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ORIGINAL ARTICLE

# Towards service-orientation—the state of service thoughts in the microfluidic domain

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**Abstract** Society is shifting towards an 'experience economy' based around services. Microfluidics, as a relatively new area with high potential for customised devices, is a profitable domain. However, what is the current situation of services in this domain? Has the domain started this movement towards services or is it, as yet, too soon? To answer these questions and identify gaps in the area, research based on academic literature and current microfluidics offerings has been undertaken. This paper briefly reviews current academic literature in this domain and then investigates the actual state of service-orientation in microfluidics, using data from company websites and brochures. The current state of servitisation in the area is then discussed.

**Keywords** Microfluidics · Microfluidic devices · Services · Service-orientation

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## 1 Introduction

Company offerings are shifting from products to services in a so-called 'natural' manner [1]. These changes are defined as 'going toward an experience economy'. This movement can be observed in many industries.

Microfluidics is a relatively new domain and appears to be profitable [2, 3]. Also, it shows a high potential for customised devices [4]. However, any movement toward an 'experience economy' in this area is not obvious and therefore needs to be explored. Moreover, an indication of whether any demand for an orientation towards services [5] in the microfluidic domain exists is required. This will provide an insight into the future of microfluidics. In addition, it will indicate the future shape of design methodology for microfluidic devices in terms of services.

The aim of this paper is to identify the state of service-orientation [6] of microfluidic devices. To capture this current state, two objectives are stated. First objective was to identify how service-orientation is viewed in microfluidic literature. This objective helped to clarify if written resources identify this area as service-oriented. Moreover, this aimed to show how the word 'service' is used in microfluidic domain. It tried to identify if it is employed in all aspects of product development, and in addition, to indicate if services for microfluidics are seen purely as something that is added to the product.

Second objective was to recognise the type of services provided for microfluidics. This allowed the recognition of which services are provided for products in this area. In addition, it provided information about the maturity of the area in terms of shifting toward an 'experience economy'. This information has been exposed by an indication of the degree to which the offerings are divided between products

and services. Moreover, an identification of whether they are combined to provide customer satisfaction was acquired.

To realise these objectives, a literature study has been conducted with its focus on service-orientation of microfluidic devices. However, investigation of selected topics uncovered the necessity for broader exploration of the literature and related topics. This was followed by an initial exploration of the current state of the microfluidic field in industry. Exploration was conducted based on publicly available information provided on company websites and in their brochures. This investigation has been focused on microfluidic company offerings and consideration of services incorporated in them.

The structure of this paper is as follows.

In the next section the literature regarding services and service-orientation in the microfluidic domain is briefly reviewed.

In the following section, the current state of orientation of the microfluidic area towards services is investigated, based on data, from websites and brochures of 38 companies.

The paper concludes with a discussion of the findings.

## 2 Movement towards services in the microfluidic domain

Society is shifting towards an ‘experience economy’ [1]. This transformation could be observed in the 1990s in USA [7]. Researchers identified “that in many manufacturing sectors, revenues from downstream activities represent 10 to 30 times the annual volume of the underlying product sales” [7]. Hence, organisations begin to focus on providing services required for operation and maintenance of products. Motivation for this was to create a strong relationship with the customer and help to attain customer loyalty. The increasing impact on profit of lowering customer retention also justified this [8]. It also allowed the acquisition of insight into customer needs. It improved suitability of offerings and helped to satisfy needs faster. However, the movement downstream may not be beneficial in case of every company. Supplying services to the customer is a large investment. Hence, it has to have an opportunity of revenue in the future.

However, this movement has not been identified in microfluidic literature, in which there currently appears to be no indication of the service-orientation concerning this domain. Instead, some authors have identified the whole domain as technology driven and seeking further applications [9].

A second method of determining whether service-thinking exists in the microfluidic domain is to study the categorisation methods for these devices.

Approaches have been found to vary from forces used to operate the device [10, 11], through type of fluid used [12], type of flow [13] to application [14, 15]. From the service point of view, most desirable would be the classification based on function performed by the product in terms of its utilisation. However, this form of categorisation has not been identified.

## 3 Services provided by microfluidic devices

Investigated literature showed that researchers refer to the devices mainly through their targeted application [14, 15]. Moreover, no general application-driven categorisation of microfluidic devices, which will include all types of devices offered, has been identified. Also, no indication of services provided for microfluidic devices has been recognised. Therefore, an investigation of company offerings in this area has been undertaken.

