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QUICK REPORT
TECHNOLOGY TREND ANALYSIS

Nanoparticle Technology – 15 Years Since the NNI

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In 2001, the Clinton administration began an active investment in nanotechnology with the National Nanotechnology Initiative (NNI). This set off the global nanotechnology boom. Japan—then a leader in nanotechnology—was no exception, with its own vibrant scene of nanotechnology endeavors across various fields, including nanomaterials and nanofabrication.

One of the signature nanotechnology research areas is nanoparticles. Much R&D is performed by scaling particles down to the nano scale, through which researchers are able to observe behavior that differs from that of bulk materials, including quantum behaviors and lowered melting points. We wondered how the results from this research can be tied into products and how R&D will change when looked at from an industrial perspective. Thus, we used Japanese unexamined patent applications as a resource to answer some portion of these questions, and we were able to elucidate the changes in developments for nanoparticle-related technologies and the players who are making those moves.

Macro Trends in Nanoparticle-Related Patents

Our target population for nanoparticle-related patents consisted of Japanese unexamined patent applications (published and republished) since 1993, including all patents that contain the word "nanoparticle" in the patents' summaries or claims, tallying up to approximately 12,000 documents. Note that as indicated in our search expressions, this study is not a comprehensive aggregation of nanoparticle-related patents.

The numbers for nanoparticle-related unexamined patent applications are shown in Figure 1. As we can see in the chart, there has been a surge in unexamined patent applications related to nanoparticles since roughly 2002. This also reflects the popularization of the word "nanoparticle." Thereafter, since 2009, the growth in

unexamined patent applications has come to a halt, but there are still approximately 1,000 patents published annually, indicating that active R&D is continuing.

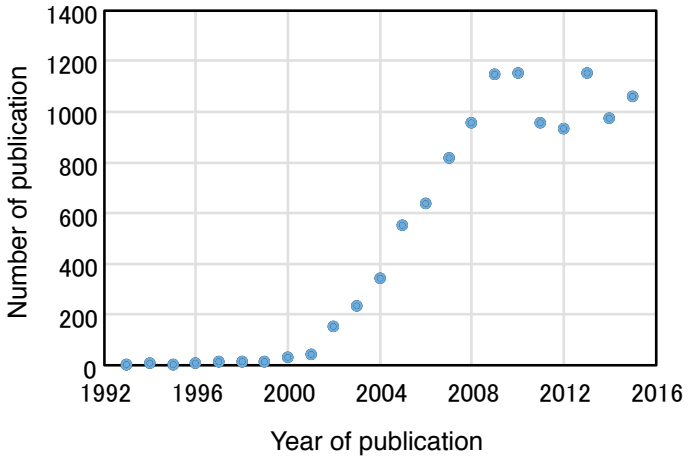

Figure 1 - Unexamined Patent Applications for Patents Related to Nanoparticles

The leading IPCs in all the nanoparticle-related patents we collected are shown in Figure 2. The top IPC, with a significant number of patent applications, is A61K, which is granted for patents related to pharmaceuticals, dentistry, and formulations for cosmetics. This classification is followed by H01L (for semiconductor devices and otherwise unrelated electrical solid-state devices) and G01N (for examinations and analyses of materials based on the determination of their chemical or physical properties).

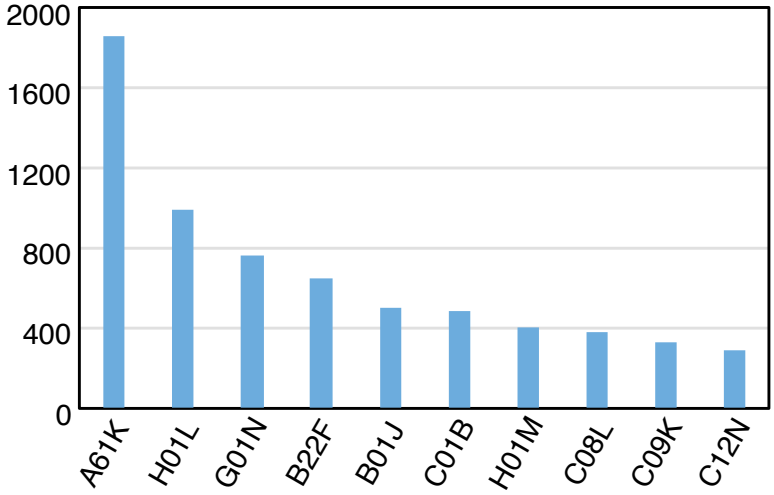

Figure 2 - Leading IPCs in Nanoparticle-Related Patents

Cluster Analysis of Nanoparticle-Related Patents

We performed a cluster analysis of the nanoparticle-related patents we gathered, using our proprietary XLUS TechRadar system (Figure 3). Our cluster analysis makes a visual representation of patents based on the mutual similarities among the entire texts of different patents. Therefore, patents that are highly similar are located near each other, while those that differ are placed farther apart. Furthermore, the direction of the axes holds no special meaning, and the entire structure is calculated so that it has the optimal position.

