Interview: Jadran Lenarčič, director of the Jožef Stefan Institute

The State Must Create the Market for Innovation

Sara Lunder
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A central task of the Jožef Stefan Institute (IJS) is intensive cooperation in promoting technological and economic development in Slovenia. The role of the IJS is evident in both the training of personnel and in developmental research intended for users, and as part of which the knowledge of researchers assists the industrial and commercial sectors in resolving complicated issues. The recent past has not been favourable for cooperation between the scientific and research spheres, but in more recent years both fields have discovered the advantages of exchanging knowledge, personnel, equipment, organisation and joint involvement in international projects. The Institute promotes collaboration through numerous activities. As our interviewee, IJS director Jadran Lenarčič, says, last year a total of 114 projects were carried out for domestic and foreign industry, and in this the partners were helped to develop new materials, products, devices and technologies.

In the last few years, those in charge of development in Slovenia have become increasingly aware of the importance of cooperation between the sphere of science and research and the sphere of development within the economy. What restricted such cooperation in the past?

Following Slovenia's independence, technological development was not vitally important for the economy. The question was more of survival, so both spheres, science and business, found themselves in a special situation. On the other hand, in the nineties there was also a change in the attitude to financing science. The number of published scientific papers, especially in international magazines, started to be promoted and emphasised, and this contributed to the very survival of science in Slovenia. If it were left to the market – at least I believe this – it would have met with a sad fate similar to that experienced in other transition countries. The emphasised orientation of science towards the academic sphere not only helped to preserve it, but in certain fields it even succeeded in breakthroughs on a high level internationally.

Since technological development was more in the background, industry and science found themselves on opposing banks, and for several years we have sought to bring them together and strengthen their cooperation. This problem was more pronounced after 2000, when the need arose within the economy for products with a higher technological value.

How far in your opinion has this cooperation improved in recent years?

This involves primarily changes in the thinking on both sides, something to which we are being forced by Europe, which is allocating enormous funds for science and technological development. The awareness of and need for urgent investment of this kind also became clearly apparent in companies, since only in this way can they compete successfully on the global market. On the other hand, researchers have also ascertained what kind of role they play in economic development. In any event, insufficient money, including public, is channelled into this. Above all there is insufficient synergy between public and private investment.

How much funds are allocated for science and development in other European countries, and what proportion of GDP is allocated for this in Slovenia?

The greatest amount, more than 3 percent of GDP, is allocated for science in Sweden, Finland and Norway, followed by approximately 2.5 percent in Denmark, Ireland and Switzerland. In Slovenia we are talking about one and a half percent, and in recent years this has fallen.

How far has the state helped improve cooperation between science and the economy through appropriate mechanisms and what are these mechanisms?

We need only one mechanism for better cooperation. It is not important how it is implemented, what is important is just that a suitable market for innovation is created. The main task of the state is therefore to prepare a basis for innovation to pay off. Innovation is a broad process, which requires the close cooperation of both spheres.

Thus far the state has provided tax relief in the area of investment in science and development. So this is not investment in equipment, as was the case previously, but in living work. I believe this is one of the highest levels of relief in Europe, but this benefit is very poorly exploited. Certain other measures were introduced, and while they were not so far-reaching, companies still did not use them sufficiently.

Certainly greater cooperation between the economy and science was fostered two years ago by the scientific and research projects which the Ministry of Defence and the Slovenian armed forces initiated. These were development projects which industry alone or science alone could not offer, but in cooperation it is possible.

What is preventing even better cooperation, and how could this barrier be removed?

The biggest barrier is without doubt a lack of funds for science and technological development. We must take a step forward at the earliest opportunity. We need a consensus in the area of scientific and technological development, since only in this way will we be able to create a "team" of all three partners – researchers, business people and representatives of the government – who will formulate a quality national project of technological development. Here everyone should recognise that such a national project also requires some forbearance, since it involves not a short-term but a long-term investment, whose positive effects can only be seen in five or ten years. This is an

Slovenian medicine for a number of years

Last December, as part of this cooperation the Institute was visited by the Minister of Health, Zofija Mazej Kukovič. She met with the Institute director Prof. Dr Jadran Lenarčič, as well as with the heads of individual departments dealing with physical and organic chemistry, environmental science, health, biochemistry and medicine. Some of the most important research on which collaboration is being pursued includes modelling environmental processes and risk assessment, which as interdisciplinary tools contribute to the linking of natural science with environmental policy, with evaluation and social objectives. Equally important is the collaboration on research enabling progress in treating certain diseases (cancer, arthritis, neurodegenerative diseases etc.) and on research aimed at identifying and validating tares for planning medicines. Cooperation is also under way on training for the use of sources of radiation in industry and medicine.