### 3.1 Investigation methodology

To view the state of service practice in microfluidic industry, an investigation of the services provided in this domain by companies has been undertaken. As the first stage of research, a selection of companies' offerings was selected. The selection was based on available resources and information available for public view—organisations' websites and their brochures.

The selection of the companies for research was based on reports regarding microfluidics market. This allowed us to choose 38 organisations as representation.

Data were gathered with focus on three aspects: products, services and services connected to products. This intersection aimed to present first insight into the depth of service thinking in the microfluidic domain.

Analysis of gathered data was carried out using Excel spreadsheets. Data were classified according to patterns discovered and commonalities observed. Based on the companies' offerings, types of services were extracted. This extraction was followed by categorisation of information according to observed dependencies. The results of this analysis are presented in this section.

### 3.2 Results obtained

Results gathered from this investigation are summarised in this section. A more detailed version of obtained results is presented in the attachment in Table 1. This table shows a number of microfluidic companies providing various types of services.

Not all of the investigated companies provide products as core of their operation. Seventy-one percent of them

**Table 1** Offerings of microfluidic companies

| Company name | Microfluidic products | Services | Services for products |
|---|---|---|---|
| Agilent [16] | 2100 Bioanalyzer, RNA solutions, DNA solutions, protein solutions, cell solutions, 1200 HPLC-Chip System | Instrument lifecycle planning, compliance services, Agilent service and support plans, relocation services, software services and update and software, revision tables | Instrument lifecycle planning and compliance services |
| AMIC [17] | 4 castchip—cardiac POC | OEM services | – |
| Aviva Bioscience [18] | Sealchip, hERG electrophysiology assay and cell lines | Electrophysiology on Demand (EPOD), cardiac safety: ion channel screening services, cardiac sodium channel | – |
| Bartels [19] | Alchemist®—dosing robot, micropumps, microvalves, CE Chips, Nano-Well Plates | – | – |
| bioMérieux [20] | Diagnostic solutions | Training for bioMérieux products, preventive and corrective maintenance of the systems, technical library access | All services scoped around offered products |
| Boehringer Ingelheim microParts [21] | MicroDegasser, X-Check Disc, Lilliput® chip—diagnostic chip for clinical microbiology | Production of microfluidic systems, development and production | – |
| Bürkert [22] | Solenoid valves and micro pumps for preferred use in analytical, medical or biotechnical applications | R&D, consulting, engineering, on-site assembly and commissioning, installation, testing, after sales services | Involvement in the specifications and requirements obtaining, design process, manufacturing and maintenance |
| Caliper [23] | LabChip® systems, LabChip® instrument and experiment-specific reagents and software | Service and support, The technical support hotline, installation services/first to science, maintenance and service contracts, instrument validation services, training and certification | All services scoped around offered products |
| CMC microsystems [24] | Environment and equipments—not products by themselves | Design environments, prototype manufacturing services, technology files and user guides for manufacturing processes, engineering support | Access to environments and equipments with support |
| Diagnoswiss [25] | GRAVI™—Chips, Lab, Cell, Soft | – | No maintenance necessary due to gravitation principle of work |
| Dolomite [26] | Microfluidic pumps, connectors, microfluidic chips, membrane devices | Custom design project, new system or instrument development project | Design of products, rapid prototyping along with the ability to ramp up to volume manufacture. |
| Dyconex [27] | Manufacturing custom products | Design support | – |
| eGene (Qiagen UK) [28] | Products for DNA and RNA analysis | Technical service | Technical service |
| Eksigent Technologies [29] | Express LC—pharmaceuticals, The ExpressRT™-100—reaction monitoring, Eksigent's flexible NanoFlow Metering platform, EKPump | – | – |
| Epigem [30] | Foundry and consultancy, manufacturing of: 'lab-on-a-chip' microfluidic devices, microlens arrays, ultra high-resolution flexible circuit boards, polymer wave-guides, other micro-optical products | Product development, contract manufacture for polymer microsystems, pilot/speciality coating and UV embossed structures | Consultancy and manufacturing for clients from polymer |
| ESI Group [31] | Software tools for: biochips, clinical diagnostics, inkjets, fluid dynamic bearings, mixing analysis and surface binding and chemical reaction analysis | Collaborative R&D, training and technical support, consultation and product development services | Simulation of interacting physics in micro-devices (CFD) and for their product (software) training and technical support |
| Fluidigm [32] | BioMark™—real-time PCR assays, TOPAZ®—protein crystallisation | Installation, service, user documentation, applications support, service agreements/support plans | All services scoped around offered products |
| Fluigent [33] | Flow control tools, genetic testing—enhanced mismatch mutation analysis (EMMA™), Emmalys (software) | – | – |
| Gyros [34] | Gyrolab Workstation, Gyrolab CD | GxP validation support, application | All services scoped around offered |

