



## Nanotechnology innovation in Brazil – a macro analysis

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*Following previous investments of about €140 million in nanotechnology, the Brazilian Ministry for Science, Technology, Innovation and Communication (MCTIC) recently launched a national action plan for this key enabling technology, defining a strategy for further development. Although behind other BRICS countries, Brazil showed 13% compound annual growth in scientific publications on nanotechnology (2000-2018), with the best Brazilian universities in the lead. Brazilian companies, some also active abroad, play a modest role in nanotechnology publications and patent applications. Important topics in science and business related to nanotechnology are e.g. cosmetics and pharmaceuticals (markets with strong growth in Brazil) and graphene (Brazil holds one of the world's largest natural graphite reserves). The last decade Brazil and the Netherlands have combined efforts in complementary knowledge fields, resulting in dozens of co-authored scientific papers on nanotechnology topics, e.g. nanomaterials for semiconductors, catalysts and drug delivery. The Holland Innovation Network Brazil will continue to monitor future Brazilian developments in nanotechnology, focusing on opportunities for international collaboration.*

In Dutch innovation policy, the so-called key enabling technologies (e.g. biotechnology, artificial intelligence, ICT and quantum technology), play an important role, and international collaboration on key enabling technologies is considered to be essential [1]. In addition to our previous articles on biotech and artificial intelligence, this article of the Holland Innovation Network Brazil provides an analysis of the state of the art in nanotechnology in Brazil. To describe this state of the art, the article addresses national programmes that support nanotechnology innovation and R&D output, by looking at scientific papers and patent applications respectively, in terms of numbers, main players and main topics.

### National nanotechnology programmes

Over the past 15 years, more than **R\$600 million (about €140 million)** has been invested in nanotechnology by the Brazilian Ministry for Science, Technology, Innovation and Communication (MCTIC). At the moment there are no dedicated nanotechnology funding programmes available (besides the undermentioned Sibratec programme). However, nanotechnology projects are eligible for general (research and innovation oriented) funding programmes or tax incentive programmes. Examples are a programme for start-ups from the Brazilian Innovation Agency (FINEP), the EMBRAPII programme, stimulating projects in public-private consortia and the Technology Fund (FunTec) of the National Development Bank (BNDES).

### National Action Plan nanotechnology

In October last year, MCTIC launched a National Action Plan on nanotechnology. This document is the first volume in a series of national action plans on various key enabling technologies. The plan defines strategies for the further development of nanotechnology in Brazil (without allocating any new funding for e.g. calls for proposals), including the following objectives:

- Unify and strengthen the national nanotechnology ecosystem
- Implement the National Nanosafety Program
- Propose the Legal Framework for Nanotechnology focused on nanosafety, harmonised with the Organization for Economic Cooperation and Development (OECD) and the Sustainable Development Goals set by the United Nations
- Promote the training and qualification of human resources skilled in the area of nanotechnology
- Stimulate the transfer of intellectual property from R&D to the industrial sector

The plan also restructures the already existing Brazilian Nanotechnology Initiative (IBN) as the main federal governance body for nanotechnology.

## Nanotechnology networks

One of the main deliverables so far of the IBN, which was founded in 2013, is the National System of Nanotechnology Laboratories (SisNano). SisNano is a network comprised of 26 laboratories [3] focused on research, development and innovation in nanosciences and nanotechnologies. The public funding for SisNano, mainly from MCTIC, serves to ensure state-of-the-art facilities, training of highly qualified staff to operate these facilities and open access for both public and private parties. Most of the SisNano laboratories also participate in the national Sibratex Nano program, which aims to stimulate companies to develop new technology using the SisNano research infrastructure. In this programme, two different networks are distinguished: nanomaterials & nanocomposites and nanodevices & nanosensors.

Furthermore, there is a private initiative called the Nanotechnology Innovation Cluster (API.nano), maintained by the Foundation Centres of Reference in Innovative Technologies (CERTI) in Florianópolis (state of Santa Catarina). API.nano is a national cluster with 127 members, with the main objective to create a communication and cooperation environment between companies and academia to promote nanotechnology development.

