From ink to sensor

The interface of chemistry, microsystems, analytics and informatics

A short review about the week in Hasselt with the topic "Functional Materials Engineering"

By Marina Mayer

Introduction

Technical devices are getting smaller and smaller, so it's a challenge to shrink all of the components to gain all the characteristics and the same working level the device has got in its general size. The solution for these problems can be found in nanoscience. To create a small electric system it isn't necessary to work with very small elements. As an option for the micro-electric circuit it is possible to work with conductive inks. The field of printing technologies opens various possibilities as well as many facilities for research. This is what we heard about and worked with in our week at the Hasselt University. During this week, we independently produced conductive ink and got to know procedures to print on different materials. At the end of the week, we implemented the printed system by connecting the printed electrical circuit with a programming element to a working sensor in small groups. The task of my group was to create a water level sensor. The following text should give a short review about what we learned and did during our internship week.

Overview

Our week started on Monday with a short welcome to the summer school. Every day until Thursday started with various lectures by different speakers all around the topic "Functional Materials Engineering". In the afternoon we worked in the lab or were taken through the labs to see different devices and their working principles. At the end of the week, we got the lab-printed parts to assemble and program a sensor. This was completed on Friday morning and presented to the participants of the Summer School and the staff of the laboratory.

The lectures

During the lectures we heard about printing techniques, requirements for inks, ink formulation and where these inks are used. In the field of printing technologies there are different chemical solutions to deposit the ink on different materials: To get a homogenous thin layer the ink can be applied to the centre of the substrate which you spin around for a certain time in a Spin-Coater. Due to the centrifugal force, the ink spreads on the substrate. In opposite to the "Spin-Coating" it's possible to work with "Ultrasonic Spray-Coating" where the drops are formed by a vibrating nozzle tip. Unlike "spray coating," small drops are created in "Inkjet-Printing" by a movable piezo element, pushing and pulling an ink chamber through a vibrating plate. In "Screen Printing", ink is drawn over a template with a small element and applied to the material in a specific pattern.

Talking about the ink design, includes a few properties which must be regarded. The ink has to be stable and compatible to the substrate and it's important to think about the toxicology of the formulated ink related to its use. To apply the ink on the substrate, it has to be solvent and it is necessary to know the morphology of the deposition to control the rheology. All these factors must be taken into account during production to set the right parameters.

Of course, conductive inks can be classified into different types. For example, particle inks can be distinguished from MOD- (Metal-Organic Decomposition)/ solution-based-inks. Particle inks consist of metal nanoparticles dispersed in solvent. Due to heating the solvent and other additives evaporate. At a temperature of 300°C the particles sinter and stick together which leads to an increase of the grain size. The final product is a thin metal layer.

The problem with these inks is that they are not compatible with heat-sensitive materials, such as plastic. In order to be able to print on flexible objects, low-temperature procedures must be used. As an alternative, MOD-inks can be manufactured. These inks are not made by particle sintering. MOD inks contain metal ions in solution. Redox potential and coordination chemistry cause metal deposition. Metal layers can be obtained via in situ reduction using formate or oxalate counter ions at low temperature, because these particular ions oxidize easily to CO_2 without leaving organic residues in the layer which could impede the conductivity.

The applications of printed elements are manifold. Their low cost, flexibility, versatility in design and application to very small elements make them very attractive to various industries. Functional inks can be used for sensors, photovoltaic cells, batteries or as electric circuits. Sensors can be printed with functionalized graphene. The photovoltaic cells can be made by photoactive materials, while the printed batteries are based on electrolytes. The printed circuits are made of metal inks and can be used for other devices. An example for an end use may be a biosensor. The sensors are used, for example, in the Food & Healthcare sector. For example pregnancy tests or Glucose sensors for people with diabetes or other diseases as well as thermochronic inks which detect fever, thereby changing their colour.

