# Nanotechnology Platforms for Commercialization

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## ABSTRACT

Much of the publicity surrounding nanotechnology covers leading-edge applications with the potential to create tremendous disruptive changes in key industries such as semiconductors. Whilst the intensive support of these projects is critical, nearer-term opportunities must be grasped across a range of technology platforms and markets in order to gain experience in the production of new nano materials and systems in more immediate opportunities. These product enhancements - more significant than evolution, less dramatic than disruption - can generate significant volumes and opportunities. Examples of "Enhanced" products and systems developed by NanoDynamics Inc. in the processing of metals and non-metals will be reviewed and conclusions drawn.

Keywords: nanotechnology, silver, copper, atomic cluster, self-assembly, golf ball.

## HISTORY

Many disruptive technologies have foundered because the compelling reason to go to market was compromised. Many inventors do not have strong business backgrounds; many business people have a very conservative approach to new products removed from their existing product line; and while a product languishes in no-man's land the existing technology has time to make up ground by increasing performance or lowering cost… or the market may transform due to external factors.

One example comes from the ceramics industry. Ceramic turbochargers - replacing metal turbochargers - were touted in the 1980s as the answer to increasing output and efficiency of automotive engines by harnessing high-temperature exhaust gas energy while maintaining performance and response time. The impetus came from the first "oil shock" of the 1970's and much of the materials technology dated from the 1960's. Many major corporations and startups focused on advanced ceramics worldwide. A great deal of energy and money was spent on ceramic materials and process technology but metals engineering fought back – and four valves per cylinder and variable valve timing using metals with no turbocharger gave the performance upgrade that was needed

A second example comes from the electronics industry where advanced optoelectronics were promoted as the way to cope with increased bandwidth demand. Industry roadmaps claimed that copper circuits could not exceed 2 Gbps whereas optical systems were capable of 40 Gbps. The optoelectronics technology (much of it developed in the 1970's for voice communication) spawned a huge expansion in existing companies and a slew of startups – but the telecom bubble burst in 2001 and left us with a customer base that would only use existing technology (at dramatically reduced prices) and a copper supply base that fought back with a five-fold improvement in the data transmission rate of copper.

## BRIDGING THE GREAT DIVIDE

Marketing professionals will always tell you that "market pull" is better than "technology push". In general that's true, but always relying on market pull from customers will limit companies to evolutionary developments. Truly revolutionary developments that can obsolete a business come from a different technology base – think of the replacement of video tapes by DVDs and subsequently by on-demand video.

The "great divide" (sometimes referred to as "The Valley of Death) comes from two incompatible positions.

***The Inventor***

- I have an idea.
- I have made a prototype and it works.
- I believe there is a market for this invention.

***The Producer***

- I have an unmet market need.
- I need a fully characterized product that is scalable, complies with all applicable regulations (TSCA, OSHA, NIOSH, shipping regulations), has a full MSDS and has a process capability proven through statistics. And it must give a total lower cost than previous solutions.

For the Inventor the cost of scaling a process to pilot or production stage can be extreme and not possible to finance readily e.g. in the case of a new or modified polymer. Even in more modest examples the inventor may be forced to go into debt or lose significant equity in the invention in order to raise capital.

The barriers on the Producer's side may also be high. Mature companies are generally risk-averse and are uncomfortable moving away from what is often a very narrow definition of core competency. They also have a pace of operation and legal mindset that can prove frustrating to the Inventor (who's looking at short-term survival) and the Producer (who finds the Inventor to be an impatient nuisance).

## THE NANODYNAMICS MODEL

NanoDynamics was formed in 2002 to produce products enabled by nanotechnology. The company brought together seasoned professionals, enthusiastic research teams and a process development group and developed a number of platform products through licensing, sponsored research or internal development. Much of the technology has been developed by universities or individuals.

In one example, NanoDynamics has licensed novel metal precipitation technology from Clarkson University and continues to support researchers there. Taking the technology from gram to kilogram to tonne has taken less than 2 years. The market pull was from the electronics industry, which needs finer metal powders to produce smaller devices.

