Chemical Engineering Research of the Future: An Industrial Perspective

L. Louis Hegedus
Arkema Inc., 900 First Avenue, King of Prussia, PA 19406

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Introduction

Chemical engineering research will maintain its unique identity, despite its migration from macroscopic toward microscopic phenomena, and despite its new fields of application beyond chemicals and petroleum (e.g., biotechnology and microelectronics). The chemical industry remains a major employer of chemical engineers, and chemical engineering research will be essential in harnessing the industry's opportunities in value-added technologies.

Technology, and the underlying sciences, change rapidly, creating or erasing professions or shifting the boundaries between them. These changes appear to be accelerating, and occasionally we find ourselves in need of redefining what is an engineer (vs. a scientist), and what is a chemical engineer (vs. a chemist).

Theodore von Kármán[1] said, "Scientists discover the world that exists; engineers create the world that never was". More recently, B.V. Koen[2] presented a definition for the engineering method: "[it] is the use of heuristics to cause the best change in a poorly understood situation within the available resources".

Historically, chemists dealt with microscopic, and chemical engineers with macroscopic phenomena. However, modern chemical engineering research overlaps in scale with chemical research, especially in the range of tens to hundreds of nanometers (Figure 1). Despite this overlap, chemical engineering research maintains its own identity for at least two reasons: due to the distinct nature of the engineering approach (as elaborated above), and due to the self-similarity (scale-independent character) of scientific and engineering work, to quote R. Frosch.[3]

Since the chemical industry remains one of the largest employers of Ph.D.-level chemical engineers (AIChE data),[4] it is of interest to discuss the research opportunities in that industry, as seen by this author.

As Figure 2 shows, the world of chemicals can be rational-

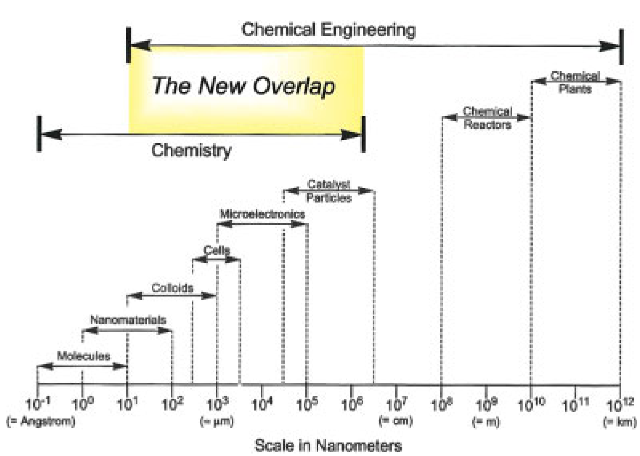

Figure 1. Scale of chemical activities.

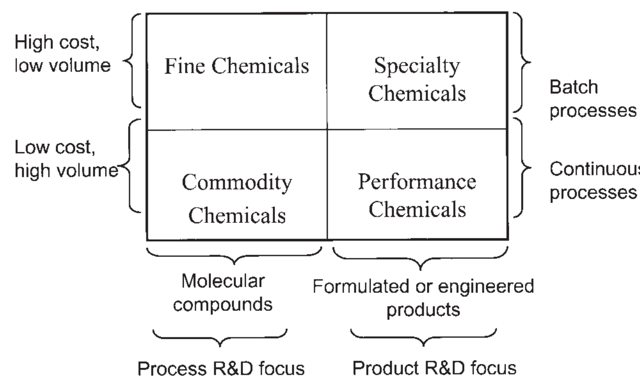

Figure 2. World of chemicals.

