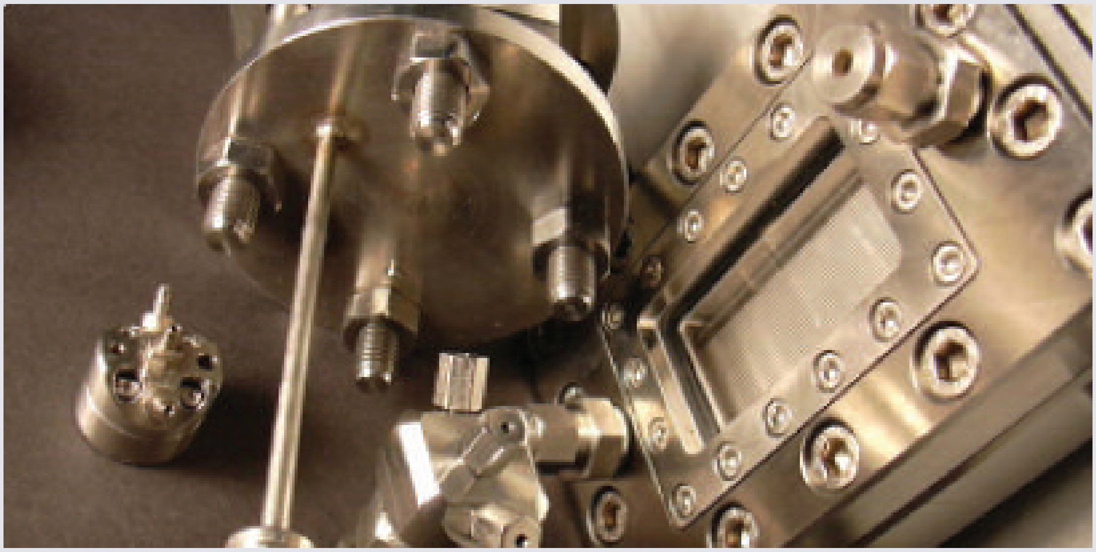

Dirk Kirschneck, Walter Linhart
Microinnova Engineering GmbH
Graz (Austria)
office@microinnova.com

FUTURE VISIONS FOR THE PROCESS INDUSTRY

Micro reaction technology can deliver some important advantages especially for pharmaceutical and fine chemical applications in comparison with the traditional batch mode production. The first point is increasing the development speed and the second one is the optimization of the manufacturing process performance. The core of micro reaction technology is a continuous working plant with microstructured devices as key elements. Microinnova's vision of chemical production in 2020 is also introduced.

Introduction to Micro Reaction Technology

Micro reaction technology can deliver some important advantages especially for pharmaceutical and fine chemical applications. The first point is increasing the development speed and the second one is the optimization of the manufacturing process performance.

The core of micro reaction technology is a continuous working plant with microstructured devices as key elements. This plant can be a development tool for the chemist and the chemical engineer, as well as a plant for small and large scale production. For process development Merck has evaluated 63 processes from 11 classes [1, 2]. They found out that the lab development time can be reduced by 30%. Since a wide range of process conditions can be screened in a short period of time. This helps to generate process competence for the knowledge space according to the quality by design (QbD) approach. In addition advantages as the possibility to cut out the "kilo-lab" are resulting. It is only necessary take the labscale development plant and let it run for several days. Amounts between 100 g and 1 kg can be produced. Lonza has proved and implemented this method. Further improvement is possible by applying online analytics according to the process analytical technology (PAT) approach [3].

The chemical synthesis in the area of pharmaceutical and fine chemical production has usually some characteristic criteria.

Production plants run in small or medium scale in batch production. Multi step synthesises are carried out with high value products and working with toxic substances is very common. In many cases a change to continuously working plants with microstructured devices may show benefits as higher cost effectiveness or higher safety.

Microinnova transfers micro reaction technology into production scale. One Microinnova developed liquid-liquid application with a throughput of 3 tons per hour has been started up in May 2005 (Fig. 1) [4]. Another process example developed by Microinnova demonstrates a plant payback of a production plant in less than two years. These examples have proved technical and economic feasibility for using microstructured devices as manufacturing method. Hessel et al report about 30 operating pilot and production applications containing microstructured devices nowadays [5].