The technology push was from a new precipitation process yielding truly monosize particles that were crystalline and protected with a polymeric coat which prevents agglomeration and cold welding. The process yields 100% fine particles so there are no yield issues as with many other processes. From the customer's point of view the powder is easy to process and control and there are applications now in industries where NanoDynamics and Clarkson team members have experience and personal connections.

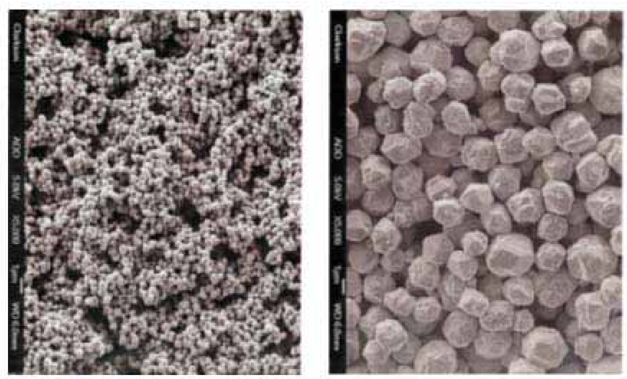

Figure 1. 200nm and 2 micron copper produced by the same precipitation process.

A second example is NanoDynamics' program with Nano Cluster Devices Ltd., a spin-off company based on an invention from the University of Canterbury in Christchurch, New Zealand. This technology combines the lithography techniques used in the semiconductor industry with selective atom cluster deposition to self-assemble conducting or semiconducting wires 1/00 of the size achievable by conventional lithography. The application to sensors and semiconductors is obvious, and although the commercialization stage is earlier than that of metal powders, the team again has the experience and contacts in the electronics industry that will allow this technology to become widely adopted.

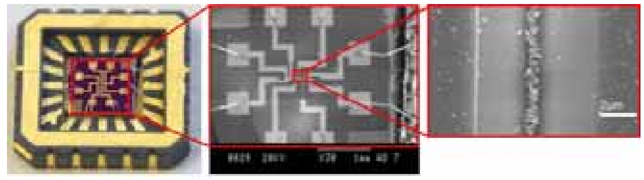

Figure 2. Directed assembly of wires and their incorporation into sensors (Nano Cluster Devices)

A third example is a consumer application, the NDMX ™ golf ball! This uses a nanostructured hollow titanium sphere in place of the rubber core in conventional balls. The titanium sphere, strengthened and recrystallized by controlled deformation, moves the mass to the surface of the ball improving directional stability during flight and rollout. It is also a surprisingly economic solution and allows the ball to be priced competitively with existing high-performance balls. Working with the inventors, Noonan LLC., the development of the ball to meet USGA guidelines has taken approximately a year. In this case NanoDynamics has assembled a team of partners to ensure a robust supply chain, necessary approvals and marketing channels.

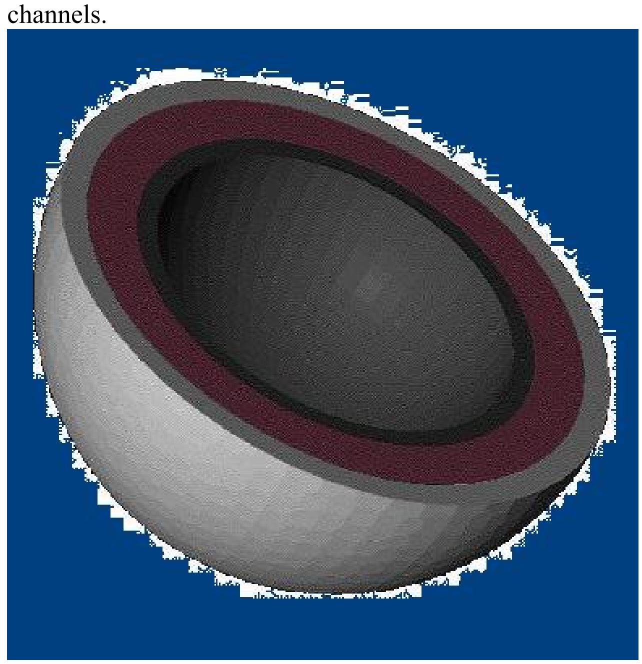

Figure 3. the NDMX ™ golf ball utilizing a nanostructured titanium shell.