**Table 1** (continued)

| Company name | Microfluidic products | Services | Services for products |
|---|---|---|---|
| | Laboratories Gyrolab software, consumables and accessories | support, instrument service | products |
| IMM [35] | – | R&D, development of prototypes, industrial analytics | – |
| Licom [36] | – | R&D services, design services, manufacturing services, feasibility studies and concept evaluation, workshops' organisation | Realisation of products |
| Micralyne Microfluidics [37] | Foundry, Standard and Protolyne® Microfluidic Chips manufactured on demand | Product development, manufacturing | – |
| Microbuilder [38] | – | Services for the development and manufacturing of prototypes and products | Realisation of products |
| Microfab [39] | Complete systems, printhead assemblies, drive electronics, dispensing devices, pressure and temperature control subsystems, optics subsystems | Manufacturing of products and technology, solder bumping services and technology, application development services, ink-jet seminar | Design and manufacturing of customer products |
| Microfluidics, division of Microfluidics International Corporation [40] | Microfluidizer® processor | Address formulation challenge, process consulting, off side demonstrations, regional seminars, purchase opinions, customised in-house seminars and training, testing, starts-up, training and maintenance, preventive maintenance contracts | All services scoped around offered products |
| Micronics [41] | MicroFlow™ system, Active™ lab cards, Access™ cards | Fluidic modelling, on-card sample preparation, mixing/separation and analysis, reagent printing and waste storage on card, Surface chemistries and materials analysis and selection for optimum card performance, integration of filters, arrays, slides, electrodes and other components on card, development, rapid prototyping | Design and prototyping of elements. |
| Micronit microfluidics [42] | Fluidic connect, fluidic chips glass, capillary electrophoresis lab-on-a-chip products | Design, simulation, prototyping and high volume manufacturing | All services scoped around offered products |
| Microplumbers [43] | Service offerings | Diffusion, flow, and chemical reaction modelling | All services scoped around clients' products |
| MicroTEC [44] | Manufacturing custom products | Development and contract manufacturing, prototyping, batch production | – |
| Nanogen [45] | NanoChip® 400 system—not for sale from 2007; products for instrumentation, reagents, test kits and CE kits | Support for sold equipment | Support for the sold equipment |
| Seyonic [46] | Pipetting systems, miniature high speed flow sensor Module | – | – |
| SpinX Technologies [47] | Microfluidic gCards™, which are organised into a gStack™, Spinx Lab, SpinXplorer™ and AssayStudio™ control and assay setup software. gCards and gStacks | – | – |
| Tecan [48] | Platforms for biopharma/research and clinical diagnostics | Installation, preventive maintenance, repair, upgrades, training | Installation, Preventive maintenance, Repair, Upgrades, Training, Service contracts |
| ThinXXS [49] | Foundry | Manufacturing services for microfluidic systems | Development, production and distribution |
| Translume [50] | Microfluidic chip, fluid monitoring system | – | – |
| Tronic's [51] | Foundry—manufacturing on demand—custom products—no off the shelf | Product development, manufacturing, translate and transition ideas and | – |

**Table 1** (continued)

| Company name | Microfluidic products | Services | Services for products |
|---|---|---|---|
| | components | product concepts to manufacturing, transfer concepts and technologies from third parties, customise product platforms, custom packaging and assembly, specialised test and characterization protocols, end-to-end services, co-design | |
| Wasatch microfluidics [52] | The Continuous Flow Microspotter™ (CFM) | – | – |
| Weidmann Plastics [53] | Cassette for blood gas analyzer, cartridge for coagulation monitoring, LabCD TM | Manufacturing, development of the production processes and mass production, technical evaluation service | – |

offer microfluidic devices as their core operation or as additional profit source. The rest of them provide consultancy, manufacturing and other services to address microfluidics field.

