Sheffield Hallam University

UNIVERSITÉ DE ROUEN

Design and development of a gripper system for micromanipulation

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Training period: 2006

Acknowledgments

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Furthermore, I would like to thank all people who have contributed towards this study:
Dr. Mark Thompson for running a pleasant visit, Jan Wedekind for his interesting demonstrate of the microscope and help for my research, Kim Chuan Lim for his help during the experiments.

Abstract

This report presents the design and development of a gripper for micromanipulation. It is included the research of the best way to obtain micro motion as muscle wire, electromagnetism or piezoelectricity. Moreover the design of the gripper is explained as the experiments which lead to it.

Résumé

Ce rapport presente la creation et le developpement d’une pince pour des manipulations microscopique. Il y sera relaté les recherches ayant menées aux technologies permettant d’obtenir des deplacements de l’ordre du micromètre. On peut citer des techniques telles que l’éléctromagnetisme ou bien la piezoelectricité. De plus l’explication de la création des pinces et des experiences qui ont permis d’y aboutir sera faite.

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General introduction

The training period represents one of the best opportunities to put into practice our physics background learned during our study at the IUT. Students normally undertake a project with a company or a research team and have to perform a task linked with an area of physics.

One of my personal wish concerning the training period was to increase my level of English and at the same time to develop my reasoning ability. The opportunity to perform my training period in a laboratory at the Sheffield Hallam University provided me with such an opportunity.

The city of Sheffield is one of the biggest of the England, and living in during ten weeks will enable me to discover the British way of life.

The Sheffield Hallam University is one of the most progressive of the country and provides high quality research tool to its laboratory. The prospect to work in contact with high-tech supports seems to be very interesting. I will describe the city and the University in the first part of this report to give a better idea of the training background.

In the same idea, in a second time, I will present the department I was integrated into. My work comes within the context of nanorobotics project. The laboratory is called Microsystem and Machine Vision. It regroups different active projects concerning micromanipulation or autonomous mobile robots for example.

As far as my project is concerned, there is a requirement to develop microgripping devices to support the micro-assembly processes of micro-system technologies which involve the handling and manipulation of various micro-components.

The aim is to create a tool which enables manipulation of sample under an optic microscope called *Leica DM LAM* automated laboratory microscope for quality control, a description of it will be done.

The first step was to search which kind of material could enable nanomoving, and then selected one which combines micro-moving and easy use.

Our preliminaries researches direct our studies to piezoelectric material. A part of the report concerns the piezoelectric theoretical aspect. Then a thought about the way to use piezoelectricity with the gripper I have to design will be described. It is included a precise description of the bimorph effect which enables the bending of a material.

Description of the experiments which lead to the gripper will take a part of this report as the way to choose the products to design the gripper and ensure is use.

My project is to start the design of the gripper, I have to realise it roughly. The main objective is to find a way of work for the future project concerning the gripper and add alternative trail.

1 Training background

1.1. Sheffield

Figure1. The Winter Garden

Sheffield is a city and metropolitan borough in the South Yorkshire of England. The population of the City of Sheffield is estimated at 516,100 people, and it is one of the eight largest English cities outside London.

Sheffield was founded in the early 12th century by the Lord of the manor, William de Lovetot and, is so named because of its origins in a field on the River Sheaf that runs through the town.

The city has grown from its industrial roots to encompass a wide economic base. It has become world famous for its production of steel. In recent years the city has attempted to reinvent itself as a sporting and technology city. Sheffield is 6th Best Location for Business in United Kingdom.
In spite of its industrial side, Sheffield wants to develop the tourism and it is redeveloping. The city hosts many attractions and parks including the Weston Park Museum, *The Winter Garden*, The Millennium Galleries, The Peace Gardens, and Sheffield Botanical Gardens…

With her two universities and more than 40,000 students, Sheffield is very much a vibrant and friendly learning city.

1.2. Sheffield Hallam University

Sheffield Hallam University (SHU) located in the city of Sheffield is based on three main campuses, one in the city centre and two in southwest Sheffield.

With more than 28,000 students, over 3,000 staff and 650 courses, the university is the country's sixth larger. The British press place Sheffield Hallam among the leading modern universities. The university's research is also highly-rated—an official assessment (the Research Assessment Exercise) in 2001 placed SHU joint top among modern universities.

The e-learning system at SHU is one of the most extensive and advanced at any university in the country.The University has a vibrant and diverse student population with over 3,000 international students who come from over 80 different countries around the world. In fact, 12 per cent of our students come from overseas. After a distinguished history as one of Britain's top schools of art and design for more than a century, it became one of the colleges that merged with the city's College of Technology in 1969 to form Sheffield Polytechnic—one of the first polytechnics in the United Kingdom.

In 1976, the Polytechnic was renamed Sheffield City Polytechnic when it absorbed the city's two teacher training colleges, one of which was itself founded back in 1902. Along with all other British polytechnics, Sheffield City Polytechnic became a university with the right to award its own degrees in 1992, and thus became Sheffield Hallam University.

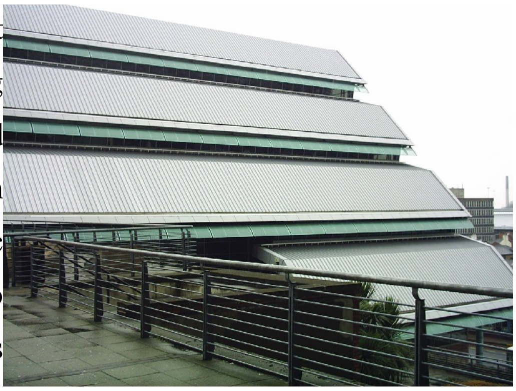


Figure2. The Adsett centre – The library of the University

Sheffield Hallam University is divided into four faculties:

- Faculty of Arts, Computing, Engineering and Science (ACES): Computing & Management Sciences, Cultural Studies, Engineering and Science & Mathematics
- Faculty of Development and Society: Built Environment, Architecture, Surveying, Construction, Urban Regeneration, Cultural Studies, Education, Environment and Social Science & Law
- Faculty of Health and Wellbeing: Health & Social Care, Science & Mathematics, Sport & Leisure Management
- Faculty of Organisation and Management: Business & Finance, Environment & Development, Sport & Leisure Management

To push its research agenda, approximately 20 centres for pure research (*Appendix 1*) had bees formed. Of this following have had outstanding success in government research exercices.

1.3. Microsystems and Machine Vision Lab

I was integrated into the Microsystems and Machine Vision Lab to perform my training period. It is part of the Materials and Engineering Research Institute in the Sheffield Hallam University. This internationally recognised centre covers a broad range of materials and engineering research.

The main research activities involve the design, development and implementation of machine vision techniques targeted at a variety of real-time and non real-time applications which include microrobotic systems, biological applications, micromanipulation, microscope imaging, Scanning electron microscopy (SEM) and Transmission electron microscopy (TEM) applications and non-destructive testing of Micro-Electro-Mechanical System (MEMS) devices.

I worked particularly in parallel of the Micron project. Its goal is to develop a multi-robot manipulation system capable of handling micrometer-sized objects. This system is based on a cluster of small mobile robots which are autonomous thanks with onboard electronics equipping each of them. These wireless robots (*Appendix 2*) can be equipped with various tools such as syringe-chips or the gripper I have to design. They can also co-operate to accomplish a range of task associated with assembly and processing from the nano to micro-range.

Members of the staff are senior lecturers as my supervisors, senior research fellows, and PhD or ERASMUS Students. The laboratory is divided in three rooms, two for informatics and office automation tasks, and the other one which is access control contains microscopes and micromanipulation devices.

2 Automated optical microscope system

The tools I have to design will be integrated in the functioning of the *Leica DM LAM* automated optical microscope for feedback control.

Leica Microsystems Automation is unique in this form. The combination of motorized microscope, external control satellite and PC allows perfect remote operation of the microscope in a variety of ways.

It could be used for 3D surface metrology that allows for the non-destructive measurement of surface profiles. Using our experimental settings we observed

- Vertical resolution 30µm and better (depending on aperture-size, magnification, projection-pattern and the surface properties of the object).
- Lateral resolution 25µm and better (depends).
- Captured area about 0.5mm^2 (can be improved by using a motorized X-Y-table and stitching software).

As a demonstration, below are some typical microscope images (showing a surface, which has been shaped using a laser beam).

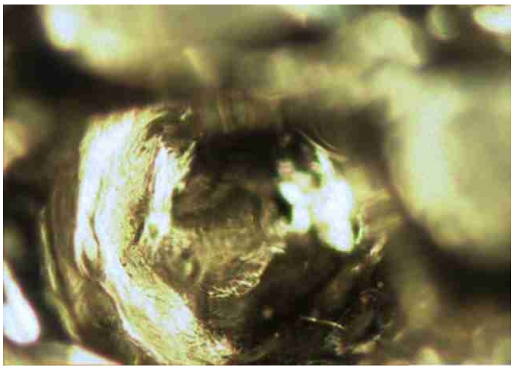


Figure3. First surfi-sculpt Object

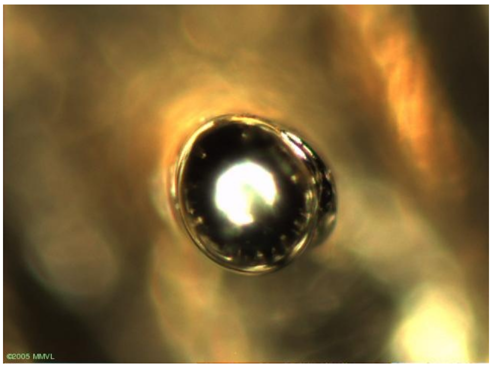


Figure4. Second surfi-sculpt Object

Using a focus-stack one can compute images with extended depth of focus:

Figure5. Extended depht of view for first Object

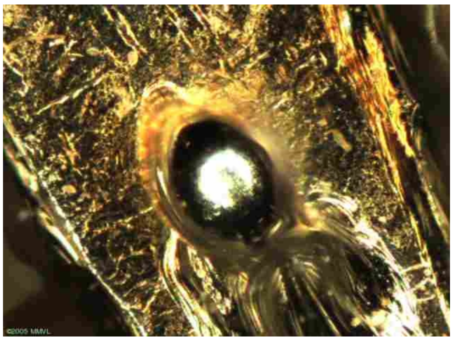


Figure6. Extended depht of view for second Object

If the surface can be illuminated properly, algorithms exist to perform a 3D-reconstruction of the surface.