Institute director Prof. Dr Jadran Lenarčič and Minister of Health Zofija Mazej Kukovič

investment for the next generation, without which Slovenia will not move forward from its current position.

At the IJS you have been striving for several years through numerous activities to establish a link between the research sphere and companies. This has also included meetings which you called "the Institute without fences". What exactly is involved in these meetings?

Perhaps to begin with I could describe an incident. A few years ago a gentleman from the European Union was visiting IJS, and he was interested in how the Institute cooperated with industry. There were several scientists at the meeting, and some of us responded that it was very hard to cooperate with industry, because at IJS we were working on the highest level of science, and the industrial sector was not interested in that kind of science. The gentlemen then responded to this by saying he was not asking what the industrial sector had not done, but what we had not done to establish cooperation with the industrial sector. I will not forget his words, and I am trying to adhere to them as far as I am able.

It is true, at the Institute we have implemented several activities which are good not just for the economy and the national interest, but also for the development of IJS itself. Through cooperation, which I understand as a two-way street, the Institute will indeed be able to develop successfully in both pure and applied research. In fact both systems promote each other, so you cannot develop just one of them.

As you mentioned, one of our activities is meetings with companies, which we have called "the Institute without fences". Any company seeking opportunities in knowledge and the chance of cooperating with us, can visit IJS on an appointed day with any group of its personnel. On that day the Institute is entirely at the disposal of the company, all the laboratory doors are open, talks are held with any group at the Institute, and this is especially an opportunity for us to get to know each other better.

Thus far we have been visited by the companies Gorenje, d. d., Lek, d. d., Krka, d. d. and Kolektor Group, d. o. o. Companies can prepare the programme of the visit themselves. With Gorenje, for instance, the meeting preparation took three months. When they arrived for their visit, we had already met for individual projects, and then we toured the laboratories. During the visit by Kolektor we gave a presentation of the Institute, and they presented their company, toured the laboratories and then we talked about where we could help them. The Institute was already cooperating with both companies, but in numerous areas and with greater possibilities we want to strengthen this cooperation. The most important thing is that such meetings often give rise to new ideas for projects that we had not thought about previously. It also often happens that at a meeting we create an entirely new concept that is different from those for which we set up the meeting.

It appears that such visits are more suited to bigger companies. How do you attract smaller companies? Do

you have any other projects that promote cooperation?

Of course we also want to draw in small companies, too. So this gave rise to the idea of doing something similar with the Slovenian Chamber of Craft, except that we would be covering several smaller companies at the same time.

One of our activities is conducted under the title "Coordinators for companies". If a company wishes to establish more permanent links with the Institute, we can appoint a coordinator for that company at IJS. This helps create new links with individual research groups at the Institute, and informs the company of possible projects, new developments, interest in cooperation and so forth. Another job for the coordinator is to bring into a potential project with the company several research groups at the Institute in different fields, or by agreement to establish contacts with relevant partners in Slovenia and abroad.

Last year at IJS we also initiated meetings aimed at creating awareness of the role of scientific research work for social and economic development. The meetings are aimed at all three actors – the state, industry and science – since we are aware that each one on their own could not achieve the right results. To date we have organised meetings such as "the Institute and industry", which was attended by around 100 CEOs of the biggest companies, followed by the meetings "the Institute and opportunity", "the Institute, environment and health, science and art – the new Renaissance" and "the Institute and creativity in school". At first the media were very interested in these meetings and reported on them, but now their interest has been progressively dwindling. The meetings are polemical and as such are interesting for all three actors and the general public. The whole of society must be aware that we can only do something together, and that you need to invest when you have something to invest. Slovenia now has something, so now is the right time for long-term investments. In five years there might be a different economic situation and that possibility will be gone. This could mean that instead of taking a step forward we take a step backwards.

So what can the Institute offer companies?

We offer companies numerous development opportunities, be it the

Kolektor Group is one of the largest Slovenian-based multinational companies and has branches worldwide. Its major market niche is production of commutators. A fruitful collaboration with the Jozef Stefan Institute lasting for over a decade has brought to development different technologies nowadays familiar in mass production. Successful research and development (R&D) projects have included the development of hard and protective coatings for saws, development of technology for metallisation of graphite-polymer composites, for selective etching and surface functionalisation of polymer materials, and for discharge cleaning of components made from copper and nickel. The company devotes much of its attention to solving ecological problems. All its technologies are environmentally friendly. They produce practically no waste since processing is carried out under a controlled atmosphere, often in vacuum conditions, and gas outlets are all equipped with specially adapted catalysts, assuring an almost perfect recombination of processing radicals to harmless molecules. The outlook for the collaboration is rosy: joint research groups are working on applications for newly developed nanomaterials in production. The most promising projects include the development of novel lubricants and of magnetic nanoparticles for medical applications.