Some examples of future visions and technologies

The communication of visions in companies is treated in different ways. Some future visions are communicated very open. Some examples are given here just to get an impression how chemical processing could be handled in the future. As shown at the beginning of this article there are some forces for a significant change. The following paragraph should give some ideas which changes might result using new technologies.

BP thinks about offshore processing [6] on mini or micro process technology. This would be logistically challenging. If the processing can be done offshore, only the transport to the customer is necessary instead of transport to the processing plant and then to the costumer. The scenario could either be a platform or a boat. Requirements for the technology would be light-weight and a small footprint design. Additionally for the boat the technology must not be motion sensitive.

The concept of miniaturized process equipment has a great impact on common production plant calculation methods [7]. One of the most famous capital cost calculation rules is the "0.6 rule". This rule teaches that capital cost of production typically increases with production volume to the power of 0.6 in the processing industries. This rule is the main reason why companies build "world-scale" plants. Since micro plants work with numbering up, in principle micro plant have higher capital factors. Van-den-Bussche describes two case studies of distributed production concepts. He shows that a microstructured plant (195 tons/day) for the synthesis of methanol can compete in price (0.70 $/gal) with a 2,326 tons/day plant using standard technology in the US (0.67 $/gal). Only the standard plant with 5,000 tons/day in the Middle East has a significant production price advantage (0.53 $/gal). In the second case the intensification potential of a distributed hydrogen production in the 1-5 kW range has been evaluated. The analysis of the flow chart has shown an intensified process with a higher efficiency and most likely with having a lower capital expenditure.

Stankiewicz *et al.* discuss other methods for providing energy to chemical reaction for process intensification [8]. Since microreaction systems are continuously operated, this energy can be provided in compact flow through devices. They discuss the process intensification potential of different types of energy-input and identify five different types of alternative energy and the possible impacts:

- microwaves (impact on reaction time and on distillation time);
- ultrasound (impact on reaction time, liquid-gas mass transfer, liquid solid mass transfer);
- electric field (impact on interfacial area and on heat transfer);
- high gravity field (impact on reaction time and on liquid side mass transfer);
- light (impact on reaction selectivity and yield).

They show several examples with these kinds of energy. The enhancement factors for the different impacts are estimated to be between 5 and 1,250. Examples are a spinning disc reactor with a times ten higher local mass and heat transfer coefficients or microwave enhanced reactions where specific heat can be applied

Fig. 1 - Three tons per hour micro reactor in production application installed by Microinnova

to chemical reactions. Ultrasound provides a very interesting effect on labscale like splitting water into radicals. These effects generate a new field of research called sonochemistry [9]. The main problem for sonochemistry is that there is not a competitive production scale solution at the moment. In principle a continuous working device based on miniaturisation could provide a homogeneous field of ultrasound can maybe solve this problem.

Stankiewicz sees a potential for hybrid operations carrying out two or more process steps in one device [8]. These steps can be one or more reaction steps combined with other unit operations. Different combinations of reaction steps and unit operations offer a wide range for new intensified devices.

Felcht [10] describes four types of business models, split up in two groups, in the chemical industry. The first group are the molecule suppliers and the second group are the problem solvers (or product formulators). The molecule suppliers can be divided into commodities and fine chemicals. The problem solvers can be divided into functional chemicals and life sciences. The possible innovation strategies are reviewed here with a focus on the process. The commodities companies can innovate by high sophisticated process technology, using the economy of scale and by interlinking process steps. Fine chemicals companies will benefit from the ability to carry out complex organic synthesis fast and efficient. A broad technology portfolio helps to succeed with difficult synthesis tasks. For the functional chemicals group a very good technical understanding (better than the customer) is one of the key parameters. They use a broad flexible technology and have some so called "magic ingredients" in their portfolio. Drug discovery and drug targeting is the core competence of the life science company. High throughput screening and testing are the innovation fields. Felcht sees advantages in micro process technology especially in the fine and functional chemical area to innovate the previous described core competences.