## Scientific publications on nanotechnology

Important indicators of the state of the art in nanotechnology are the number of scientific publications and their focus. The data used in this paragraph come from a bibliometric analysis of documents retrieved from the Web of Science database. From 2000 to 2018, researchers affiliated to Brazilian institutions published 26,308 research papers related to nanotechnology. Brazilian scientific production on the topic only accounts for 1.6% of the world total, but its annual growth rate of 13% (though behind countries such as China and India) does reflect great potential.

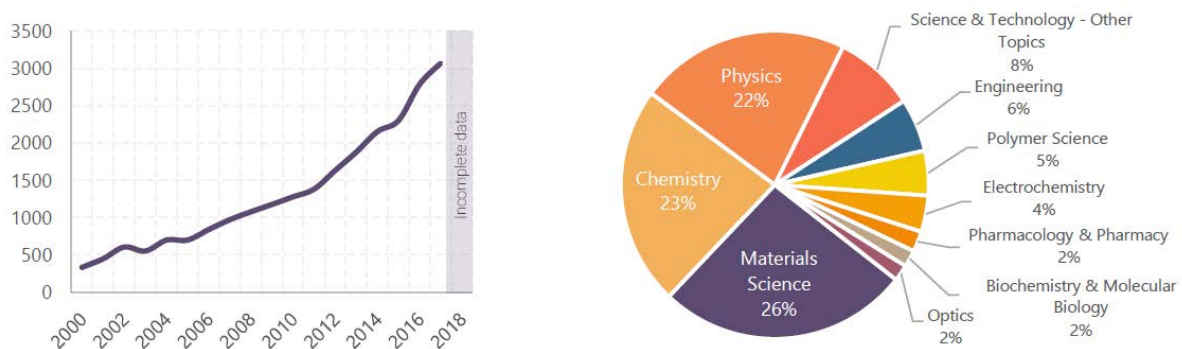


Figure 1 & 2 – Scientific publications (quantity and categories) on nanotechnology from Brazilian researchers

Figure 3 shows the Brazilian universities with the highest publication output in nanotechnology, with the **University of São Paulo (USP), Brazil's best university** according to Times Higher Education [4], ranked number one. The universities listed here are all in the top 20 of best universities in Latin-America [4], with a leading role for public universities in the State of São Paulo. In the period considered, about 50% of the research papers had an author affiliated to an institution in the State of São Paulo, indicating the **region's** relevance as a strategic hub for nanotechnology development in Brazil.

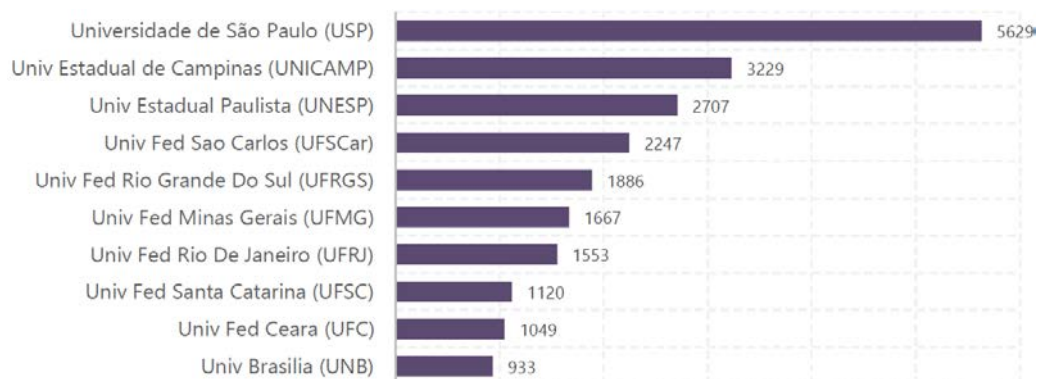


Figure 3 - Ranking of Brazilian universities (co-)authoring scientific papers related to nanotechnology

When considering only high impact research papers (i.e. papers with more than 50 citations), the University of São Paulo (USP) and University of Campinas (Unicamp) continue to lead the ranking, followed by the Federal University of São Carlos (UFSCAR) and Federal University of Minas Gerais (UFMG). Frequent topics in these high impact papers are nanoparticles, carbon nanotubes, nanocomposites and graphene. A relevant observation on high impact papers is that 53% of them have an international co-author, versus 39% of the total number of (Brazilian) publications.