Investigation showed that majority of companies that offer microfluidic devices indicate their functionality or area of application. However, the 'name' of the device rarely indicates its designation. For a person without specific knowledge about the area often it is impossible to predict how the device can be used. This situation is due to the fact that majority of these devices are offered on business-to-business (B2B) basis.

Therefore, customers are highly specialised and are able to identify the operating principles of particular microfluidic devices.

It can be observed that 79% of companies have been identified as incorporating services into their offerings. Of these services, 77% are scoped around the products. These services are diversified. They are connected to the product loosely, such as training, or directly e.g. maintenance. Other category which can be identified among services is that they can be used to help in the creation of the device, e.g. design, simulation, feasibility study, only manufacturing, and/or microfluidics connected services, e.g. design environment, process optimisation, R&D.

Variety of categorisation methods can be applied for services. To analyse data gathered, common characteristics of service offerings were extracted. Based on these characteristics services have been classified as presented in Fig. 1. It can be observed that majority of companies offers consulting services, i.e. helping in optimisation and/r establishment of manufacturing processes for microfluidics.

Microfluidic organisations offer training for their own equipment—how to use it—and for the general study. Their services vary from design and simulation to manufacturing and support.

Also services provided by companies are generally scoped around design and manufacturing of the devices as B2B contracts. Due to the high cost of manufacturing equipments and lack of literature discussion of services for microfluidic devices, organisations providing services for microfluidic domain were expected to be mainly established as foundries. However, investigation showed that among identified only 16% offers manufacturing facilities. This means that 20% of the microfluidic organisations offering any services offer also manufacturing.

On Fig. 2, it can be observed that the number of services offered by microfluidic companies, as well as their offering patterns, varies. Organisations offer only products, only services or combination of both. There is no clear pattern in which various types of services are combined. Not all of the companies which offer design offers also prototyping also not all that delivers training sell their own microfluidic devices. There are no commonalities on how companies structured their offerings. However, among each company, services and/or products offered are connected. Companies focus on the particular part (front end, middle, back end) of the product life cycle. Moreover, some of them scope their offerings and support around whole life cycle of the microfluidic product. In this way, companies diversify their profit source and exploit potential of the business developed with core offering.

Microfluidic companies offer not only products but also services. However, none of the services identified for