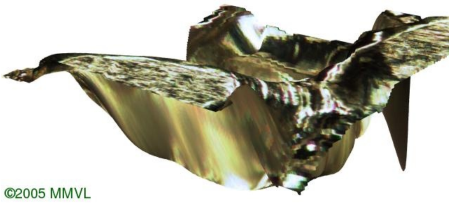


Figure7. 3D-Reconstruction of first object

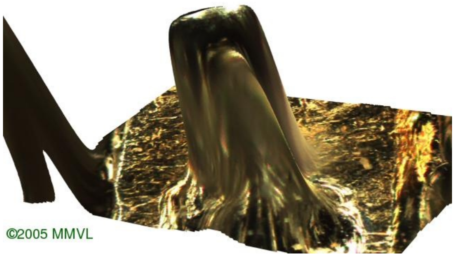


Figure8. 3D-Reconstruction of second object

3 Manipulation in a microscope environment?

This projects aims to look for materials or technologies which enable the motion of an arm. Currently we know of several systems in different fields that make use of magnetic or electric fields which offers some possibility for development. We will attempt to find the ideal method to perform the tasks that the gripper unit should be able to perform.

3.1. Muscle Wire

Muscle wire represents one of these possibilities. Indeed, some metal alloy can present two different shapes according to the surrounding characteristics; we also say it is shape memory alloy. It may be interesting for our project because the two shapes could be used to move between two different positions of the arms gripper, one closed and the other one opened. The wire has a characteristic shape for a characteristic temperature.

When the wire cools, it goes back to a non-programmed shape. As the wire is heated, it tries to return to its programmed shape. This change could be explained by the change of crystalline structure between the two temperatures. As the wire cools, it changes to martensite, and when it is heated, it changes to austenite and the wire contracts.

The martensite is much more flexible than austenite, allowing the cooled wire to expand. When in the austenite state, the wire is much more susceptible to stress, which can damage the wire. In addition, the resistance of the wire changes as the crystalline structure changes, making the wire difficult to control. As far as the gripper is concerned we need precision to perform task at the micro-range. Moreover during the manipulation it is hard to modify precisely the temperature of the wire.

This system could be very attractive in many fields but for us it is not the good one because we need precision concerning the motion and easy use.

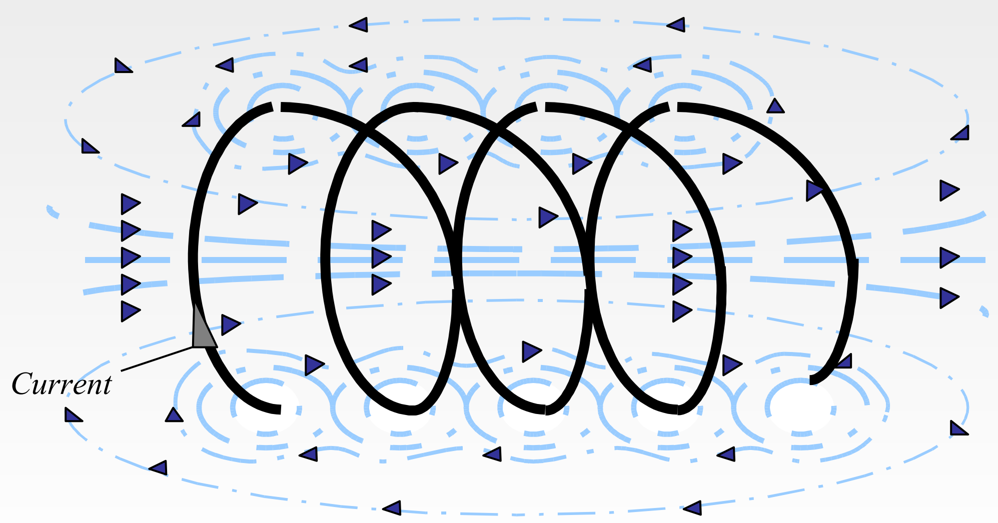
3.2. Electromagnetism

The use of electromagnetism to produce motion without physical contact is a technique that is investigated within this study.

The term "electromagnetism" comes from the individual component electrical and magnetic forces involved. A changing magnetic field produces an electric field. The same, a changing electric field generates a magnetic field.

When a current carrying conductor is formed into a loop or several loops to form a coil, a magnetic field develops that flows through the centre of the loop or coil along longitudinal axis and circles back around the outside of the loop or coil. The magnetic field circling each loop of wire combines with the fields from the other loops to produce a concentrated field down the centre of the coil.
The strength of a coil's magnetic field increases not only with increasing current but also with each loop that is added to the coil. A long straight coil of wire is called a solenoid and can be used to generate a nearly uniform magnetic field similar to that of a bar magnet.

Figure9. Magnetic fields generates by a coil



In combination with a magnetic material the attractive force of the coil could be used to generate motion. Fusing a layer of this material on the arms of the gripper could be a design possibility. A number of different magnets exist, such as a mendelium magnet which is very powerful or neodymium iron boron magnet.

To conclude with electromagnetism we note that it could be an interesting way of generating gripper movement nevertheless the accuracy induced is limited and forces generated are high.

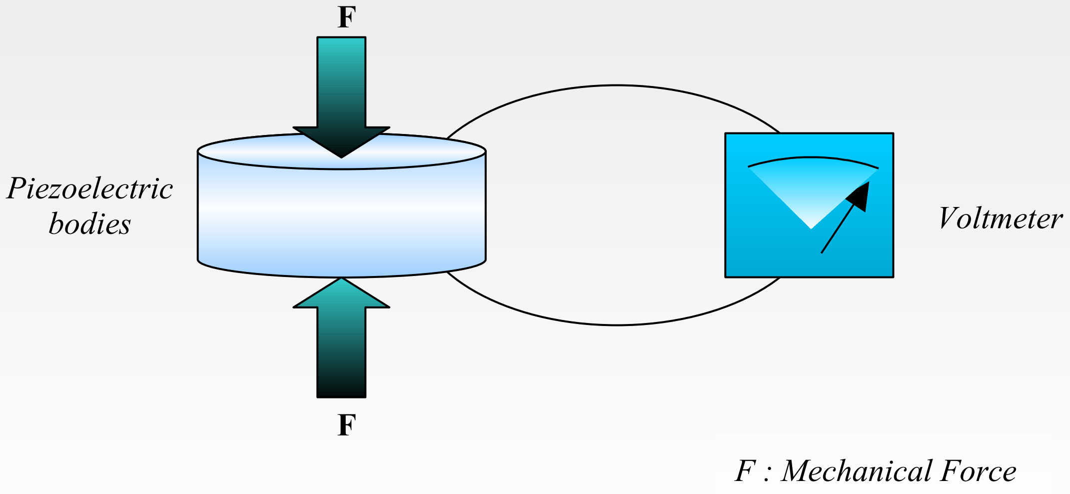
3.3. Piezoelectricity

Piezoelectricity, as its name indicates, also uses electricity. Motion can be produced when we generate an electrical field. A vast amount of information is available about the way to create the gripper using piezoelectric material. That is why this is the system of choice to achieve our task.

3.3.1. Principle

Piezoelectricity is a property exhibited by certain classes of crystalline materials. When mechanical pressure is applied to one of these materials, the crystalline structure produces a voltage proportional to the pressure (*Figure 10*). Conversely, when an electrical field is applied to one of these materials, the crystalline structure changes shape producing dimensional changes in the material. Piezoelectricity was discovered by Pierre and Jacques Curie in the 1880’s.

Figure10. Piezoelectricity principle



Piezoelectric bodies provide a coupling between electrical and mechanical forces and hence can serve as transducers between electrical and mechanical energy. In principle, they can complete with all other electromechanical transducers, including electromagnetic motors and generators. In practice, piezoelectric transducers are limited to devices involving only very small mechanical displacements and small amounts of electric charge per cycle

Effective use of piezoelectric devices depends on matching the electrical and mechanical impedances of the energy source and the driven load. The limited charge density and strain amplitude of piezoelectric makes them unattractive for low frequency applications (such as 60 Hz) and essentially inoperative for static forces and fields. They become increasingly useful with increase in frequency since electric current is proportional to charge times frequency.

3.3.2. Piezoelectric actions

The poling process permanently changes the dimensions of a ceramic element. The dimension between the poling electrodes (x) increases, and the dimensions parallel to the electrodes (y) decrease. These effects are shown greatly exaggerated in *Figure 11*. The dimension between the poling electrodes (a) is called the poling axis.