### Nanotechnology in Brazilian industry

Brazilian industry also (co-)authors scientific publications in nanotechnology, though at a much smaller scale than **the country's** universities and research institutes. The companies that published the most scientific papers in Brazil are oil & gas multinational Petrobras SA (69 publications), petrochemical multinational Braskem SA (38 publications) and health & beauty biotechnology company Innovatecs (14 publications), which launched a product called Nanoskin to treat scars and wounds.

Despite only having published three scientific papers, the company Nacl Grafite Ltda stands out in the Brazilian scenario. Located in the state of Minas Gerais, the company was founded in 1939 and is active in the mining and processing of natural high-quality crystalline graphite. More recently, the company has shown a growing interest in making graphene, which **could be boosted by the company's central** role in the Brazilian graphite market.

Aside from the aforementioned main players in the field of nanotechnology research, the Brazilian private sector has also seen some interesting start-ups, such as

- Nanum Nanotecnologia S/A, a start-up from the Federal University of Minas Gerais (UFMG) founded in 2003, focused on the production of nanoscale metal oxides, used for various products, such as magnetic ink used in thermal inkjet systems,
- Nanox, a start-up from the Federal University of São Carlos (UFSCAR) founded in 2005, focused on antimicrobial solutions based on silver nanoparticles,
- Nanovetores, a start-up founded in 2009 in the incubator CELTA, linked to the CERTI Foundation, focused on nano and micro encapsulation systems with natural additives (e.g. for application in cosmetics and textiles).

### Main research topics

The main topics in Brazilian nanotechnology research include synthesis, characterisation, morphology, mechanical properties and effects of nanoparticles (mainly related to nanosilver, carbon nanotubes, titanium oxide, nanocomposites in thin films with optical properties) and biocompatibility (mainly related to water and ionic liquids). These topics reflect the maturity levels of nanotechnology research in Brazil, highlighting the focus on synthesis and characterisation of simple nanomaterials.

The two biggest emerging terms in Brazilian research papers are "graphene oxide" and "reduced graphene oxide". After the emergence of graphene the topic has become important in Brazil. The country has great potential, since it holds one of the biggest natural graphite reserves in the world and is **currently the world's third largest** graphite producer. A hub for graphene research is the state of Minas Gerais, where organisations such as start-up company Neographene and technology centre CT Nano are expected to make further progress in the development of graphene products. MackGraphe, a research centre located in São Paulo initiated in 2013 with an investment of US\$20.000.000, is also considered a relevant player in the field of graphene and nanomaterials (focused on photonics, energy and composites).

### Collaboration with the Netherlands

Of the Brazilian papers co-authored by international researchers, 1% is in collaboration with researchers based in the Netherlands (amounting to 112 papers), far behind collaborations with, e.g. the USA (24%), France (15%) and Germany (11%). Brazilian-Dutch collaborations in this field are relatively recent, with the vast majority of these papers published in the last decade. The reason for the increase towards the year 2016 and subsequent decrease has not been studied in depth, but it is assumed that the availability of scholarships has an impact, e.g. the 'Science without Borders' programme, which awarded the bulk of its scholarships between 2012 to 2016.