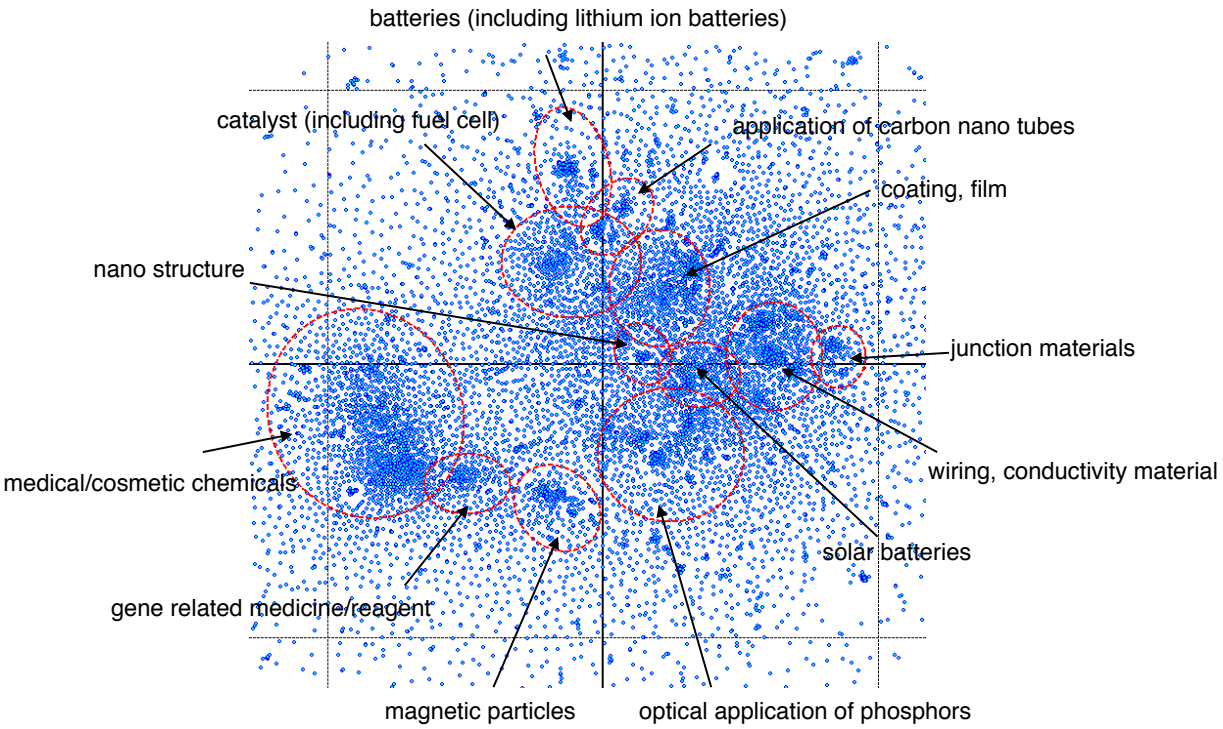

Figure 3 - Results of the Cluster Analysis of Nanoparticle-Related Patents

Looking at the results of our cluster analysis, we find the largest region with a dense population of patents is related to medicine, cosmetics, and drugs on the left side of the chart. Furthermore, a region nearby is taking shape with a dense population of patents concerning gene-related drugs and reagents, and continuing horizontally we find patents related to magnetic particles. In the top center of the chart, there is an aggregation of energy-related applications, such as catalysts (including fuel cells) and lithium-ion batteries. Finally, to the lower right of that region, we see an expanse of applications for membranes, including coatings, solar batteries, nanostructures, wiring, and conductive films.

To see how the development of technologies seen in nanoparticle-related patents has changed over the years, we made visualizations of the cluster analysis data (Figure 4). Within the diagrams, regions with the highest density of patents within each time period

are shown in red, with the density decreasing, in order, from yellow to green and, finally, to blue.