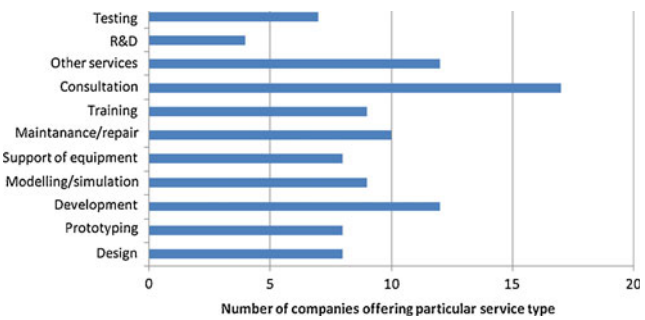


**Fig. 1** Types of services offered by microfluidics companies

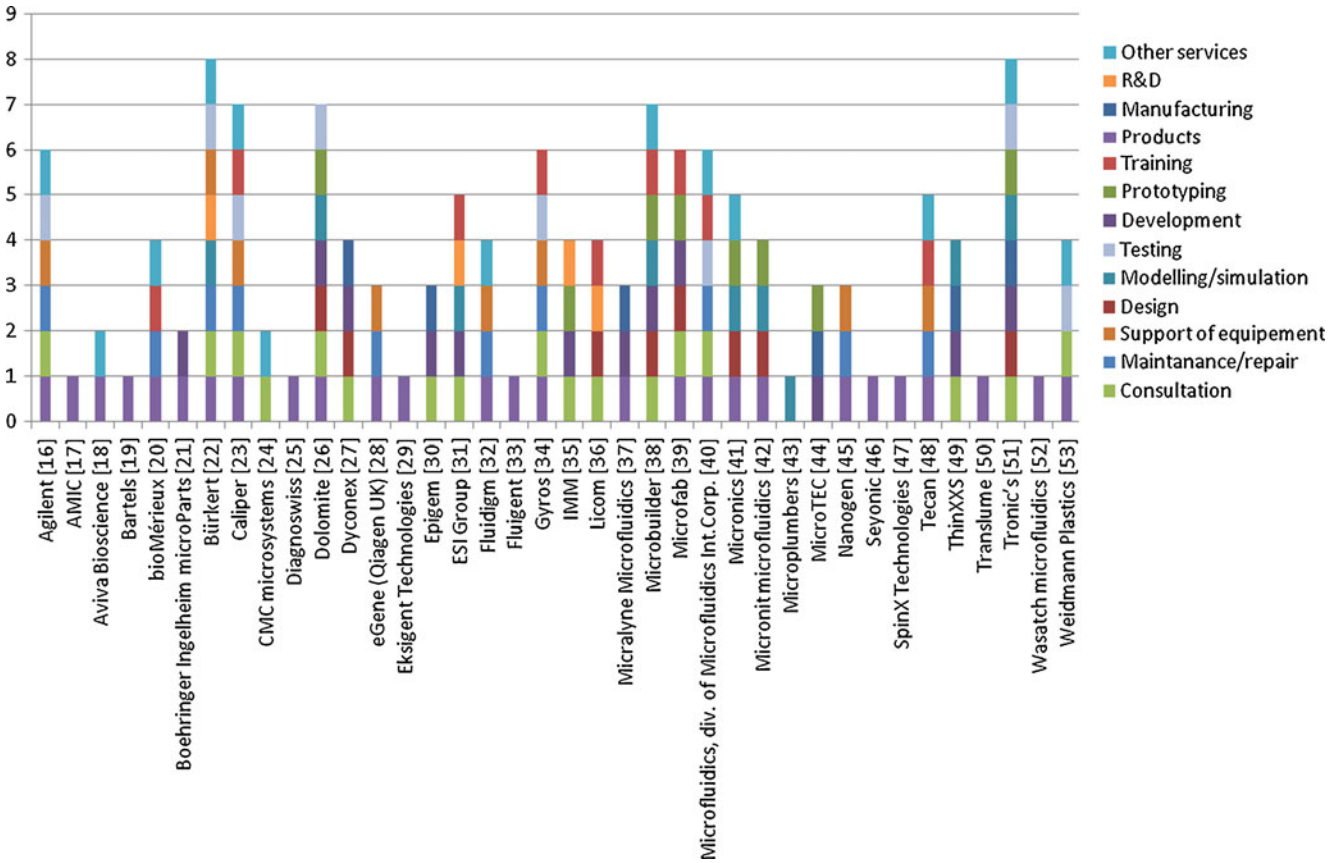


**Fig. 2** Offerings of the microfluidics companies

products was offering them as functionality instead of as a device. Discussion of the results in connection to microfluidic literature is provided in the next section of the paper.

## 4 Discussion

Investigation of the categorisation of microfluidic devices has been undertaken to show whether service thinking is incorporated in these products.

The most relevant from service point of view were categorisations according to functionality and application. However, both of them were more focused more on operating principles of the devices than on the needs that device will fulfil.

Hence, investigation of the offerings of 38 companies' has been undertaken. This investigation showed that services offered in the industry seem broader and more mature than lack of literature in this area for microfluidics suggests.

Seventy-nine percent of the companies were identified to incorporate services into their offerings. This indicates that majority of them scope their operations for providing not only microfluidics as technical solutions but also as a 'whole package'—product plus additional service. This indication is supported by the fact that 77% of services identified were directly connected to microfluidic devices. Moreover, not all of the identified microfluidic companies offered products. Seventy-one percent of the investigated organisations scoped their core operation around developed devices. However, other 29% organisations based their offerings purely on services. This raises questions about the maturity level of the industry as well as differences between industry and academic view on microfluidic area.

Although services identified vary in terms of type, they are mainly scoped around design consultancy and production capabilities. Services range from the feasibility studies through design, maintenance to manufacturing of the device. However, these services are not exhaustively described with indication of adaptability to individual needs. Services designated for the product described are identified as technical and cover in majority of cases maintenance, repair and user training.

Regarding indication from literature majority of the services identified in the industry was expected to be manufacturing based. To make their own production economical, due to the high cost of the production equipment for micro-manufacturing, some companies di-

versified service offerings around manufacturing process—design, simulation, etc.—rather than developed products. Therefore, they use other companies manufacturing facilities. Hence, studies were expected to indicate that only the service identified will be the establishment of the organisation as foundries and providing manufacturing capabilities. Surprisingly, the results obtained showed that 80% of the companies offering services do not include manufacturing on demand. It was unexpected to note that other services are dominant in comparison.