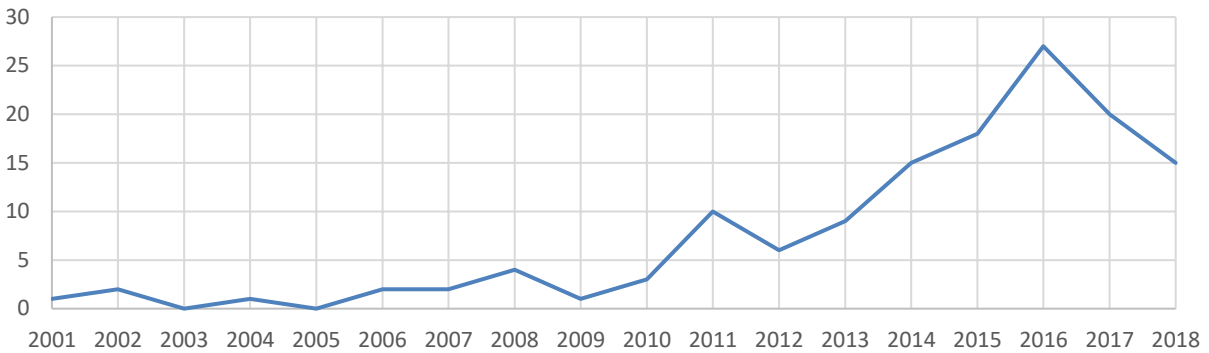


Figure 4 – Brazilian-Dutch co-authored papers related to nanotechnology

The five main Dutch institutions to co-author nanotechnology research papers with Brazilian institutions are Eindhoven University of Technology (18 publications), University of Groningen (15), Utrecht University (15), Leiden University (11) and Delft University of Technology (10). On the Brazilian side, the University of São Paulo (USP) and the State University of Campinas (Unicamp) occupy a central position in Brazilian-Dutch collaboration. Some of the most frequent terms in Dutch-Brazilian publications are “graphene”, “dental materials” and “electrical conductivity”.

Looking at the joint publications several application areas can be distinguished, such as semiconductors (Eindhoven University of Technology), catalysts in chemical processes (Utrecht University), ceramics and coatings for dentistry (Academic Centre for Dentistry Amsterdam, ACTA) and materials for functional foods and drug delivery (Wageningen University).

### The patenting landscape

A second important indicator for the state of the art in nanotechnology is the patent landscape. The data used in the following segment is obtained from the Derwent Innovations Index database. Between 2000 and 2016 (data from 2017 and 2018 is not yet available due to an eighteen-month publication delay) 7,716 patent applications related to nanotechnology were submitted in Brazil. Of those, 1,142 were submitted by Brazilian residents.

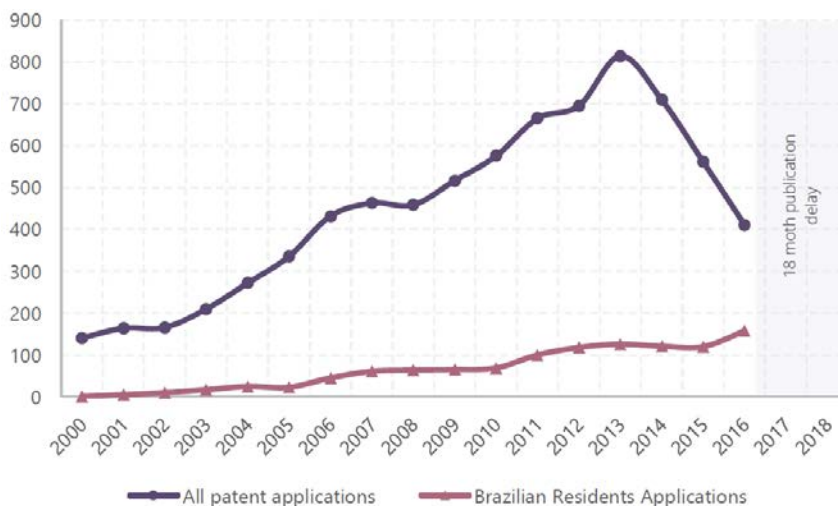


Figure 5 – Total number of patent applications in Brazil compared to the number of applications by Brazilian residents

### Leaders in nanotechnology patents

Considering only resident applications, universities were responsible for 66% of nanotechnology-related patent applications, followed by companies (20%), and research institutes (11%). Among the leading universities are Unicamp (95 patents), UFMG (92 patents), USP (91 patents) and UFRGS (83

patents). Brazilian companies play a relatively small role in nanotechnology patent applications, with Petrobras having the highest ranking at position 10, with 22 patent applications in the period considered.