Microinnova's vision of chemical production 2020

Numerical methods gain more and more importance in mechanical and chemical engineering science. Microinnova thinks that simulation methods are one of the key areas on the way to knowledge based development of processes. At present chemistry and chemical engineering are far behind other branches. The automotive industry is able to design a complete virtual car. On the way to the "virtual process" simulation, methods need to be improved and validated.

In the research and development centre plants will run completely automated. Chemists and chemical engineer design experiments

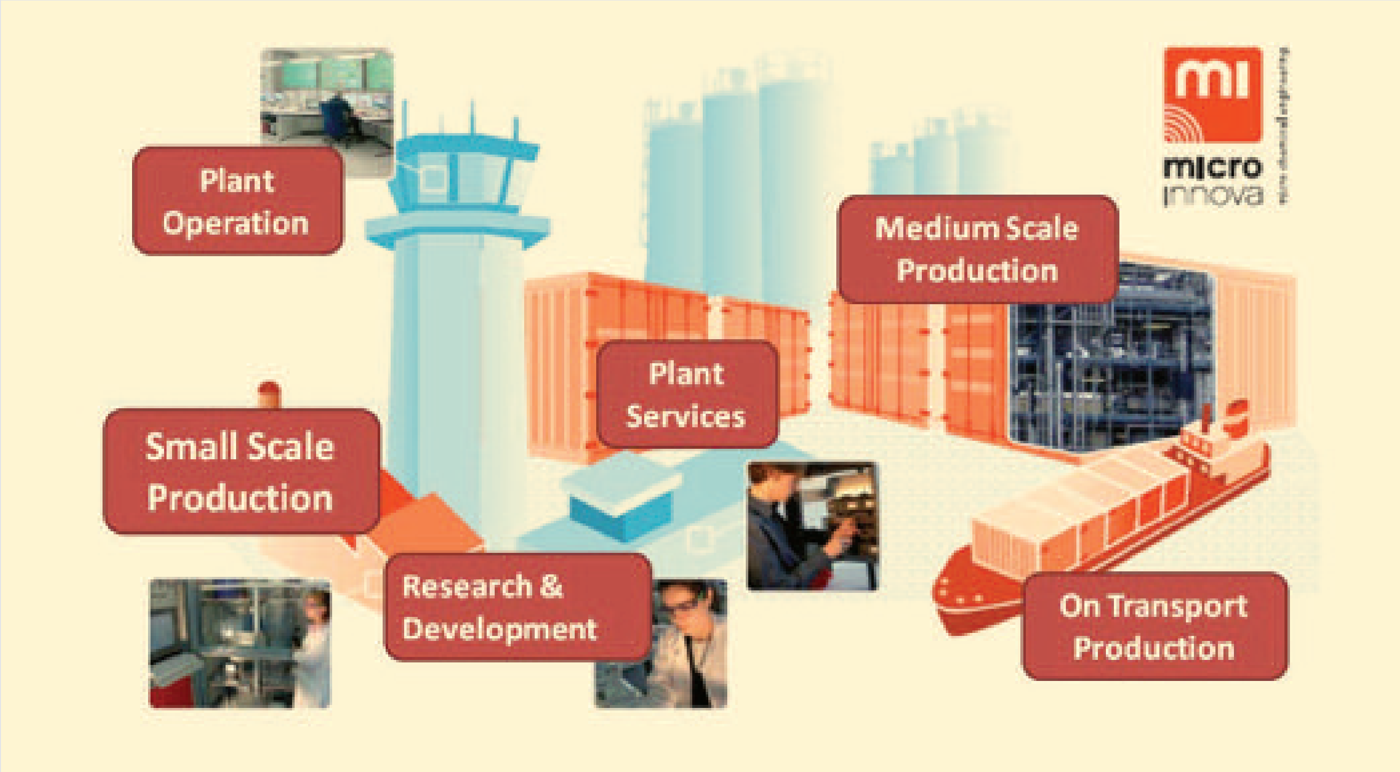

Fig. 2 - Microinnova's vision of chemical production in 2020

on an interactive basis. The plants optimise automatically defined parameter, using high automation in combination with online analytics. Main tasks for the lab technicians are analysis, evaluation, plant-setup and plant-service.

