Microsystems

Headed by Jaap den Toonder

Microsystems can be found everywhere. Examples are micro-pumps and -mixers in medical diagnostic devices, wearable devices such as smart watches and health patches, sensors and actuators in cars, and electronic skin for soft robotics. Trends in microsystems are the ongoing miniaturization, hybrid integration, adaptivity to environmental conditions, and interaction and merging with biological materials.

Focus of our research

The Microsystems group focuses its research on the investigation and development of novel microsystems design approaches and rapid, flexible out-of-cleanroom micro-manufacturing technologies for microsystems. Our application focus is on microfluidic chips, biomedical microdevices, and soft microrobotics. Our approaches are often biologically inspired, translating principles from nature into technological innovations. We typically start from a specific application need or a problem that needs to be solved, and then design, realize, and test the microdevice.

Subprograms

1. Micro-manufacturing technologies

This forms the heart of the group. The emphasis is on out-of-cleanroom technologies such as laser micro-manufacturing, soft lithography, on-foil processing, and 3D-printing. The basis of this subprogramme is the new Microfab/lab managed by the group.

2. Microfluidics

In microfluidic systems, active control of fluids and species is essential. Examples are fluid pumping, mixing, mechanical actuation, micromechanical probing of cells and tissues, and biomolecule capture for diagnostics. We develop and apply micro-actuators, responsive surfaces, and magnetic bead actuation systems, to realize these functions. Our approaches are often biologically inspired, translating principles from nature into technological innovations. In addition, we develop methods to study meso-structured and soft materials such as gels, emulsions, foams, and polymers.

3. Biomedical microdevices

In collaboration with biological, biomedical, and clinical groups, we develop biomedical microdevices to study and understand the behavior of cells, tissues, and organs. This work is aimed at learning about health and disease, and eventually developing novel therapies and medicines. Specifically, we develop organs on chips as in-vitro disease models focusing on brain and cancer, and we study mechanical properties of single cells.

4. Micromechanics

Micromechanical actuators and sensors can be found in many areas. We work with industrial partners to develop relevant technologies for these applications, in wearable sensors for healthcare & lifestyle, water quality, and advanced sensors and actuators. A new and exciting area we are currently expanding is soft microrobotics.

micro systems

Projects with Industry

Integration and testing of an ultrasound needle for prostate cancer treatment

In this project Philips Research was involved and the research was carried out by student Tim van Zoeren. After skin cancer, prostate cancer is the most common cancer in men in the United States and is the second leading cause of death from cancer in men. The generally accepted therapies like surgery, radiation etc. are highly successful, but have severe side effects.

Radiation in a very small spot

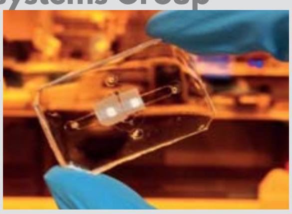
To reduce these side effects, ablation devices/techniques were developed. Conventional ablation devices create a point source like field that may also heat up healthy tissue in case the tissue is not spherical. Additional research resulted in a new technique called directional ablation that could reduce the aforementioned side effects even more. This technique is generally known as High Intensity Focused Ultrasound or HIFU. It allows for directional radiation in a very small spot, on one particular part of a medium.

Ultrasound elements in the needle

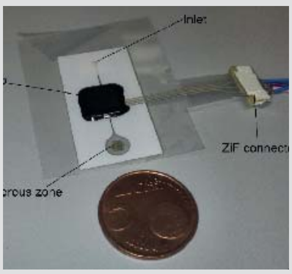
Currently, Philips is investigating the possibility to create US needles. The needles contain tiny ultrasound elements at the tip. These needles are being inserted through the skin and are located a few mm from the prostate tissue to directionally ablate the area of interest. The focus is not created by the needles itself, but by using multiple needles to create an overlapping field. This graduation assignment by Tim van Zoeren aimed at the implementation and characterization of these ultrasonic elements in a needle for the treatment of prostate cancer. Integration was done by gluing and wire-bonding a 10*1.4 mm CMUT (capacitive micromachined ultrasound transducer) array onto a small PCB and assembling this in a needle. The needles were tested with a hydrophone needle and radiation force balance setup to characterize the ultrasound field and acoustic output. These results show that the CMUT should deliver enough power to be used in cancer therapy.

Highlights in the Microsystems Group

Cancer on a chip: we have developed a microfluidic chip, in which we can study the development of cancer. This chip can in the future be used to develop new cancer drugs, and for personal diagnosis of cancer patients.



Wearable sweat sensor: we have designed and realized a flexible thin patch that can be attached to the skin, and that automatically samples sweat and flows it continuously along a sensor that measures the content of the sweat, for health and well-being applications.

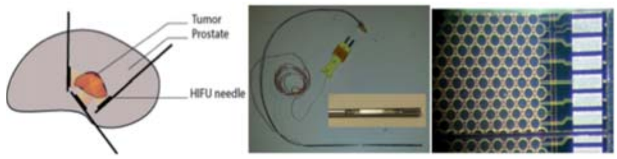


Microsystems and the industry

In our research group we work together, among others, with Philips, ASML, Holst Centre, TNO, Solliance, Bracco, Micronit, MA3 Solutions, Axxicon, DSM, Sabic.

Initial tests

Initial tests were performed with phantom material and chicken liver to investigate the ultrasonic absorption in a tissue. The results are promising: the needle is indeed working, but more quantitative and long-term temperature measurements (with multiple needles) have to be performed to tell if these needles capable to be adopted to ultrasound therapy.



PhD-student Hossein Eslami Amirabadi

'Cancer is a highly complex illness, and we need new insights and ideas to understand it better. That is why I am developing an application with the working title "cancer on a chip". We simulate specific processes that we see in the development of cancer. In this way, we will learn more about the why and how of the illness.