A novel technological process developed in collaboration between Kolektor Group and the Jožef Stefan Institute has been protected by 12 patents in EU countries, the USA, Mexico, China, Japan and Korea.

Fruitful collaboration between Kolektor Group and the Jožef Stefan Institute

Impossible becomes reliable

Some materials are incompatible due to exclusively different surface properties. A modern material used for gasoline pumps is a graphite-polymer composite. It exhibits excellent thermomechanical and electrical properties and is an ideal substitute for metals that tend to corrode during exposure to aggressive liquids. The drawback of this material is poor surface energy

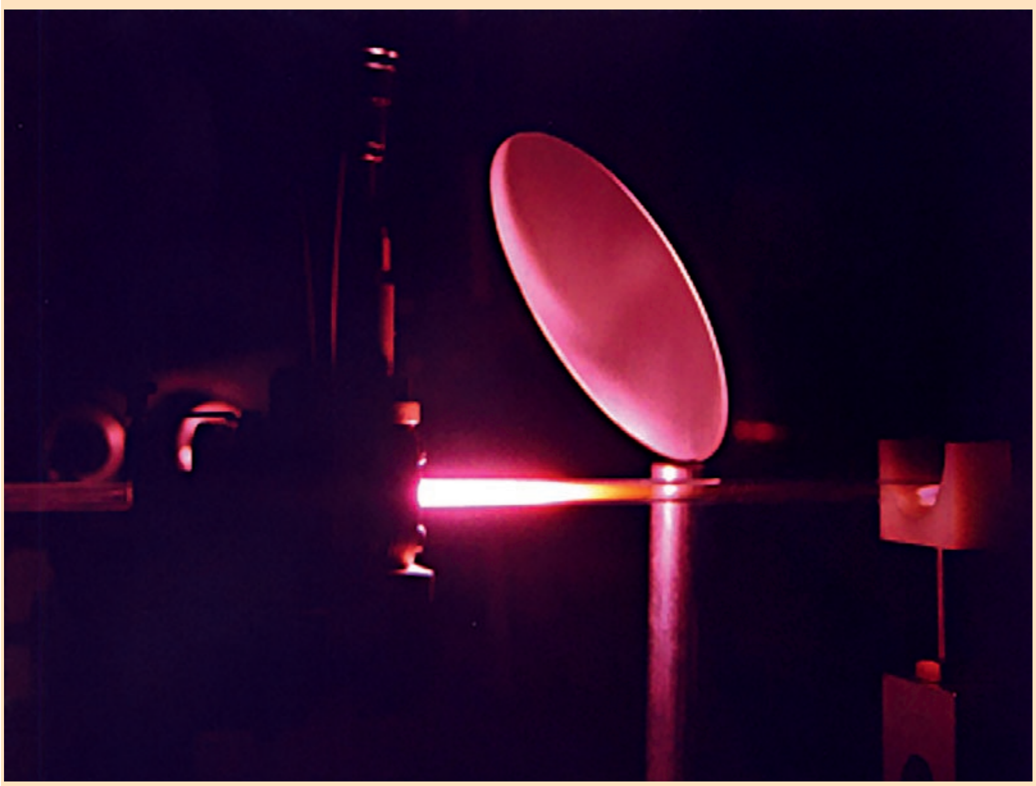
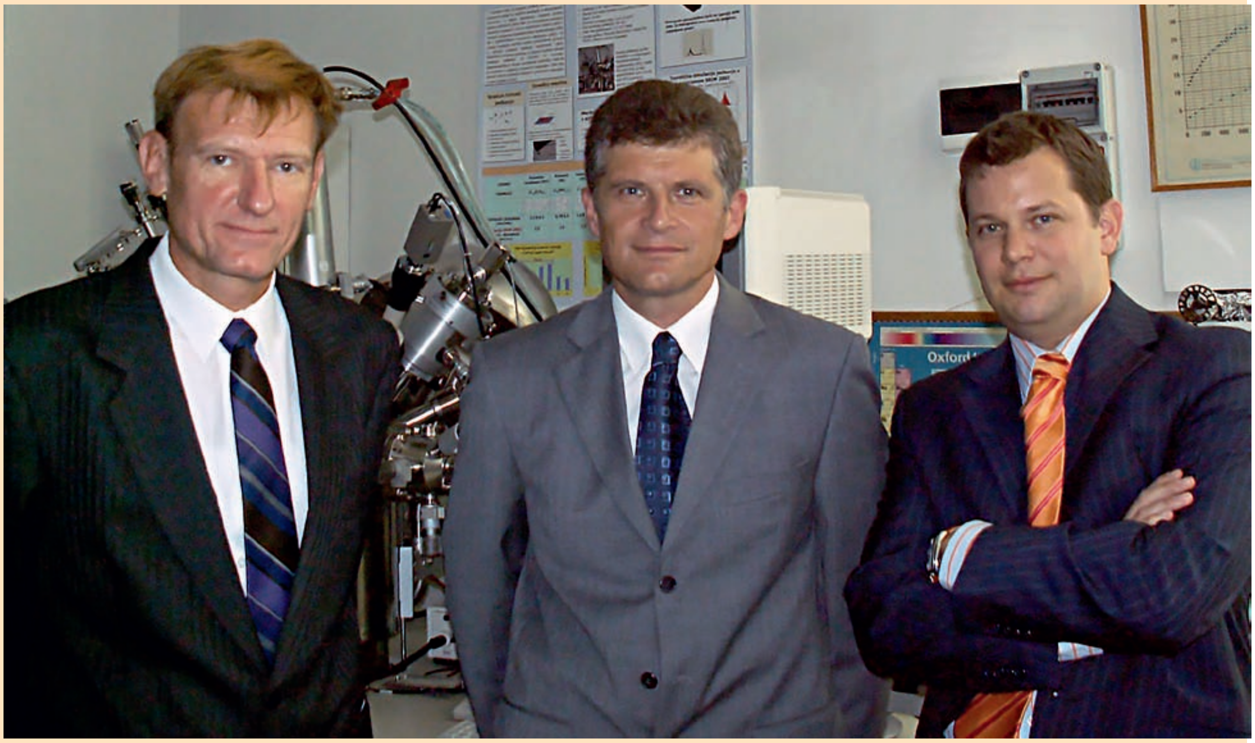