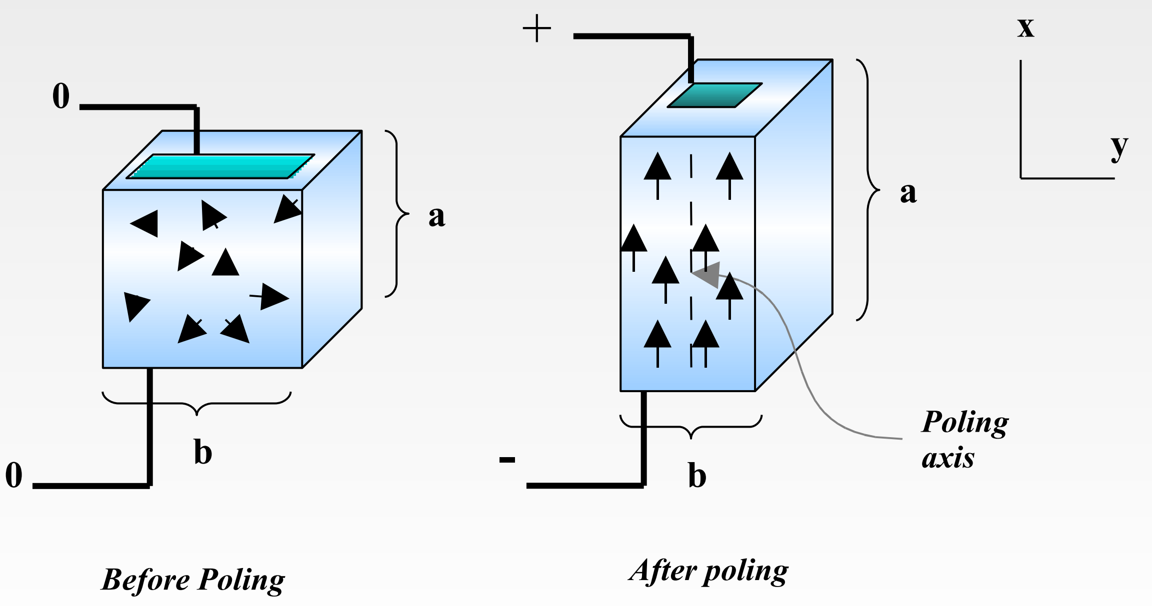


Figure11. Effects of poling

Before Poling ***After poling***

After the poling process is complete, a lower voltage than the poling voltage changes the dimension of a ceramic element for as long as the voltage is applied. A voltage with the same polarity as the same polarity as the poling voltage causes additional expansion along the poling axis (x) and contraction perpendicular to the poling axis (y). A voltage with the opposite polarity has the opposite effect.

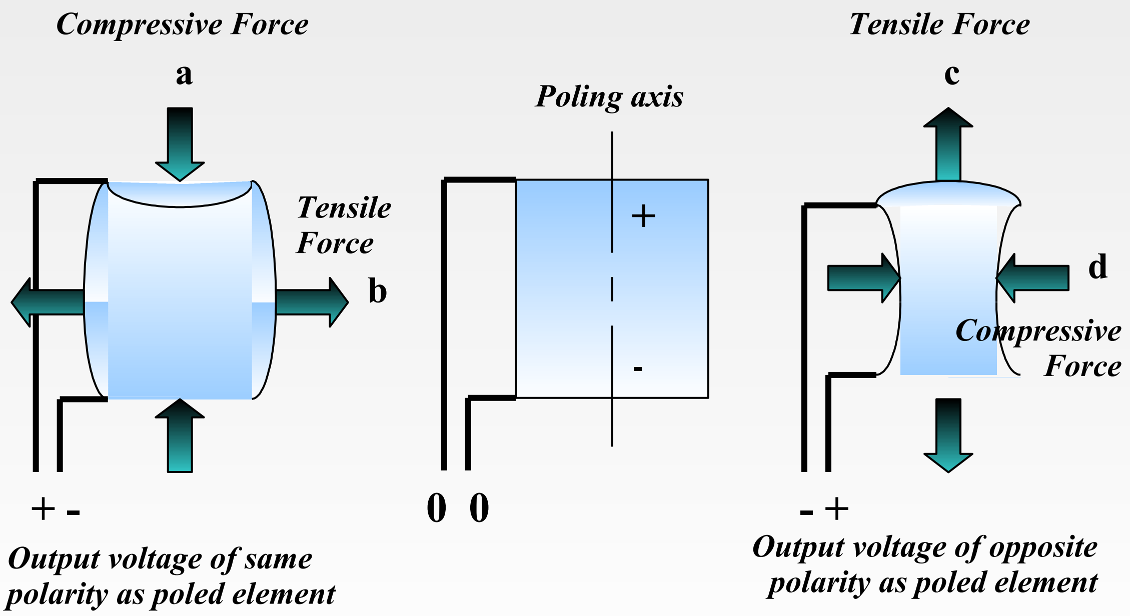
In both cases, the ceramic element returns to its poled dimensions when the voltage is removed from the electrodes.

A ceramic material is composed of many randomly oriented crystals or grains. With the dipoles randomly oriented, the material is isotropic and does not exhibit the piezoelectric effect. By applying electrodes and a strong electric field, the dipoles will tend to align themselves parallel to the field, so that the material will have a permanent polarization.

3.3.3. Piezoelectric Voltage

After the poling process is complete, compressive and tensile forces applied to the ceramic element generate a voltage. Refer to *Figure 12.* A voltage with the same polarity as the poling voltage results from a compressive force (a) applied parallel to the polling axis, or from a tensile force (b) applied perpendicular to the poling axis. A voltage with the opposite polarity result from a tensile force (c) applied parallel to the poling axis, or from a compressive force (d) applied perpendicular to the poling axis.

Figure12. Piezoelectric voltages from applied forces



3.3.4. Aging

Most of the properties of piezoelectric ceramics change with time. The changes tend to be logarithmic with time after poling. Because of aging, exact values of various properties such as dielectric constant, coupling, and piezoelectric constants may only be specified for a standard time after poling. The longer the time period after poling, the more stable the material becomes.

3.3.5. High stress

Most of the properties of piezoelectric ceramics vary with the level of applied mechanical stress or voltage. Data is usually presented for piezoelectric ceramics at fairly low levels. Operating at high levels accelerates the aging process.

3.3.6. Curie point

The Curie point is the absolute maximum exposure temperature for any piezoelectric ceramic. Each ceramic composition has its own Curie point. When the ceramic element is heated above the Curie point, all piezoelectric properties are lost. At elevated temperatures, the aging process accelerates, electrical losses increase, efficiency decreases, and the maximum safe stress level is reduced. For example, the curie point of Barium Titanate 300 is 115◦C and for Lead zirconate Titanate 300◦C (this two materials are piezoelectric ceramics).

3.3.7. Dynamic Performance

Dynamic performance relates to the behaviour of a material when subjected to alternating fields or stresses at frequencies close to the mechanical resonance of a component. To obtain optimum performance from a piezoelectric device, the circuit to which it is connected must have certain characteristics which are dictated by the design of the device. In discussing this subject, it is convenient to divide piezoelectric devices into two categories.

Non-resonant devices are so named because they are designed to operate below resonance or over a relative large frequency range.

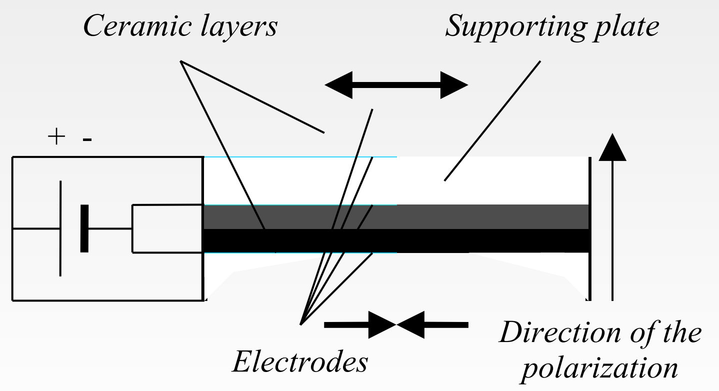
A resonant device either operates as its mechanical resonance or over a band of less than one octave around this resonance.

3.3.8. Bimorph actuator

A mechanism that puts something into automatic action is called actuator. In engineering, actuators are devices which transform input signal into motion.

A piezoelectric bimorph actuator is created by flattening layers of piezoelectric

Figure13. Bimorph Effect



3.4. Conclusion of theoretical research

We have finally chosen to focus our studies around the piezoelectricity and electromagnetism. However, piezoelectricity is preferred over electromagnetism because it offers better accuracy and it is simpler to design with. Moreover piezoelectric bimorph actuators seem to be perfect to obtain the bending required for the work of the gripper. In addition to that we have examples of grippers that use piezoelectric material to function (*Appendix 3*). This document gives an idea concerning the design of the gripper.

4 Experiments

4.1. Piezo buzzer test

The first step of my research was to study the motion of a Piezo buzzer. Indeed, piezoelectronic ceramic buzzer element has a simple structure in which piezoceramic element is glued to vibration plate. This system is used in alarm devices because the bending of the element generates sounds. Driving the piezoceramic will lead to deformation of the entire structure.

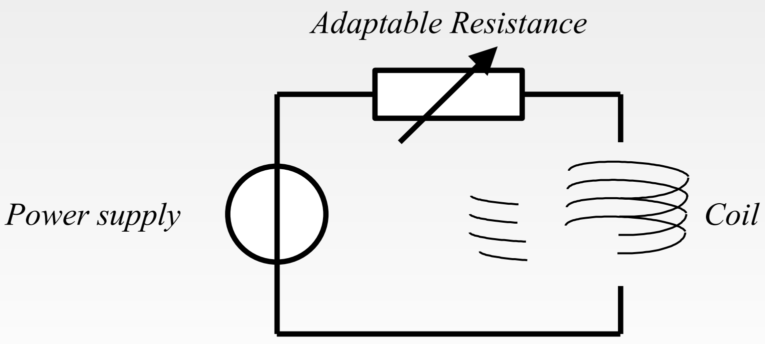
The experiment consists in watching under an optical microscope the motion of the piezoelectric buzzer. The sound of the buzzer could enable me to know if the Piezo buzzer was supplied. After having found the resonant frequency (13.5 kHz), that is the frequency which produces the most important vibrations so the biggest sound too, I have to watch the motions under a microscope.
The aim of this experiment was to discover the bending effect and its results, we didn't try to get measurements at first. That is why to enlarge the motion I stocked out a rigid item from the centre and I watched the vibrations of this item.