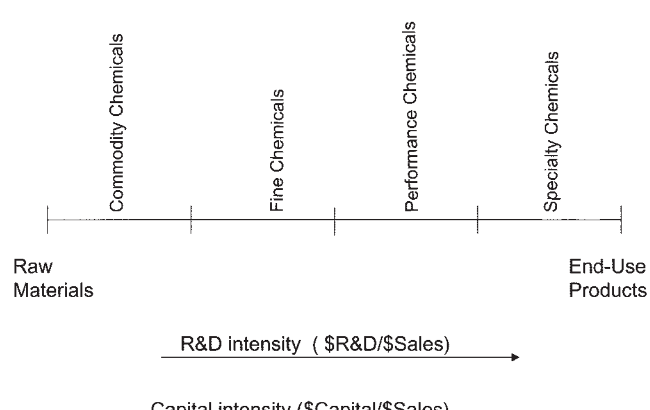

Figure 3. R&D intensity vs. capital intensity.

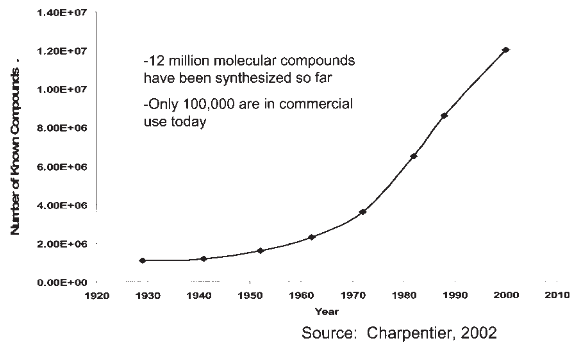

Figure 4. The world of chemical compounds is literally endless.

ized in a simple 2 × 2 matrix. Chemical engineering research evolved around the needs of commodities, and is now rapidly expanding into fine chemicals, specialty chemicals, and performance chemicals. As these opportunities are downstream in the value chain (Figure 3), they represent issues with higher R&D intensity vs. the high capital intensity of commodities.

I would like to refer to an industrial example for this last point, quoting the dollar value of materials per KW of proton-conducting fuel cell performance. On that basis, utilizing typical manufacturing costs for high-performance polymers, the membrane's monomers are worth about $1, the polymers about $6, the membrane (solvent-cast polymer) about $56, and the membrane-electrode assembly (which now includes the catalyst) about $152.[5] Noteworthy is the large value multiplier due to the engineering activity of forming a workable membrane.

Many of the opportunities lie in the industrial production or application of new compounds (as per Charpentier,[6] as of 2002, about 12 million chemical compounds have been synthesized, while only about 100,000 were in commercial use, see Figure 4), while there are exponentially growing additional opportu-

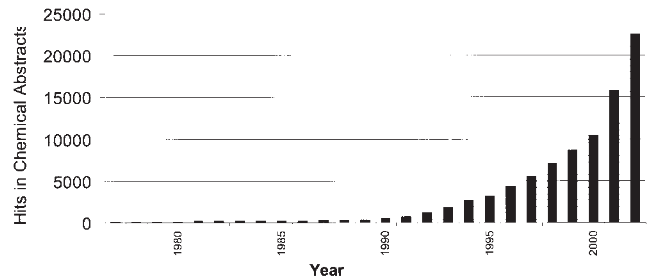

Figure 5. The world of nanostructured materials is growing exponentially.

nities in structured (e.g., nanostructured) materials of existing compositions (Figure 5).

Value-adding R&D opportunities abound in the chemical industry in product, process, and applications research. New methodologies of experimentation ("parallelize, automate, robotize, miniaturize, model, and simulate") have drastically enhanced R&D output, driving an ongoing renaissance of the R&D activities in our industry.

On the basis of this brief analysis, I see a continued distinct identity and bright future for chemical engineering research.

Literature Cited

1. See Reference (2).
2. B.V. Koen, University of Texas, Austin, published an interesting book about the engineering method (Discussion of the Method, Oxford University Press, 2003).
3. R. Frosch, discussions at the NAE annual meeting, 2003
4. Such data can be found at the AIChE web site.
5. TIAX (2003) published a DOE-sponsored study of fuel cells.
6. J.-C. Charpentier, International Journal of Chemical Reactor Engineering, Vol. 1 (2003), Article A14.