations. For example, Nanocrystals made by Nano Crystals Technology of Briarcliff Manor, New York, is an organophosphor-based material. These materials fluoresce based on the intensity of the radiation absorbed. As with other materials innovations, a change to the process modifies the product characteristics. The resolution offered by Nanocrystals is about 6 nm, which is two orders of magnitude greater than the current film-based diagnostic technology. Nanocrystals are being marketed as a replacement for X-ray films (see Fig. 2 market-pull, replacement product) based on a skill set from outside the existing industry. But because the improvement in resolution is so great, it is possible that there are additional technology-push applications, which have yet to be determined. **J.D.L & S.T.W**

Similarly, steel producers, such as the US firms Nucor and Chapparal, originally pioneered continuous casting of steel as a way of reducing costs by exploiting a cheap source material (scrap metal) and the production of near-net shape castings (with shapes very close to the final product). The result was improved material properties owing to the relatively small cross-sectional area of the casting. It also allowed manufacturers to use scrap metal with high levels of impurity because there was insufficient cooling time during casting for the impurities to migrate. Ultimately, this led to new products such as 'weathering steel' — that has a protective oxide coat for outdoor uses — from low grade/high copper scrap.

Last, but not least, is the example of silicon processing in the semiconductor industry. Since the advent of current semiconductor processing technologies, single silicon crystals have been sliced into 'wafers' with the initial intent of etching a single device onto each piece of silicon. As the process changed it became possible to grow larger crystals with lower impurity levels and improved planarity, with the result of creating silicon wafers of greater size. These larger wafers allow for the manufacture of greater numbers of smaller products comprised of circuits of increasing complexity and density.

In each of these three cases of advances in material-based innovation, product and process innovation went hand in hand. It is important to keep this relationship between product and process innovation in mind when considering the commercialization of advances in materials science.

## MARKET DYNAMICS

Another important factor when considering commercialization is the relationship of the new product to the market[4]. Products reach the marketplace either through a market-pull or technology-push mechanism (Fig. 2). In both cases an innovation must offer advantages that customers (or users) value. In addition, a market-pull innovation will typically satisfy two criteria: first, no change in customer or user behaviour required, and second, little or no perceived risk to the customer or user. Examples of market-pull innovation include: curved glass for automotive windshields and extruded ceramics for exhaust purification of automobiles. Indeed, modifications to the composition or processing of a product that improves its physical properties, consistency or cost, without involving risk or changing user requirements are so common that users may not even realize that they are occurring.

Sometimes, of course, innovations involve risk and/or a change in customer or user behaviour. Because they are not requested by the market, they have to be 'pushed' onto the marketplace. For the market to accept the risk, and/or changes, required by the innovation, customers must highly value the additional performance that the innovation offers. Usually, the benefits must be at least one order of magnitude greater for some critical parameter for the technology-push mechanism to work.

For example, in the aerospace industry new products based on microsystems technologies were adopted because of a reduction in weight and size of over an order of magnitude. This is clearly an important characteristic in this industry, because changes in size and weight are directly related to fuel consumption. Similarly, optical fibres were initially of little interest to the marketplace, requiring sustained product development and marketing investment by the originators, Corning, to develop potential customers. But once the information demands of communication networks reached a certain point, markets for optical fibres rapidly developed owing to their tremendous information-carrying capacity.

Finally, coated nanoparticles dispersed in a carrier liquid, known as ferrofluids, are an early success story in the commercialization of nanotechnology. Ferrofluids were adopted in the early 1970s by the disk-drive industry, despite changes required of users and the risks associated with adopting the new technology. This was largely because of a cost saving of over an order of magnitude, as well as performance benefits including near-zero friction, essential for their main application as bearings in hard-disk drives. Today, ferrofluid bearings are a key component in greatly reducing the incidence of hard-disk failure.

Although the process of commercialization is still far from a science, by considering whether an innovation is likely to enter the market through market-pull or technology-push mechanisms, the transfer of laboratory discovery to marketplace may be easier to understand. Moreover, by clarifying the relationship between product and process innovation in materials-related industries it becomes easier to identify markets and applications that could benefit from advances in materials science.

**TAKING A CRITICAL LOOK AT YOUR INNOVATION AND UNDERSTANDING ITS MOST LIKELY ROUTE TO THE MARKETPLACE IS ESSENTIAL BEFORE YOU SEEK INVESTMENT**

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