We observed that the oscillatory motion was too fast, and so it could not be seen. The vibration of the support, which is much slow, is visible. However when we increased the frequency of the signal generator the motion was impossible quantify. The vibrations can be felt but not seen under an optical microscope.

4.2. Creation of magnetic field using a coil

As explained earlier it is possible to create a magnetic field when current passes

Figure14. Electrical circuit for generate a magnetic field



The power applied to the coil has to be carefully adjusted. According to the resistance characteristics the maximum power is 0.5 W.

The coils we created are composed of a magnetic core (consisting of a nail) surrounded by copper wire (*Appendix 9*). We noticed that the number of turns and the winding configuration determines the magnetic field which is created when we current is applied.

We noticed that a weak current (few milli amperes) was enough to create a magnetic field which is insufficient to attract larger objects. To move a steel bar of 50 mm in length the current applied is close to 1 A. However this value is not fixed, since we found that there is a about 50 mA difference each time the experiment is run.

5 Design of the gripper

The design of the gripper makes use of different aspects of my experience. It has been carried out in collaboration with the researcher and the workshop.

The design of the gripper was a delicate part of my research. Information about the shape of micro gripper used in surgery was obtained and analysed because the gripper that was to be designed had similar characteristics.

Some very interesting information was found in a report of Finnish researcher Aurelian Albut, Quan Zhou, Carlos Del Corral, Heikki N.Koivo (*Appendix 4*).
They combined piezo actuators together with stainless steel tips which enabled better micromanipulation. This idea was further developed in order to design a first gripper system.

5.1. The choice of the products

We have to choose among different bimorph actuators in different catalogue. So we have to determinate the characteristics of the gripper we would like to create.
Obviously the size of the actuator must correspond with the size of the sample manipulated.

The price of the products chosen must be cost effective since the work carried out is in its early stages the aim is to find idea and concept which could be re used for the creation of the final gripper.

The choice of the products has been discussed with the researcher in charge of the manipulation of the microscope. The lens focus of the microscope helps us to determine the ideal bender actuator. We concluded that a Piezo actuator with 1.00mm nominal displacement will be the most useful for our gripper system.

Amongst the bimorph actuators which presented the required displacement, we chose the one that was easiest use. That means a bender which could be integrated in a micro gripper and in an electrical circuit. Our researches lead to PI products, the PL140.10 Piezo Bender Actuators (*Appendix 5*).

In addition of the multilayer Bender, we decided to use an amplifier designed to be used with it. The LVPZT Amplifier is specifically designed to drive a Multilayer Bimorph actuators such as the PL140.10. It is equipped with a special circuit that can provide one fixed voltage and a variable voltage in the range of 0 to 60 V. It can be operated in two ways: Manual control with DC offset potentiometer or External Control thanks to an analog signal applied to the BNC input.

The addition of this amplifier and the multilayer bender actuator reduces uncertainty of manipulations and measurements.

5.2. Design with piezoelectric actuators

Concerning the design there were a number of areas that presented difficulties. For example, concerning the fixing of the multilayer actuator, it is very difficult to cut 0.60 mm wide (the tick of the actuator) with known accuracy. We know we could do that with EDM technology, but the University does not own an EDM unit. Moreover we do not know exactly the shape of the steel tip as far as sizes are concerned.

In collaboration with the workshop of the University, we have created the first model of tips (*Appendix 6*). The size of the piece we would like to manipulate is around few hundred micrometers.

As can be seen in the picture, the grippers are too thick and too high. Indeed the size of the tip prevents the user from seeing the object. The distance between the top of the tips and the object is too important and prevents from watching clearly the object and the tip in a same plan.
As a consequence we created different tips, trying every time to improve it (*Appendix 7*).
First we reduced the tip of the gripper to solve the problem of focus.

Second, we reduced the height to enable the manipulation under our microscope. Indeed the dimensions of the microscope guide our research and the size between the lenses and the tray is at least 5, 00 mm.

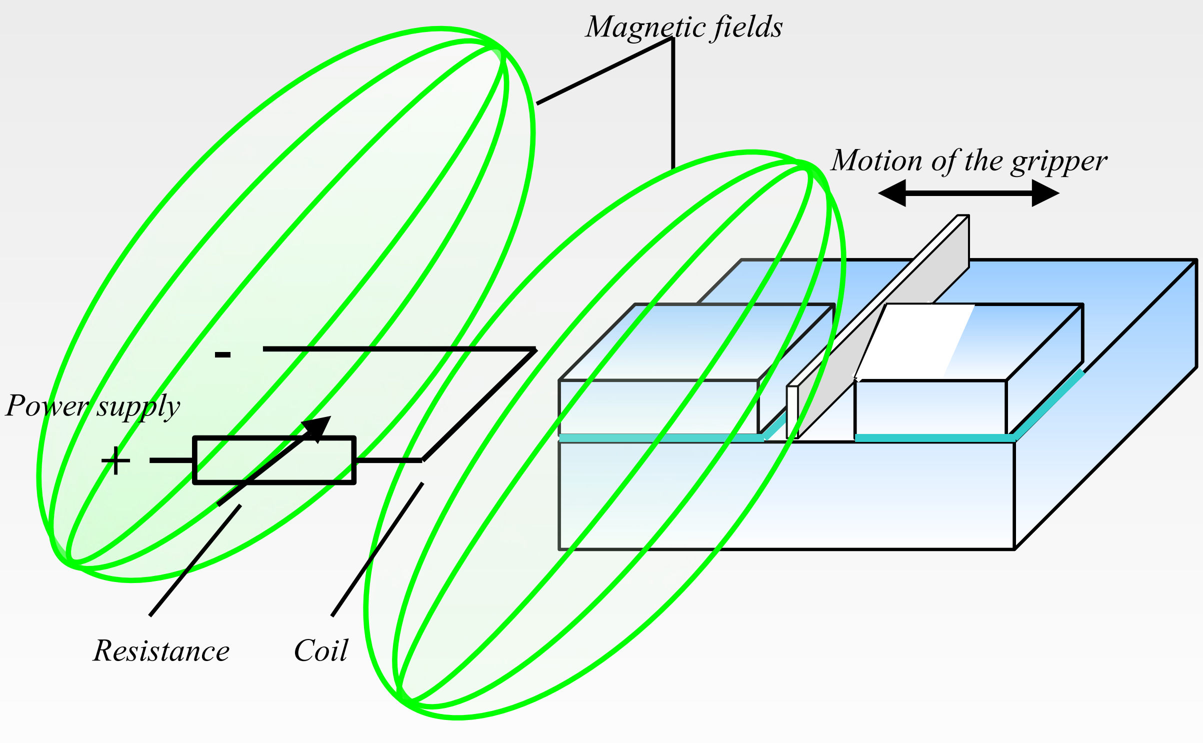
Due to delays in delivery the piezo benders will only arrive on the 26th of June 2006, which means that I will be unable to make use of it. Hence the need for an alternative actuation method.

5.3. Design with magnetic field

Electromagnetic displacement could be an alternative way to generate motion but it is more difficult to control precisely the displacement of on arm of the gripper with magnetic effect. The only thing we can do it is to frame the motion according to the motion we want to generate.

We used the gripper we designed for piezoelectric actuators because they are made in stainless steel which is a magnetic material and in order to enable micro-displacement we designed a board which integrated the gripper in a gap shaped according to the motion wanted. This Perspex acrylic board contained a fulcrum to enable the swing of the gripper's arm. This board is shown on *Appendix 8* and on

Figure15. Magnetic effect on an arm of the gripper

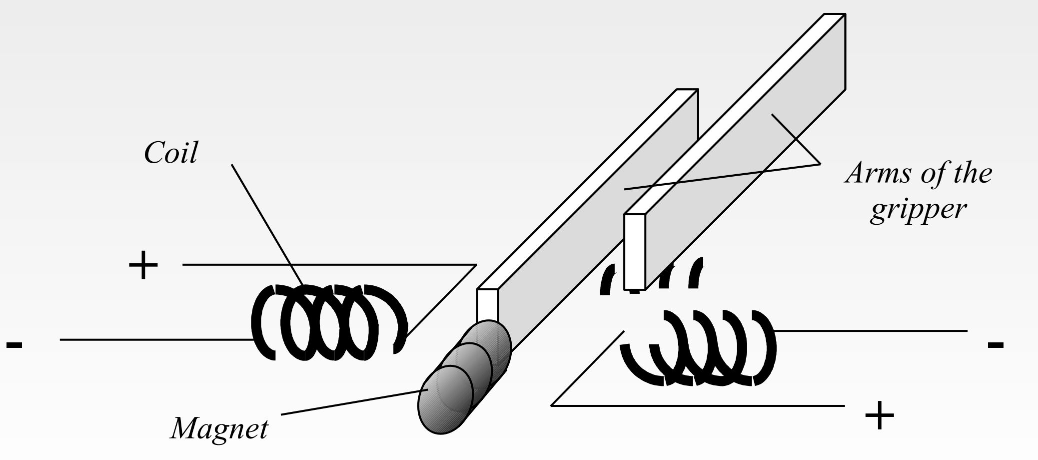


A second solenoid was designed to generate motion in two directions. Depending on which coil is switched on we generated leftward or rightward motion. This lateral motion caused the opening and the closing of the gripper. This system could be is equivalent to the operation of a motor since rotary motion is created by alternatively supplying either positioning coil. A second stationary gripper arm was clamped to the unit. In this way we obtained a gripper system with a closing an opening positions using the movement of only one arm.

In order to increase the magnetic effect we added a neodymium iron boron magnet on the moving arm of the gripper system. This is shown in *Appendix 9* and in *figure 19*. This magnet controlled the motion of the arm so we applied an electromagnetic field on this permanent magnet.