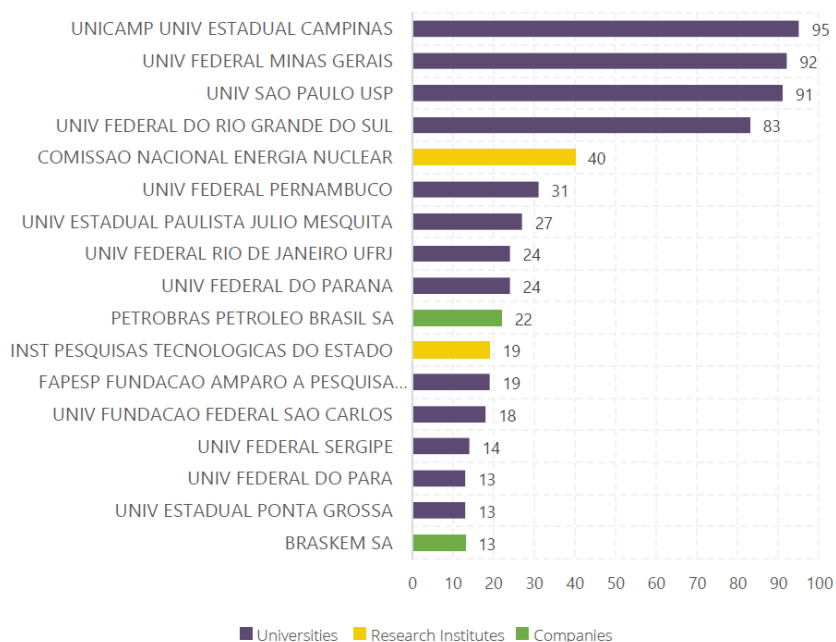


Figure 6 – Top Brazilian organisations by number of resident patent applications

### Main topics in patent applications

The International Patent Classifications (IPC) subclass most frequently identified in nanotechnology-related patents from Brazilian applicants is Pharmaceuticals and Cosmetics, which reflects the fact that Brazil is the 4<sup>th</sup> largest Personal Hygiene, Perfumery and Cosmetics Industry market in the world. Other themes in Brazilian nanotechnology patents include Micro-Structure & Nanotechnology, Materials & Metallurgy and Macromolecular Chemistry & Polymers.

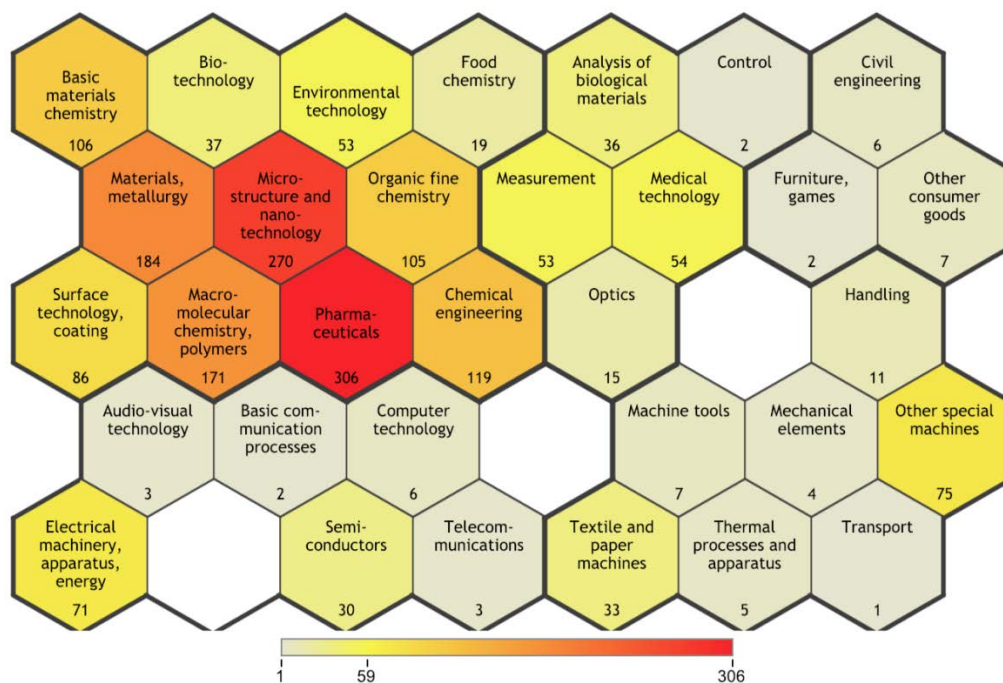


Figure 7 – Overview of Brazilian resident patent applications by field of technology

#### More information

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