Also, in contradiction to literature is the offering of the maintenance and repair for some of the microfluidic devices. While literature sees them mostly as low cost and disposable devices which do not need to be maintained, the industry presents even enhancement services for microfluidic products. However, these services are offered only for devices design and developed 'in house'. Maintenance and/or repair utilities were identified as offered by 26% of the investigated companies. This shows that there is a market for microfluidic devices which can be used frequently, not as a one-time cheap product. This perspective in connection to promising customisation forecasts for microfluidic devices creates opportunity for service-based offerings to be more exploit in this area.

Creation of services around products, such as maintenance and repair, in types of organisations which manufacture other designs requires high flexibility. Manufacturing processes for microfluidics require individual consideration and planning for every type of device. Therefore, manufacturing facilities have to be adjusted to satisfy client requirements. Since even the process of production is discussed with the customer, providing services for products, which are not standardised, would increase the risk in organisations' operations. Development of general processes for utilities based on other companies' products will be not only insufficient as a result but also not economically feasible. High risk incorporates lack of property rights for the device and high flexibility required to make it. Therefore, they provide a broad range of utilities for 'in house' developed devices and services on the front end of the manufacturing process. These include help to obtain specifications, clarify them, confirm feasibilities of concepts, in modelling, simulation, prototyping, testing and fabrication.

Offerings provided by microfluidic companies do not show any pattern. They vary across the area. Some of the organisations offer only products, others offer only services, while majority combine both. Companies focus their work on particular phase of the product life cycle focusing their operations on the front, middle or back end of the process (disposal and/or reuse phases were not identified). However, not all of the companies that offer design capability also offer modelling, simulation and prototyping. There are no commonalities between these selling prospects. This can be caused by the infancy of the area, which was indicated by literature, where everything is mainly developed 'in house' and offerings were established because of the existing demand rather than planned as a whole.

Offers of devices as services were not identified. Offerings were product focused and devices even by name indicated more operating principle than usability. Also classifications of products were according to areas in which they can be applied to or operating purpose, e.g. DNA analysis not usage such as cancer detection. Review of literature suggested that industry is not ready for incorporation of this type of thinking into design process. However, investigation of offerings is in opposition to this claim. This area in terms of services is more mature than literature would suggest.

Therefore, practical investigation of services provided for microfluidic devices is suggested in this paper. Also regarding differences between information provided in the literature and on companies' websites, further research is recommended, since the websites indicate higher maturity of microfluidic domain in terms of services and orientation of the design process towards them. These issues are proposed to be investigated through the industrial/academic survey. This survey should include organisations working in the design and development of microfluidic devices and offering them to the market.

## 5 Conclusions

An investigation of service-orientation of microfluidic devices in the academic literature yielded no relevant information.

Orientation of microfluidics towards technology is, however, still visible in systems used to classify them. Application-specific and functionality-focused categorisations methods show movement towards intangibility and the customer in the offerings. These methods indicate that the first step towards services is being undertaken.

This was confirmed by an investigation of microfluidic companies' offerings. This indicated that there is a higher maturity of service-orientation in the microfluidic domain than the written documentation suggests.

It also allowed to the identification of how the word service is currently used in the microfluidic domain—in terms of intangible offerings: design, maintenance and repair. Moreover, it showed that although offerings are highly based on the products, services play significant role in many organisations.

The investigations conducted showed that microfluidic organisations are evolving in terms of service-thinking faster than microfluidic literature. They indicated some organisational readiness to meet new customer needs by enhancing and customising their offerings.

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44. http://www.microtec-d.com/html/a_homepage/e_start.html
45. http://www.nanogen.com/
46. http://www.seyonic.com/
47. http://www.spinx-technologies.com/
48. http://www.tecan.com/mandant/apps/home/default.asp?MenuID=1040&ID=50&Menu=1&Item=12
49. http://www.thinxxs.com/
50. http://www.translume.com/miva/merchant.mvc?Screen=SFNT
51. http://www.tronics.eu/
52. http://www.microfl.com/
53. http://www.weidmann-plastics.com/index.php