Editorial

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Moving from convergence to divergence: the future of nanotechnology

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Nanotechnology has been considered as a main hub for the convergence and multidisciplinarity of research fields. Since it emerged, a number of researchers with a variety of backgrounds, including, but not limited to, chemistry, biology, and physics, have converged in this academic melting pot, where synergetic designs of merging multiple principles have been conducted to generate substantial and unprecedented outputs. Based on this interdisciplinary nature, nanotechnology plays a central role nowadays as a bridge to interconnect multiple scientific boundaries. During the convergence in nanotechnology, however, there were unexpected challenges and debates that suppressed the progress of the research development. For example, the integration of different scientific disciplines that were already established in their own fields sometimes had to face troubles owing to the lack of gold standards and clarified definitions. In some cases, reproducibility of the research results was doubted. One suitable example is the case of nanoparticle syntheses. The shape and size of certain types of nanoparticles were often unable to be systematically controlled as reported in literature.

The era of uncertainty of nanotechnology, however, is almost over. The gold standards in a variety of fields of nanotechnology are being set up, and the necessary definitions have been prepared, or at least they are ongoing. For example, there are ongoing activities on the creation of the systematic nomenclature of nanomaterials. The systematic and worldwide evaluation of the toxicity of nanomaterials is also in progress. The development of molecular spectroscopy has clearly elucidated the role of trace impurities in synthesis of nanoparticles, which had not been carefully discussed in conventional chemical reactions. Based on such accomplishments today, nanotechnology has not only consolidated its territory as an independent research area but also expanded to divergent areas as a starting point. That is, nanotechnology does not simply merge things together just to see something new anymore, but has begun to provide divergent views and scopes to researchers to better understand and investigate their own sciences.

The reviews in this special issue distinctly demonstrate both the convergent and divergent aspects of nanotechnology, by reporting the recent studies and results in their own fields in view of nanotechnology. The investigation of perovskite-type superconducting copper oxides by electron microscopy and diffraction is explained by Oku, where nanotechnology certainly provides a state-of-the-art tool for materials science and physics. The conventional photonics in combination of nanotechnology for the investigation of DNA is outlined by Bregadze et al., where nanotechnology is taken advantage of for biological investigation. The modeling of mass transfer at nanoscale is demonstrated by Kalinitchev, which is an exemplary review of using nanotechnology for investigating theoretical physics. Lee's review on the silver nanomaterials for the detection of chemical and biological targets deals with how new nanomaterials can be utilized for practical purposes in our lives, with respect to both chemistry and biology. Finally, in a research highlight, the advantages of noble metal nanoparticle catalysts over the conventional ones are reviewed in association with their synthetic methods by Sergeev et al., which obviously show that chemistry can also be an ultimate destination from nanotechnology based on its divergence.

All these articles provide excellent demonstrations of advances in diverging nanotechnology heading to the distinctive, major sciences, such as materials science, biology, physics, and chemistry. This collection indicates that such divergence of nanotechnology is definitely noticeable, as a part of the scientific research orientation. As the beginning of convergence of nanotechnology showed troubles, however, the effort to understand the conventional sciences through the window of nanotechnology may also have potential difficulties. Plenty of discussions and communications would be needed to guide researchers in an appropriate way in the future, and I believe that this special issue could be a good point to begin with.

Last, but not the least, I would like to thank all the contributors for their support of this special issue. Their valuable devotion to this special issue of *Nanotechnology Reviews* is deeply appreciated, without which the completion of this issue would have not been successful. I also appreciate every effort and assistance from the editorial office of *Nanotechnology Reviews*.

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