Our labwork

Monday was our chemistry day. To build a sensor with a printed circuit, the first step is to create the ink. Our labwork were split in three parts: synthesis of copper formate, synthesis and spectroscopy of silver nanoparticles and the synthesis and properties of copper MOD inks. Because we were a very large group and had very little time, the experiments had to be stopped at some point. Unfortunately, many things did not work for our group. On Thursday and Wednesday we were shown around in the labs. They showed us a glovebox, a scanning electron microscope and printing techniques like an inkjet- or a screen-printer. The whole equipment to see, among other things also a Raman-Spectroscope was very interesting. We have already discussed many devices in the lectures during the course of studies in “Instrumental analytics”, but never really seen them. It was very good to stand next to the device and get the theory explained.

From ink to sensor

On Thursday we started with our own project. There were five sensor-projects available: humidity-, waterlevel-, proximity- and temperature-sensor and a capacitive piano. My group chose the water level sensor. The water level sensor consists of three components: the signal receiver, the signal transducer and the signal output. The sensor is responsible for the signal income, which means that it registers the water level. Our sensor was a small cup that worked on the base of a capacitor (figure 2). To produce our capacitor, we had to print a circuit. By using a conductive ink we printed silver nanoparticles on a polymer substrate. To print the circuit, we used an inkjet-printer which is an optimized process depending on different parameters such as temperature, drop spacing, solvent compatibility and other parameters (figure 1). The sensor is responsible for the signal income, which means that it registers the water level.

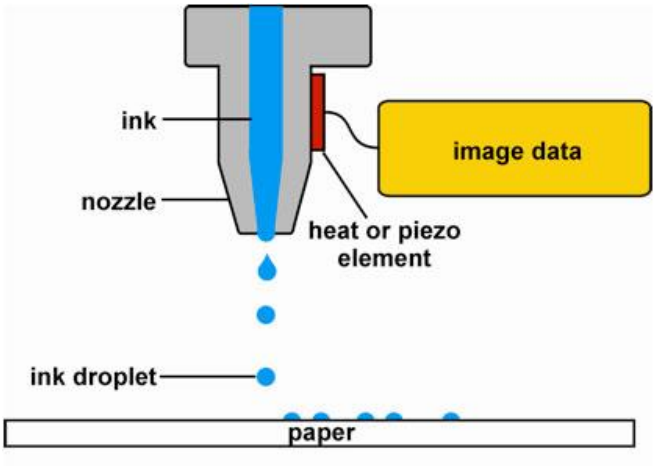

Figure 1: Working principle of the inkjet-printing: small drops are formed by a movable heat or piezo element pushing and pulling an ink chamber through a vibrating plate.

Figure 2: Sensor with inkjet printed strips.

The transducer used was a microcontrol board called "Arduino" with special software, as seen in figure 4. The Arduino sends pulse-width-modulation-signals of 5 Volts into the capacitor. The capacitor charges and the outcoming voltage is measured by Arduino. As the capacitor needs time to charge, there is a time-difference between input- and output-voltage. The time-measurement will start with the pulse-width-modulation-signal and ends with recording 2,5 Volts at the output. The time-difference is directly related to the capacity which is charged by the dielectrica (figure 3).

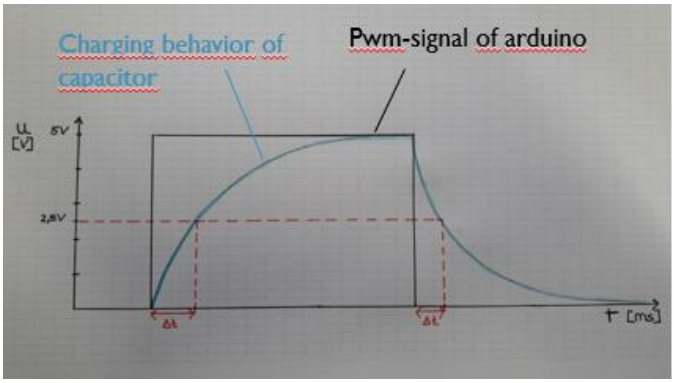

Figure 3: Charging/ discharging function of the capacitor.