Other product platforms include carbon, mineral and polymer nanotubes, Quasam ™ quasi-amorphous diamond coatings, single and mixed oxides and novel gel-casting technology. Many of these are incorporated in a novel solid oxide fuel cell system to be launched this year.

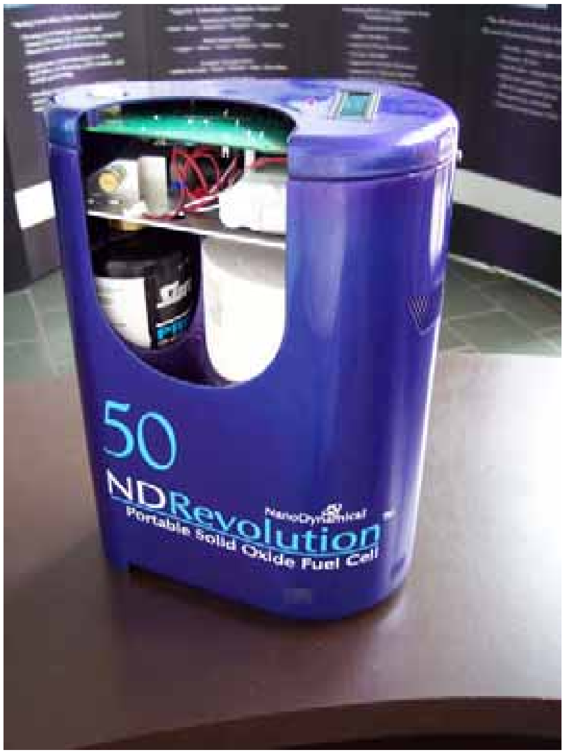


Figure 4. The Revolution 50 ™ solid oxide fuel cell system using nanomaterials in its construction to reduce size and increase performance.

## SUMMARY

Nanotechnology is proposed as the answer to materials issues as diverse as the impending "silicon crunch" in 2015 when silicon integrated circuits can be made no smaller, to biocidal clothing, implants, cancer therapy, biological analysis, super-strong composites, novel conductive materials etc.

Most startup companies are looking at the revolutionary changes – the major steps where commercialization and revenue is some years out. These companies are supported by SBIR and venture funds but have to cross the chasm of commercialization. Many don't have the commercial experience or financial backing.

Many established companies are looking at the evolutionary changes – the "quick fix"- where nanomaterials can be plugged into an existing material or system that they are comfortable with. They rapidly come to the conclusion that the incremental benefits do not justify the increased cost of production of nanomaterials.

One way to bridge the gap is to create an agile organization run by individuals with industry and commercial experience who have an open mind and attitude to risk, and to allow them to identify technology platforms that can be married to a demonstrated industrial need. The technologies can be situated with individuals, with startup companies, with universities or can be orphan technologies neglected by other companies.

So what have we learned from previous technology waves and what lessons have we applied in commercializing these technologies?

- Choose your team carefully. Balance experience and innovation!
- Choose your backers carefully. Make sure you know their preferences and sensitivities.
- Don't rely on a single market.
- Don't rely on a single technology – "the one trick pony".
- Make sure that your IP is free and clear.
- Be realistic in your valuation. Just because $10 million was spent in development doesn't mean the technology is worth $10 million…or that it won't need another $10 million.
- Assume the existing technology will catch up when prodded by competitive pressure. Your performance advantage may and probably will erode in the time it takes to reach market. Watch the rear-view mirror!
- Develop a portfolio with managed time-to-market and managed market size.
- Apply appropriate management techniques to ensure that development targets are met.
- Integrate the supply chain as appropriate.
- Ensure that all the processes chosen will make you a low-cost supplier.
- Partner as appropriate to commercialize the materials (production partnership, sales partners, logistics partners, research partners). You can't do it all yourself!