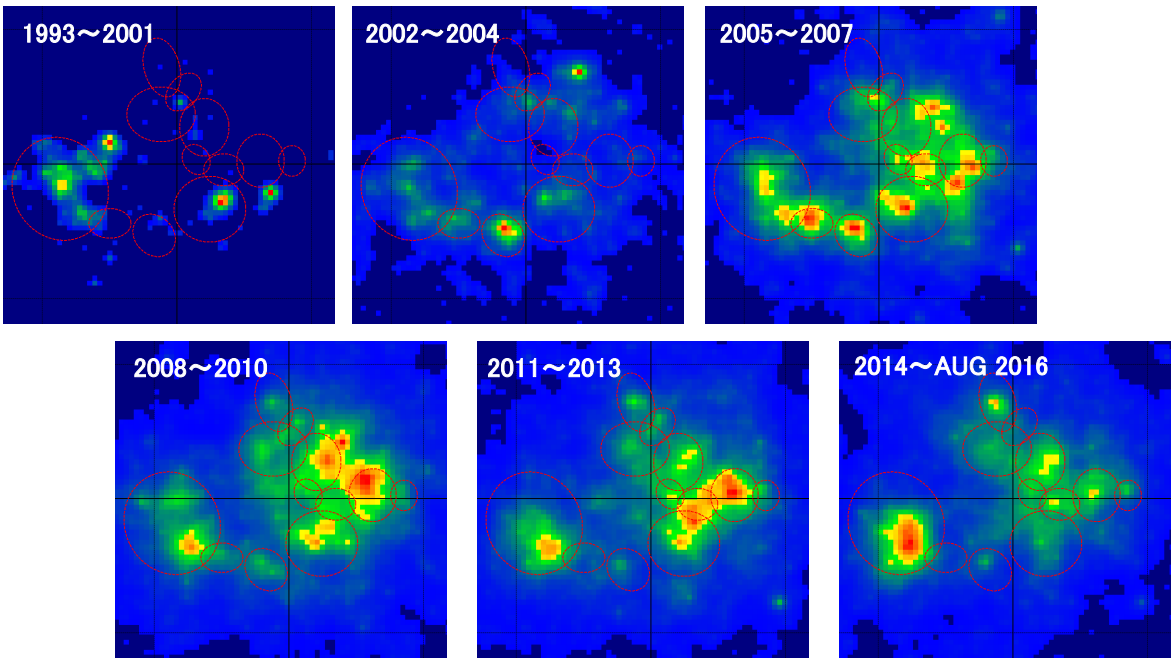

Figure 4 - R&D Changes in Patents Related to Nanoparticles

Before the rapid growth in nanoparticle-related unexamined patent applications in 2001, we see patents such as those in the pharmaceuticals-related region, as well as patents for surface treatment and light-emitting elements. Thereafter, from 2002 until 2004, magnetic particles were an active field of research. Then, from 2005 to 2007, we begin to see the scope of the patent applications in the cluster analysis expand. From 2008, we see a trend in R&D with a focus on technologies such as wiring, conductive materials, and coatings, while, since 2011, there are many patents in the region for solar batteries. Looking at the last three years, there is a significant number of patents related to medicine, and it is clear that these patents and patents related to lithium-ion and other types of batteries are on the rise.

Patent Application Regions for the Major Players

The active regions for the development of nanoparticle-related technology patents are related to medicines and lithium-ion and other types of batteries, as seen in Figure 4. The characteristics of the major players in these two regions over the last three years are summarized below.

Medicine-related region

The major players and the top three organizations for patents submitted in the region for medicine-related applications of nanoparticles are shown in Figure 5.