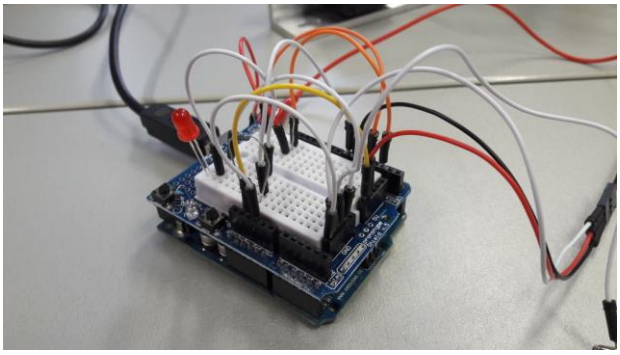

Figure 4: Arduino Hardware: Microcontrolboard.

Signal outcome was a small motor connected to the Arduino. By hand, we have painted a display that indicates the water level analog. Through various commands, we have programmed the Arduino so that the wooden stick moves depending on the level in the cup.

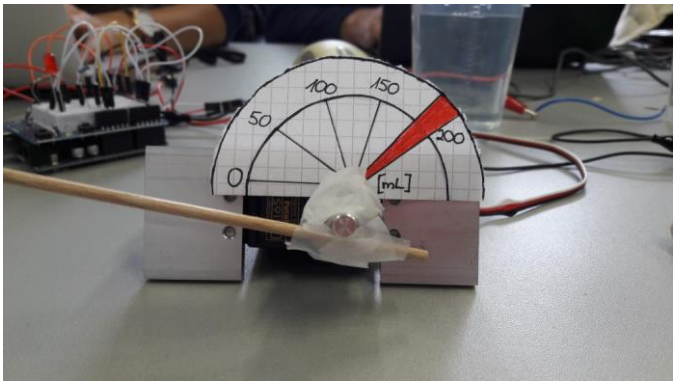

Figure 5: Motor as signal outcome, the wooden stick moves when the water is filled.

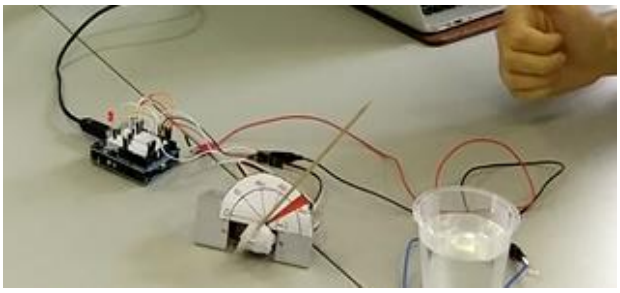

Figure 6: Construction with all components.

Conclusion

In summary, I learned a lot of new things during the week in Hasselt. I have experienced many interesting things and the subsequent practical work has made it much easier to understand. We have come in contact with many new things that are not taking part in my “Applied Life Sciences” course. That made the lectures and assignments difficult at first, but in the end I was able to link the information in my mind well.

Apart from the academic education, we also had a lot of fun during the week. On two days we had a program with all participants of the Summer School. On Monday, the city rally unfortunately had to be cancelled because of the bad weather, so we visited a rooftop bar and had a lot of time to exchange ideas and get to know each other. On Tuesday evening we were in a small group with all of the students from Zweibrücken and could walk a little through the city and eat in a very good sushi restaurant for dinner. The next group activity was on Wednesday. In the group we went for dinner in the restaurant "Reballion", which is known for its special meatballs variations. On our last night in Hasselt we were out in the small group agein, in various bars and have tried various beers we do not have in Germany.

All in all, I had a great time in Hasselt. We had time for our own activities even though the program was very busy. Hasselt is also a great little town that has a lot of charm. A visit is definitely worth it. An internship is a great way to get in touch with new people, meet new cities, eat well and learn many new things. Even if the topic does not fit exactly to the study profile, it is always worth it. I would recommend it to everyone.

Figure 7: Group picture.

References

Figure 1-6 is taken by myself. Figure 7 is photgraphed by Wim Deferme.

Every information is from the presentations by the speakers or from my own notes taken during the summerschool.