The schematic of the electromagnetic gripper system (*Appendix 10*) is shown

Figure16. Diagram of the magnetic gripper



We can observe the two positions of the gripper according to the power supplied on each coil:

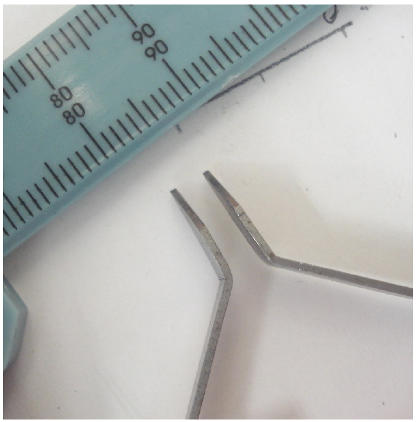


Figure17.Opened position

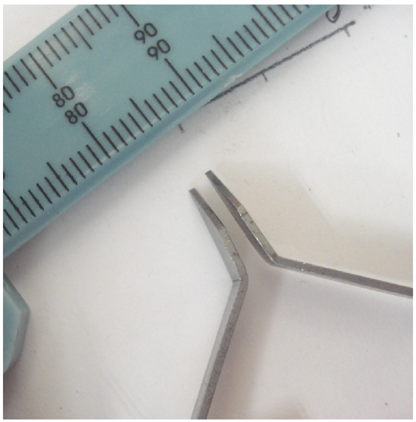
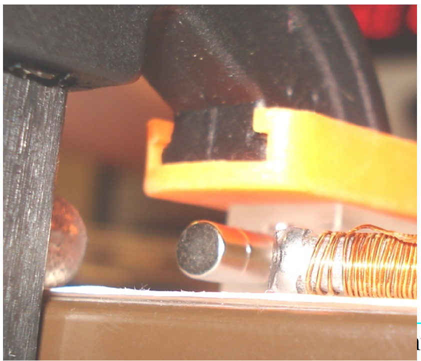


Figure18. Closed position

The gap between the two arms of the gripper is important because if they are too closed they attracted themselves and they could not be control. Indeed one of the two arms is in touch with the magnet so he produces a weak magnetic field which attracted the two arms.

The magnetic field is applied to the neodymium iron boron magnet so we could observe its motion:



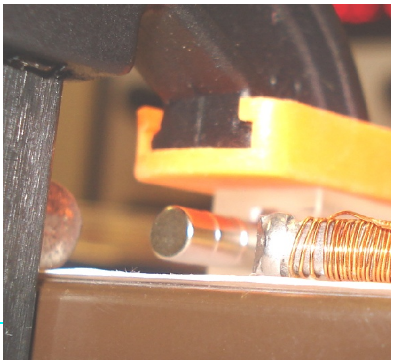


Figure19. Magnet position for opened gripper

Figure20. Magnet position for closed gripper

The system has to be isolated from other magnetic components in the area. For example the screw we added to the board to control the displacement actually affected the motion of the arm because the magnet was attracted also by it, so we removed the screw. It is possible to use plastic screws to solve this problem. Moreover the equilibrium position of the coil which surrounds a nail is difficult to determine because it should be closed to the magnet but not too closed to be attracted before applying power. The perfect position can not be measured because it depends on many factors.

The displacement obtained is around one millimetre due to the restrictions imposed on the support board. Unfortunately the motion cannot be accurately controlled by the voltage or the current applied to the coils. The gripper only has two positions. When the current increased in the coil, the arm didn’t move up till a value close to 1 A. Hence it is impossible to find a link between the current applied in the coil and the displacement of the arm. It is impossible to achieve the control of the displacement.

In conclusion, electromagnetism is not the ideal way to obtain micro motion because magnetic fields have too much effect on the size and position of the gripper. Moreover the motion is too important according to the displacement we would like to get. And forces are not controllable which is incompatible with micromanipulation.

We were unable to find a method that uses electromagnetism to bend a material to be used as a piezoelectric bimorph actuator. The motion of the tip of our arm the gripper included the motion of the entire arm. To obtain a bending arm with electromagnetism we could use soft plastic arm clamp with a magnet stick on the free tip.

6 Problems encountered

Obviously for a foreign student the language is the first problem. At the beginning it was hard to communicate, in the way to understand and to be understood. Moreover my lab was composed of researcher coming from all over the world and Erasmus students. Each person was obviously speaking in English but with an accent specific to the region where they are coming from.

The first half of my training period spent during the exam of the student and the end of their project. So I didn't have access to all the material I need.

More than two weeks and a half of my training I was waiting for the multilayer bender actuator. So I only could work on subject surrounding the main topic as the design. But in every work I undertook I was always stopped by the no receipt of my order.

The delay of order is a component I can't imagine before doing this training. Indeed students used to have everything ready for practical work and I neglected this side of the work.

I started working on piezoelectric solution for the gripper during more than six weeks. Then the change of topics is difficult especially when it only stay three weeks of training. It is involved new research and new theoretical side to assimilate add with the stress of finding no alternative solution.

Conclusion

The investigations during my training period demonstrate electromagnetic gripper could perform task of gripping but not in microsystem. The piezoelectric actuator seems to be the ideal solution because it enables controllable micro displacements contrary to the electromagnetic way which enable only two positions of the gripper.

Hence I am disappointed not having design a piezoelectric gripper. I'd rather designed a competitive gripper but I hope to have given by this report the clues to create it when the bimorph actuators will be received.

For this kind of project which involves the order of specific and uncommon object it could be a good idea to start the research during the tutorial project.

This training period was very interesting from my personal side. Indeed it combined technical work with research development. I managed my project in collaboration with a staff members, students, and technicians, which gives me a foundation for the future professional work. It improves my English level thanks to the contact of different persons from different departments.

To finish this placement highlights the quality of the IUT training. Indeed the physical background received during the last two years enable me a better approach of the stages of my training which have concerned electronics, materials, and mechnanics area.

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Booklet about *Piezoelectric Ceramics Data book for Designers* Morgan Matroc Limited

Table of appendices

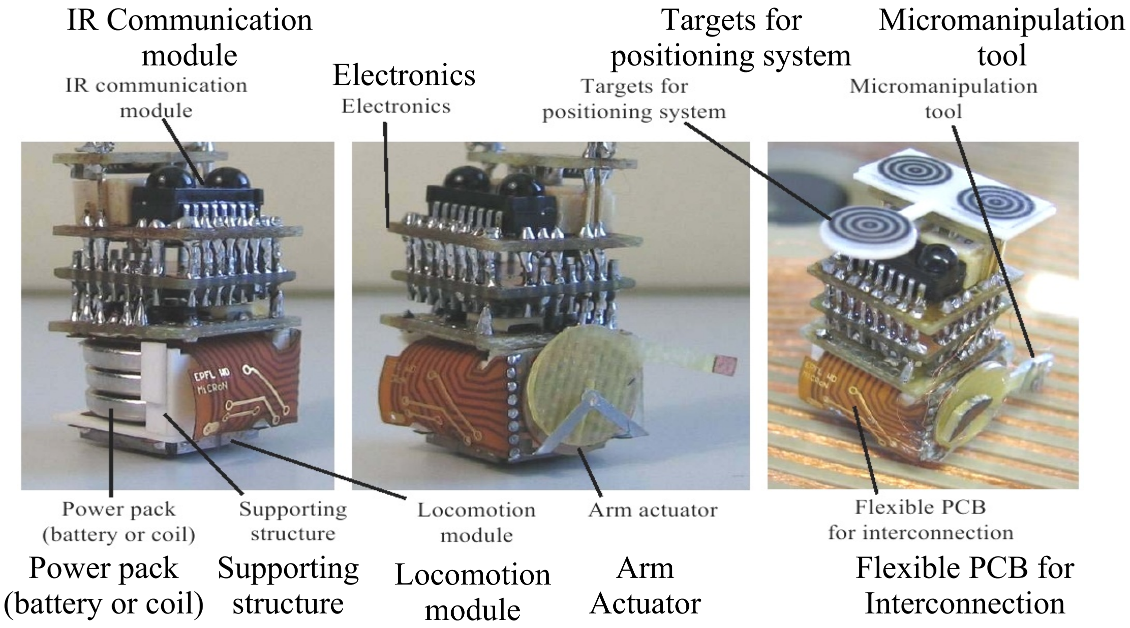
Appendix 1: Centres for pure research in the University

- Materials and Engineering Research Institute - MERI
- Biomedical Research Centre - BMRC
- Centre for Education Research - CER
- Centre for Sport and Exercise Science - CSES
- Centre for Health and Social Care Research - hsc
- Centre for Professional and Organisational Development - CPOD
- Centre for Sustainable Consumption - CSC
- Culture, Communication and Computing Research Institute - C_3RI