I study how individual elements around the tumor influence the spreading of cancer cells throughout the body. Hopefully, this research will contribute to the development and testing of new drugs. So it is a highly topical subject that has a great deal of social import, and that makes the research so interesting.

I like the fact that my research involves so many different disciplines. That is very inspiring, because I like to see new horizons. I have contacts with colleagues in other research groups and people in the professional field. That is a great source of inspiration for me. I also think it is very special to contribute to solving topical and socially relevant problems.

I am convinced that Microsystems is the best research group in the Mechanical Engineering faculty. The teachers are highly professional, but also friendly and open. That makes it a pleasure to work with them. And researchers and students reinforce each other. For me as a foreign student it is great to work in such an international environment. As a result, I have a wonderful social life. We are all in the same boat.

I am finding that when you do a PhD, you develop yourself both in academic terms and in personal terms. That's why it is important to choose a research project that suits you. I think the choice of your subject and the choice of your research group are very important in that. In fact, I made inquiries with other PhD students, because the choice of research group is just as important as the subject itself.'

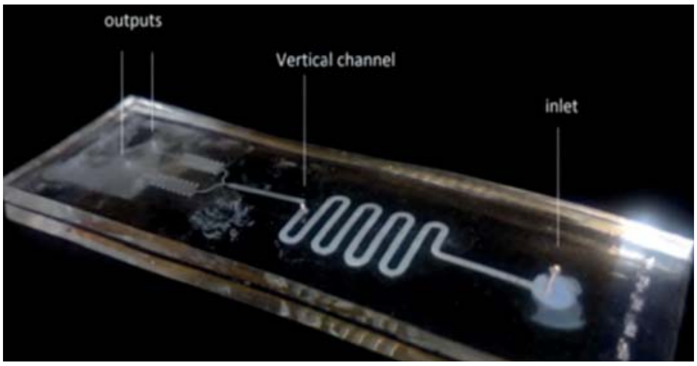
Professor Jaap den Toonder

'The Microsystems research group covers a very broad range of subjects. We design, make and test systems for various applications, which might be medical applications, but also something in the semiconductor industry. We tend to concentrate on actually realizing new, creative technological solutions. We certainly do not shrink from fundamental research, but our focus is always on making systems that have a function.
In almost all graduation projects we start with an idea or a practical problem that we want to solve. We then translate that into a system at a micro level. The students then go through the whole process, from idea all the way to concrete solution. This is not just very instructive, but also a lot of fun.
Creative minds that like to get their hands dirty and are not afraid to try things out in the lab, will find our research group just what they are looking for. As a Master's or PhD student, you don't have to be afraid of failing, because trial and error is vital in our research group. A healthy dose of creativity is also a good thing to have.

Because we are almost always working on some application, the link to the world of business is obvious. In fact, we collaborate intensively with companies both close to home and further afield: Philips and ASML are examples, but also university hospitals. You will find our graduates in a wide range of professions. One alumnus recently joined Ernst & Young.
Microsystems is the smallest research group in the Mechanical Engineering faculty, but we are the fastest growing. We do not want to keep growing indefinitely, though. It is important to know what is going on in the group in order to create fruitful collaborations. We always go for quality over quantity.'

Master's student Jorn Broers

'After my Bachelor's I deliberately chose the Microsystems research group. I am curious by nature and also have a very hands-on mentality. These qualities now stand me in good stead.
For my graduation project I decided to focus on water purification. Almost all water on earth contains, next to pure water, also millions of suspended particles. They can be sand or dust, but also viruses or other micro-organisms.
I developed a microchip that can makes it possible to separate the suspended particles from the water. The water and the particles are physically separated from each other, resulting in two separate circuits, one of which is clean water. We have demonstrated at the micro level that this technology works, but that doesn't necessarily mean can developed into a large-scale application. So now the challenge is to scale it up. Of course, the ultimate goal is to purify large amounts of water.
I don't know exactly what the future holds for me. I am talking to companies and would like to work as an engineer. I don't know yet whether I will be working on microsystems. It is a niche market, and I don't mind working in other areas. I chose this department because it is so versatile and because there is a clear link to biomedical technology. Apart from that, this field of work is completely fascinating. Things often work counter-intuitively, and you keep being amazed. Translating this 'elusiveness' into everyday applications is something that has always appealed to me. The ultimate goal of my research was to make clean drinking water for everybody, something that is easy to understand. And that is what makes it so much fun.'



Master's student Remco van Erp

'What attracted me in the Microsystems research group from the beginning was that you work on very practical applications: a useful little working machine on a micro scale. What I also liked is that multiple disciplines come together in this group.
During my Master's program I worked in America for ten months at the Wyss Institute for Biologically Inspired Engineering at Harvard in Boston, where I did my graduation research. It was a wonderful time: I worked in a lab that was developing organs-on-chips. You can implement human tissue on a small gadget that simulates the environment of the human body. One example might be a lung chip: a small piece of human lung tissue that has air flowing along it on one side and blood on the other. This stretches the tissue, which is precisely what happens in your lungs when you breathe. This application can then be used to conduct all kinds of research, like for example testing new drugs.
For my graduation research I developed a new kind of sensor for this application that can detect and quantify certain proteins quickly and relatively cheaply. That can give you information about how well a drug is working or how healthy the tissue is. The benefits of working on such a small scale is that you work with smaller volumes, which generates results more quickly and makes financial sense.
I recently finished my Master's degree. Unfortunately, I can't take a sabbatical, because I want to study in Switzerland. There is a university in Lausanne that has marvelous facilities for micro-engineering; a whole department is dedicated to this field. It would be great if I could do my PhD there. It is one of the best places to be to study microsystems.'