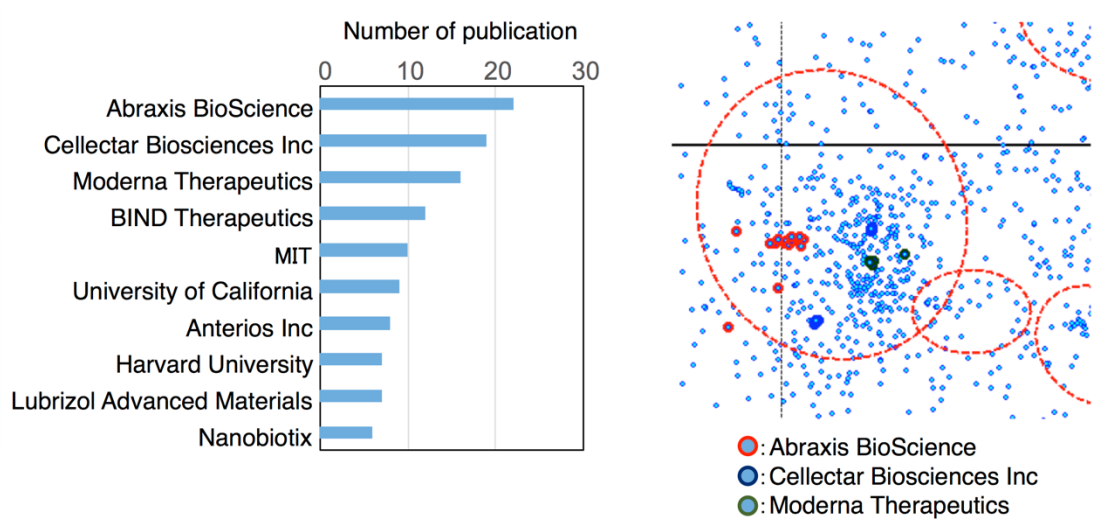

Figure 5 - Major Players and Patent Application Positions since 2014

This region is dominated by multinational organizations, with the major players being specifically American based companies and universities.

Recently, the organization with the most unexamined patent applications in Japan is Abraxis Bioscience, and if we look at characteristic words in its patent descriptions, it is clear that the company has been developing nanoparticles related to anti-cancer drugs. However, the company was acquired by Celgene in 2010. The second-place unexamined patent applicant is Cellectar Biosciences Inc., which features nanocarriers for drugs. Moderna Therapeutics comes in third place, featuring drugs related to mRNA. The company has been active since 2011, but there are also reports that it is receiving funding of over ¥100 billion.

Region for lithium-ion and other batteries

The major players in the lithium-ion and other batteries region and their application positions are shown in Figure 6. However, since the top three major players submitted joint applications, we show the application position for only Nippon Chemi-Con Corporation.

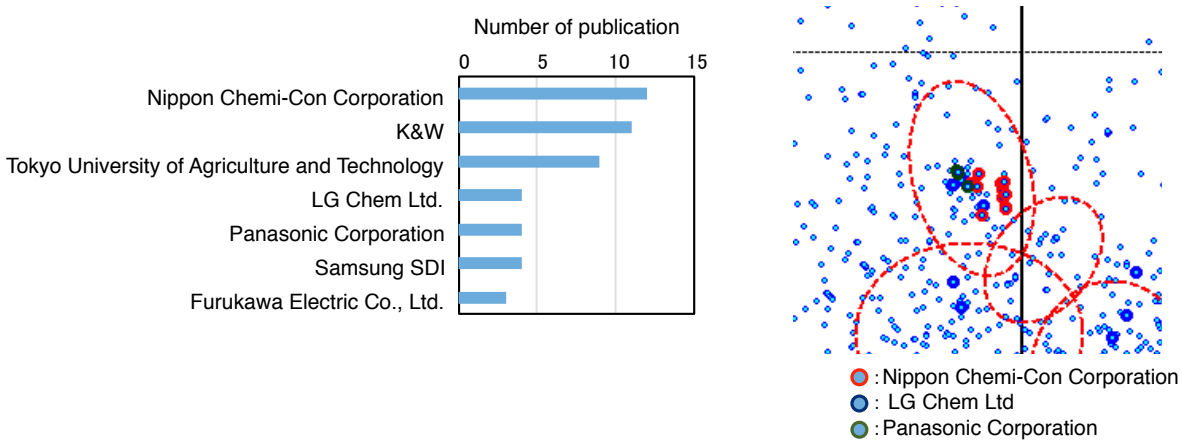

Figure 6 - Major Players and Patent Application Positions since 2014

This company (TYO: 6997) had the most applications of all the players in this region. Nippon Chemi-Con's patents (with K&W and Tokyo University of Agriculture and Technology) are related to synthesizing composite materials of carbon-based materials and nano metallic oxide particles, meaning that they are applications for electrode materials in lithium-ion batteries. LG Chem Ltd. has patents related to anodes using nano silicon-based materials and capacitor electrodes. Panasonic Corporation (TYO: 6752) also uses nanoparticles for battery electrodes, featuring unique surface and layered structures.

Conclusion

The development of technologies related to nanoparticles has seen a swell of activity since the US's NNI. The period from 2005 to 2007 saw a significant expansion of technological development in all directions, and those technologies covered a wide range of fields, from medicine and cosmetics to energy devices. In recent years, we see that a high level of interest in nanoparticles continues, with unexamined patent applications active in pharmaceuticals and applications for lithium-ion and other types of batteries. Meanwhile, in the pharmaceuticals region, the major players in the last three years have been predominantly non-Japanese applicants. This trend is also seen in other regions, such as the coatings region, where 3M is the top player, and the region for wiring and conductive materials, where Xerox Corporation has the most unexamined patent applications. It is said that Japan's strength is in manufacturing, but it appears its superior position is gradually losing ground, at least in relation to nanoparticles.

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