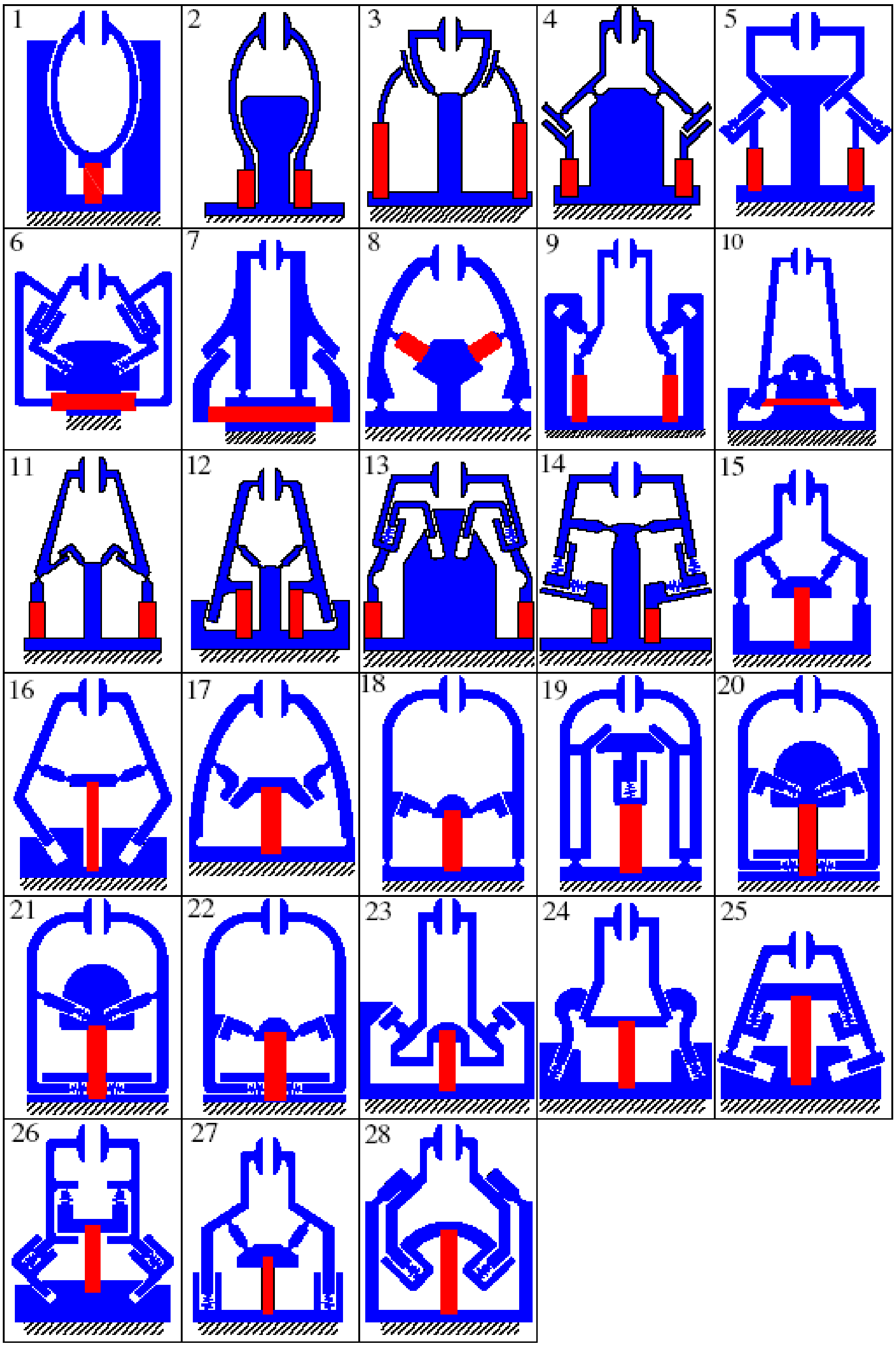
University spin-off companies formed

- Sheaf Solutions - automotive and aerospace organisation
- Materials Analysis & Research Services (MARS) Centre for Industrial Collaboration - expertise in materials analysis and solutions
- Hallam Biotech - biotech analysis and synthesis
- Bodycote - materials coating
- Design Futures - design providers

Appendix 2: Micron robots



Appendix 3: Design of microgripper



Red square: Piezoelectric material

Ying Chien Tsai, Sio Hou Lei and Hendra Sudin. Design and analysis of planar compliant micro gripper based on kinematics approach. University of Taiwan, 2004

Appendix 4: Architecture design

The design of the microgripping system follows the engineering design methodology of [6]. Different methods of actuation and measurements have been considered to satisfy the requirements. Despite the demands of very wide range of micromanipulation capability and adaptability to different dimensions and environmental conditions, the microgripping system is not required to have high speed to carry out the planned research tasks.

Combining different actuation and measurement methods for the gripping and positioning systems, as many as 23 variants have been evaluated. For Z axis actuation, alternatives such as a piezo ultrasonic linear stage, DC motor and screw drive, voice coil motor, piezo bender, piezo stack, pneumatic and hydraulic linear stage have been taken into consideration. For grasping/ releasing microparts, possibilities such as piezo benders, two-axis piezo bars, hydraulic and pneumatic gripper, and vacuum gripper have been studied. For measuring the displacement of the gripping system, laser displacement sensor, rotational and linear encoder are considered.

Each variant has been evaluated according to the requirements while taking into consideration criterias such as: capability, feasibility, costs, safety measures, and risks. Some of these alternatives were not suitable for our application because either the movement is not sufficiently accurate, or the required mechanism and control is too complex. Vacuum gripper is also not suitable due to large variation of the shape and the dimension of the microparts. Alternatives such as

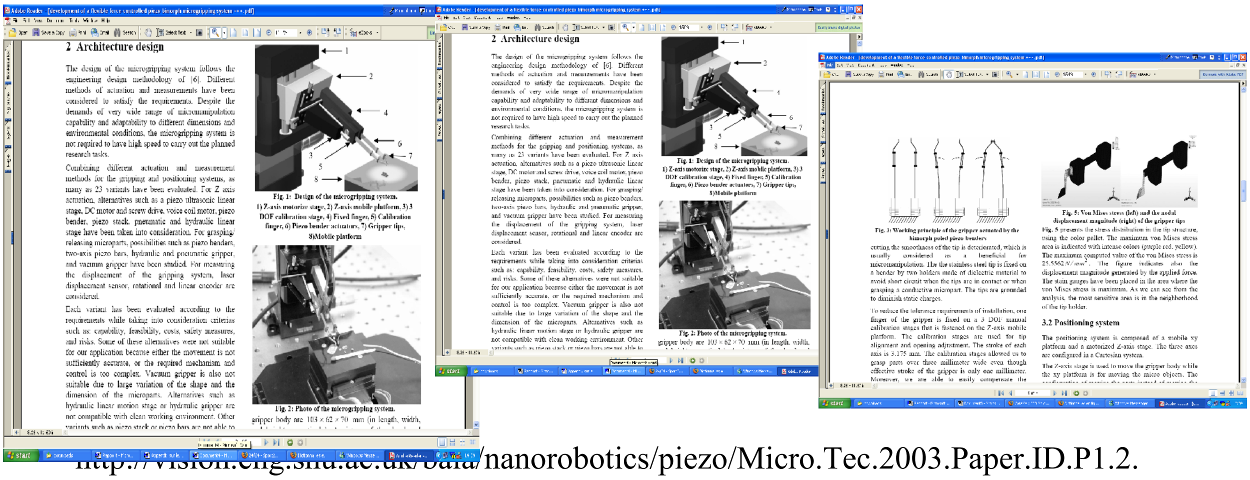
for our application because either the movement is not sufficiently accurate, or the required mechanism and control is too complex. Vacuum gripper is also not suitable due to large variation of the shape and the dimension of the microparts. Alternatives such as

hydraulic linear motion stage or hydraulic gripper are not compatible with clean working environment. Other variants such as piezo stack or piezo bars are not able to provide sufficient displacement. After the evaluation, 4 variants are left. The selected variants are re-evaluated according to technical and economical criteria, giving us solution as shown in **Fig. 1**.

The mechanical structure has been designed considering the basic specification, especially high-precision gripping, manipulation and positioning. The microgripper uses two 1 DOF fingers made of two piezoelectric bender actuators and two stainless steel tips, a 3-DOF manual stages for calibration of the tips and a motorize stage for movement in Z-axis. The tips are fixed to the benders with four holders made of rigid plastic. The tips are electrical isolated from the benders. One bender is held by the fixed finger and the other is held by the calibration finger. The calibration finger is fixed on the 3-DOF calibration stage and both the fixed finger and the 3-DOF calibration stage are installed on the Z-axis mobile platform. The mobile platform is driven by the Z-axis motorized stage having 50 nm gripper body are 103 × 62 × 70 mm (in length, width, and height respectively). A picture of the developed system is shown in **Fig. 2**.