Knowledge based approaches drive the development. Experimental need is minimized by this approach. Models become the most important part (e.g. molecular modelling, computer fluid dynamics and process simulation) in terms of effort. Chemical development and process design change from trial-and-error to model predicted development. The production of small scale quantities will be realized in compact and completely automated continuous plants. This plants can be designed mobile and for the use in a fume cupboard in lab environment. Medium scale applications will be carried out in flexible plants with a modular concept. This modular concept enables multi purpose use of production plants. Containers for example can be used to build up several units. Degussa has presented this concept in different conferences [11]. These modular units are connected to each other according to process needs. Similar to the small scale production units, these modules are connected to the peripheral as power supply, media tanks, and products storage. Separation will be done in attached modules, which are mobile and can be exchanged between different plants, since they are small enough to transfer them by forklift or pallet carrier. The control of the production plants will be organized at a centralized control room. Plant service and maintenance personnel will take over tasks of the former plant workers since it is expected that no staff is needed during plant operation (Fig. 2).

Conclusion

There are strong driving forces for a fundamental change in the process industries. One is the pressure to reduce costs to be worldwide competitive. Another is to keep the innovation level high for the same reason. New development possibilities will cause a change in the organization of the development process. Micro process technology offers concepts for innovative cost saving process development and production. First pilot and production scale examples give strong hints that micro process technology becomes an important production technology in the medium future. Also production reliability of a microreactor in the tons per hour scale has been proved. Other promising technologies like membrane and alternative energies (e.g. ultrasound, microwaves or UV-Light) can be integrated in the technology concept. Since microreaction systems are continuously operated, this energy can be provided in compact flow through devices.

References

[1] D. Schmalz *et al., Chem. Ing. Technik*, 2005, **77**(7), 859.

[2] D.Schmalz et al., AIChE Spring Meeting Orlando, Florida, USA, 2006.

[3] D.M. Roberge *et al., Chem. Eng. Technol.*, 2005, **28**(3), 318.

[4] D. Kirschneck, G. Tekautz, *Chem. Eng. Technol.*, 2007, **30**(3), 305.

[5] V. Hessel *et al.*, Chap. 6 in Process Intensification in Micro Instumentation for High Throughput Experimentation and Process Intensification - a Tool for PAT, M.V. Koch et al. (Eds.), Wiley-VCH, Weinheim, 2007, 85.

[6] J.J. Font Freide, Mini vs. Maxi: The miniaturization and intensification of technology, in Proc. of the 17th International Congress of Chemical and Process Engineering, Praha, Czech Republic, 2006.

[7] K.M. VandenBussche, Chap. 3 in Process Intensification in Micro Instumentation for High Throughput Experimentation and Process Intensification - a Tool for PAT, M.V. Koch et al. (Eds.), Wiley-VCH, Weinheim, 2007, 43.

[8] A. Stankiewicz, *Chem. Eng. Res. Des.*, 2006, **84**(A7), 511.

[9] T. Mason, J. Lorimer, Applied Sonochemsitry - Uses of power Ultrasound in Chemistry and Processing, Wiley-VCH, Weinheim, 2002.

[10] U. Felcht, *Chem. Eng. Technol.*, 2002, **25**(4), 345.

[11] R. Schütte *et al.*, Prozessintensivierung bei Degussa: Bessere Produkte plus neue Produkte at Infotag Prozessintensivierung - Ansichten der Industrie, 29.5.2006, DECHEMA, Frankfurt.

ABSTRACT

Previsioni sul futuro dell'industria chimica di processo

Viene introdotta ed esemplificata la tecnologia che utilizza reattori o circuiti miniaturizzati e valutato il loro possibile impatto economico confrontato con tecnologie che utilizzano sistemi tradizionali. È altresì presentata la personale visione di Microinnova su un possibile scenario futuro e su come potrebbe evolvere il lavoro dei chimici e degli ingegneri chimici di processo.