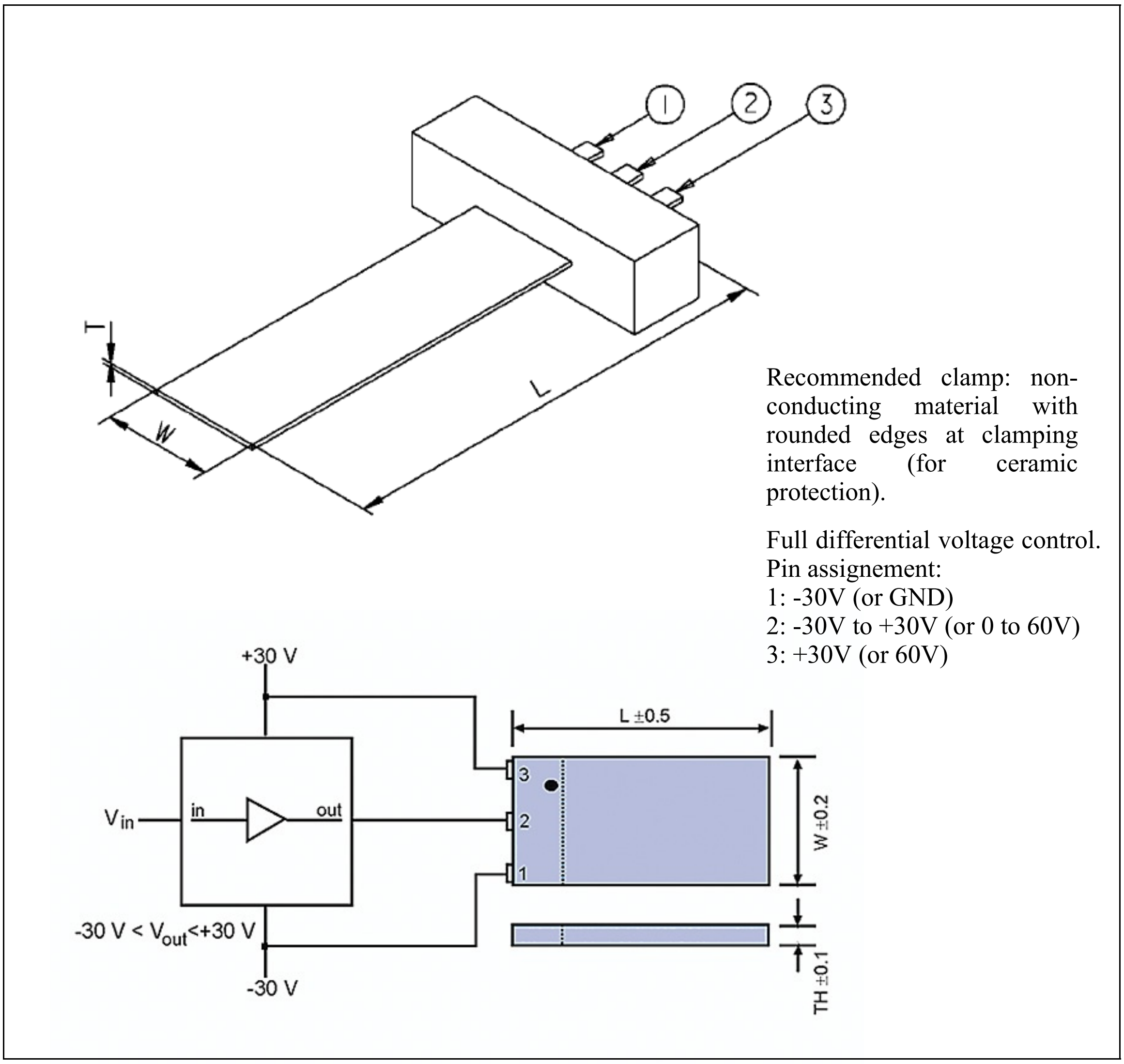
The gripper is actuated by two bimorph piezoelectric benders that provides movement having resolution in the nanometer range and relatively high reaction speed (up to 100 Hertz). The bender has a displacement of ±250 μm and a blocking force of $\pm 0.07N$. The weight of the bender is 0.4 g. The working principle of the gripper using piezo-benders actuators it is illustrated in **Fig. 3**.

Two stainless steel tips are used as the end-effector of the gripper. The tips are produced by laser cutting. The dimensions of the tip are 15.76 × 1.00 × 0.30 mm (length, height, thickness). The end of the tip has a shape of knife edge. Such shape helps it grasps a micropart even if the parts are placed very closely. Due to laser cutting the smoothness of the tip is deteriorated, which is usually considered as a beneficial for micromanipulation. The the stainless steel tip is fixed on a bender by two holders made of dielectric material to avoid short circuit when the tips are in contact or when grasping a conductive micropart. The tips are grounded to diminish static charges.



http://vision.eng.shu.ac.uk/bala/nanorobotics/piezo/Micro.Tec.2003.Paper.ID.P1.2.5.ver2.pdf

Appendix 5: PL140.10 Characteristics



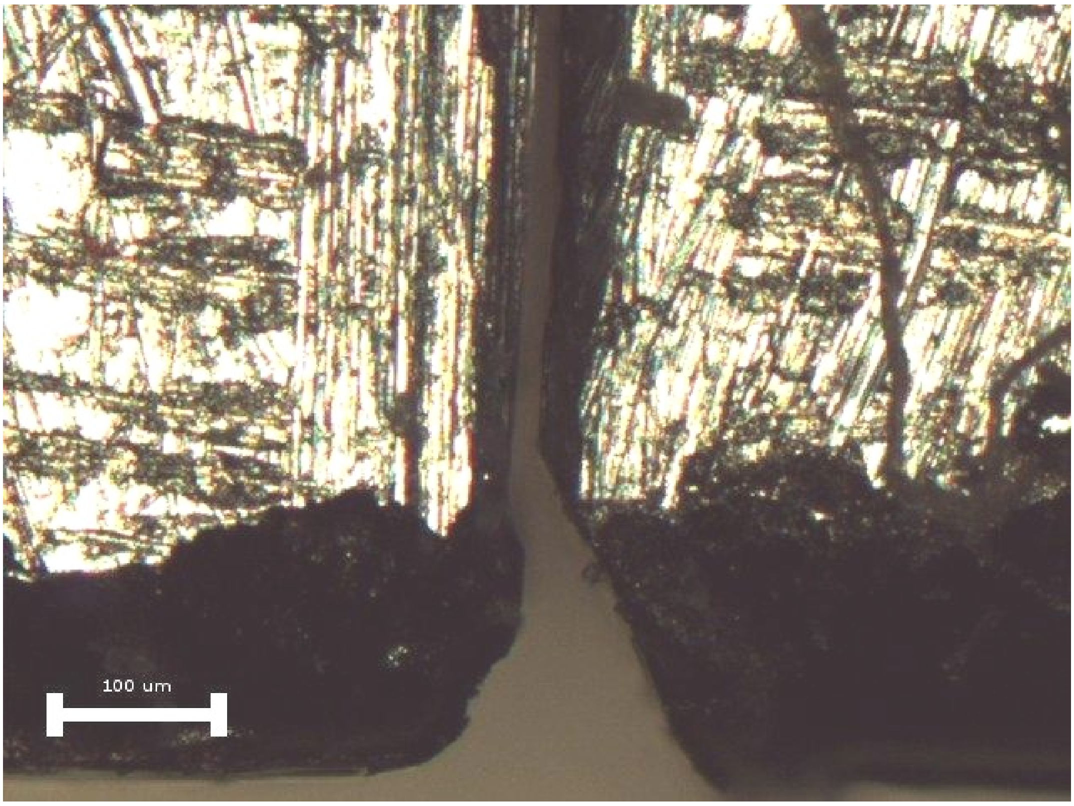
Recommended clamp: non-conducting material with rounded edges at clamping interface (for ceramic protection).

Full differential voltage control.
Pin assignement:
1: -30V (or GND)
2: -30V to +30V (or 0 to 60V)
3: +30V (or 60V)

Order number	Operating voltage (V)	Nominal displacement (µm) 20%	Free length (mm)	Dimension L*W*T (mm)	Blocking force (N)	Electric capacitance (µF) 20%	Resonant frequency (Hz)
PL140.10	**0 - 60**	**1000**	**40**	**45.0*11.0*0.60**	**0.5**	**2*4.0**	**160**

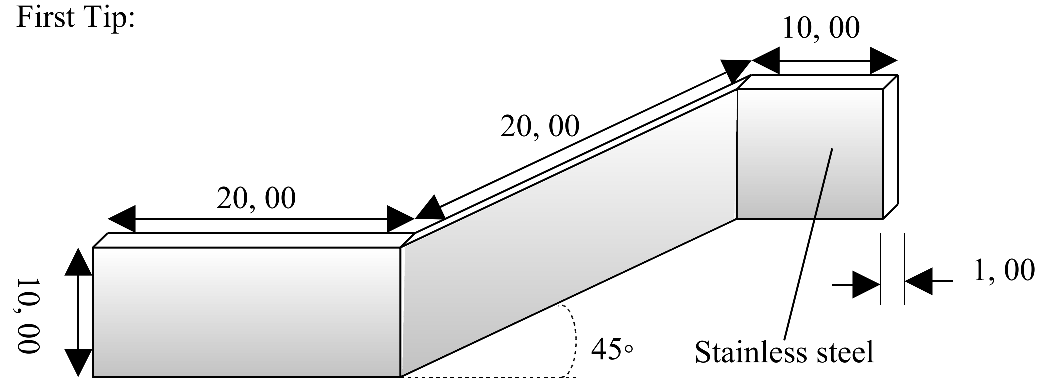
http://www.physikinstrumente.com/en/products/prdetail.php?sortnr=103000&cat=produkte&subcat=sec1

Appendix 6: Image of the gripper tip

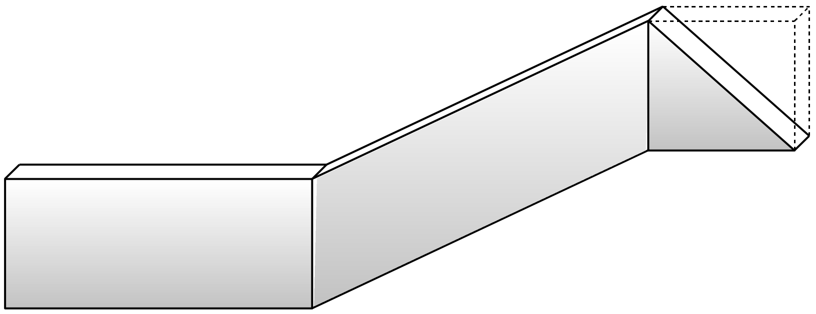


Appendix 7: Stage of tips design

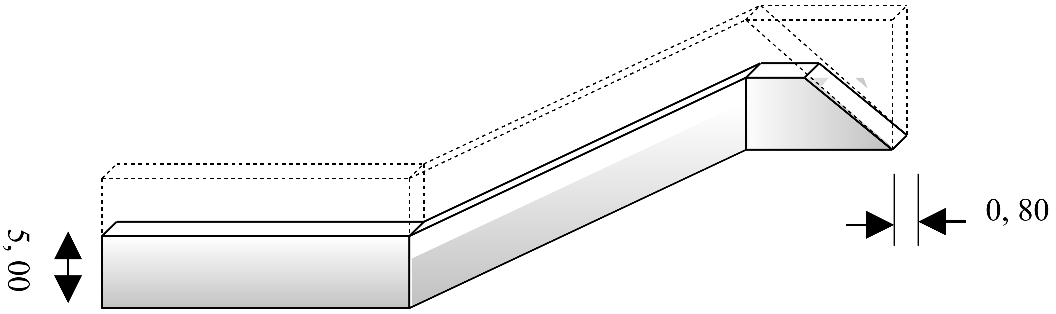
First Tip:



Cutting of the tip:

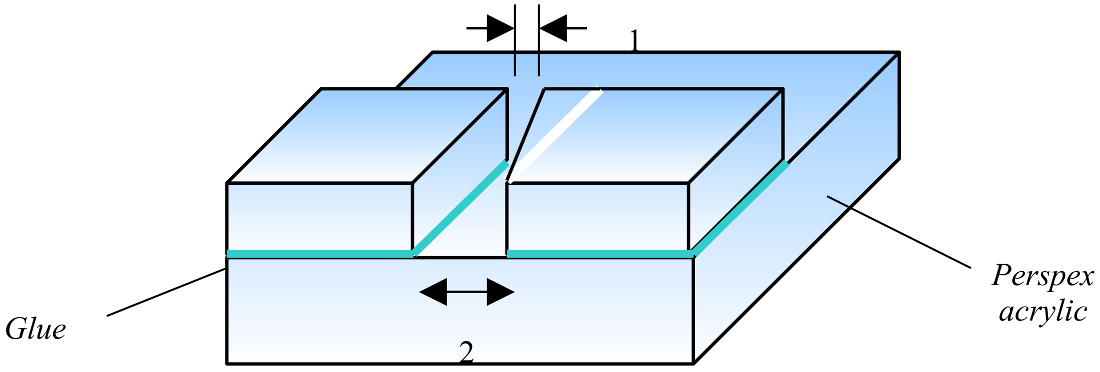


Reducing of the height:

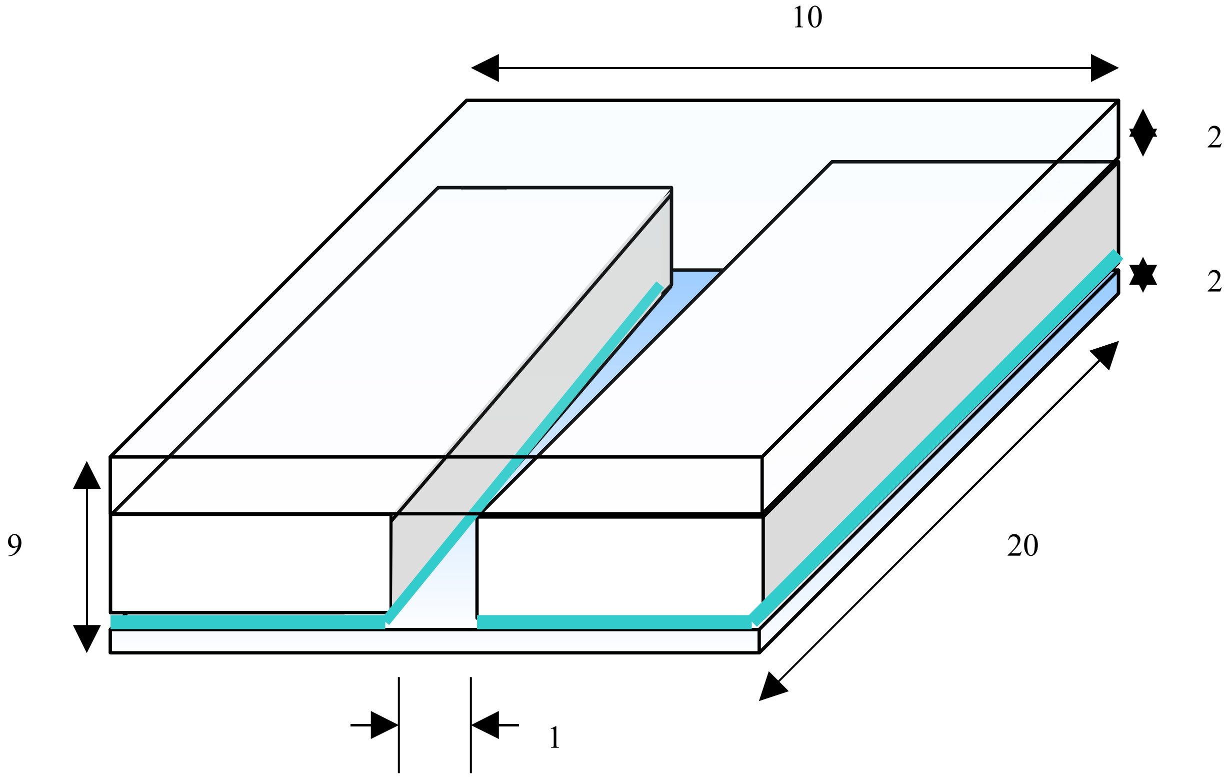


Appendix 8: Board for displacement thanks to magnetic fields

First design of gripper clamper:

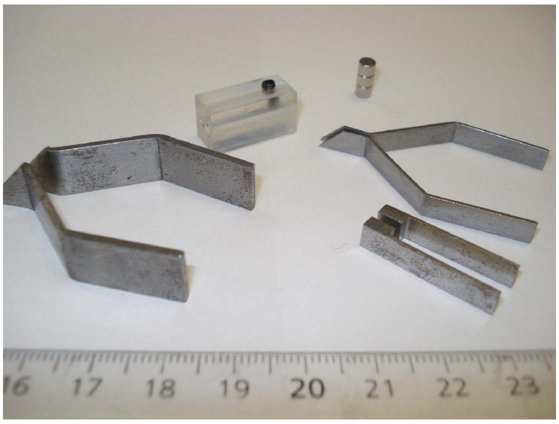


Second design of gripper clamper with crew and covered:

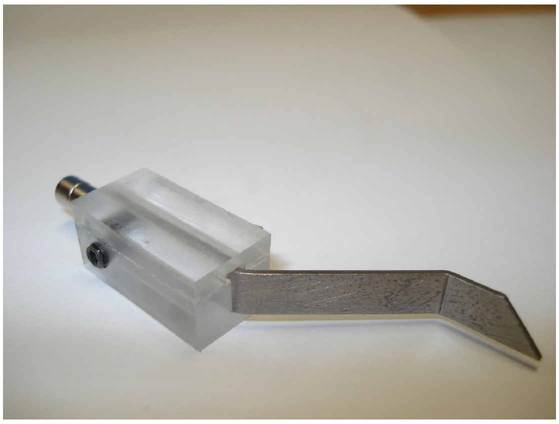


Appendix 9: Pieces designed

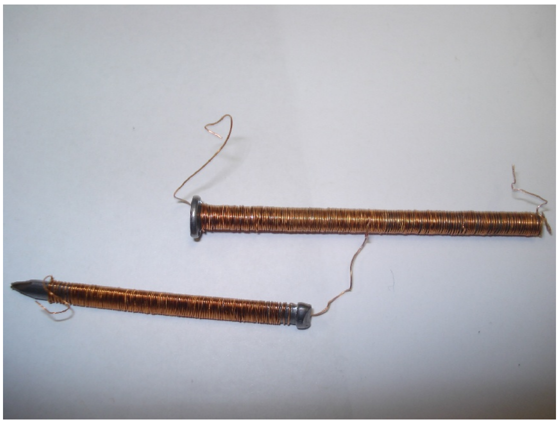
Grippers:



Perspex acrylic board with one arm of the gripper and magnet on tip:

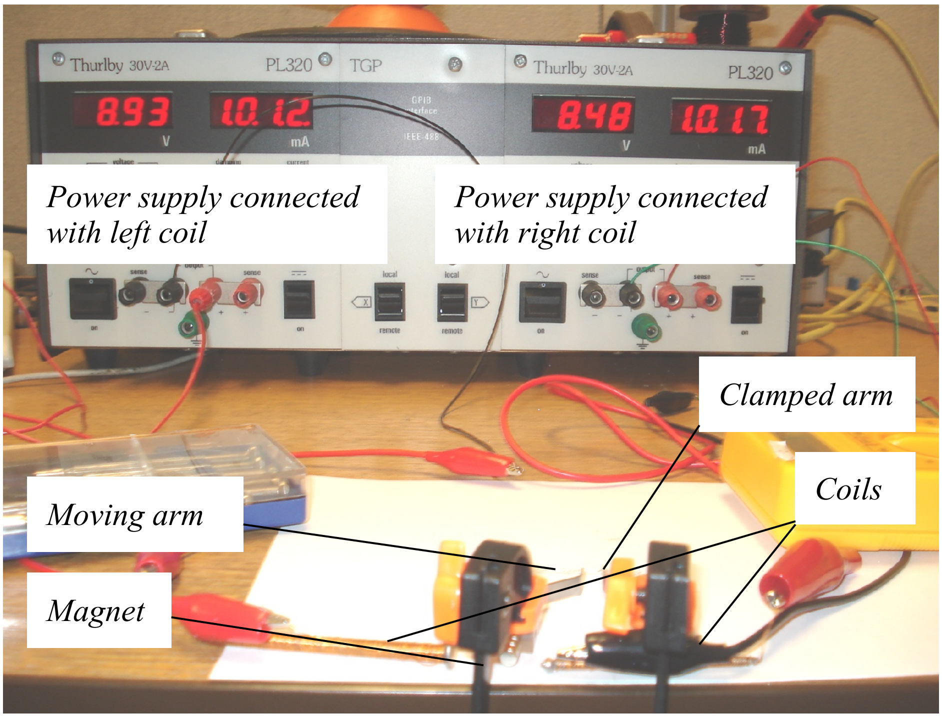


Coils:



Appendix 10: Pictures of the electromagnetic gripper

Electromagnetic gripper with its double power supply:



Electromagnetic support