Figure 2: Gaseous discharge is an excellent source of plasma radicals

Graphite-based composites are promising substitutes for metals. Unlike most metals, the composites are immune to corrosion and exhibit excellent thermomechanical and electrical properties.

that prevents metallisation by standard electrochemical processing. Previously, the only known method was based on application of different ecologically harmful wet chemical treatments. The Executive Director New Products at Kolektor Group, Univ. Dipl. Engineer Ludvik Kumar, however, was resolved to overcome this problem. He contacted the head of the Plasma Laboratory at the Department of Surface Engineering and Optoelectronics of the Jožef Stefan Institute, Prof. Dr Miran Mozetič and together they ran the project entitled "Plasma Technologies for Treatment of Composite Commutators". The project was partially funded by the Ministry of Higher Education, Science and Technology of the Republic of Slovenia. In less than three years, the project team developed a novel technology for treatment of the graphite-polymer components that allows for excellent adhesion of the metallisation layer on the surface of the composites. The technology is based on application of different dry gaseous processes. A plasma reactor was constructed that allows for generation of an extremely non-equilibrium state of gas. At the neutral gas temperature below 300°C, the inner temperature of the gaseous molecules exceeds 30,000°C! The dissociation fraction of gaseous molecules exceeds the ionisation fraction by about 1,000,000 times. Such conditions are achieved only through the proper choice of plasma reactor materials as well as optimised coupling between the discharge power supply and the plasma inside the reactor. An extremely high flux of gaseous radicals on the surface of the graphite-polymer composite assures rapid removal of the surface layer of the polymer as well as of loosely bound graphite grains. The surface of the composite becomes free of polymer and extremely rough. Furthermore, the surface of the graphite grains becomes nanostructured as shown in Figure 3. An extremely rough surface, however, is not sufficient for good adhesion of a metallisation layer on the modified material. In the next step, the composite is exposed to a proper dose of oxygen radicals. This final procedure leads to formation of extremely polar functional groups on the surface. The richness of the functional groups on the polymer-free surface of the composite, together with the extreme roughness, causes a transformation of the surface properties of the composite. If the untreated material is heavily hydrophobic, the processed material becomes highly hydrophilic. Furthermore, project researcher Dr Uroš Cvelbar found that, under limited process conditions, the surface becomes superhydrophilic. This state has never previously been reported in the scientific literature for the surface of a hydrophobic polymer matrix composite. The superhydrophilicity leads to excellent adhesion of the metallisation layer on the surface of the composite. This method for treatment has been protected by international patents and is currently used in mass production: over 3,000,000 pieces are produced annually and the quality of the products is superb.



The research team from left to right: Prof. Dr Miran Mozetič, Ludvik Kumar and Dr Uroš Cvelbar

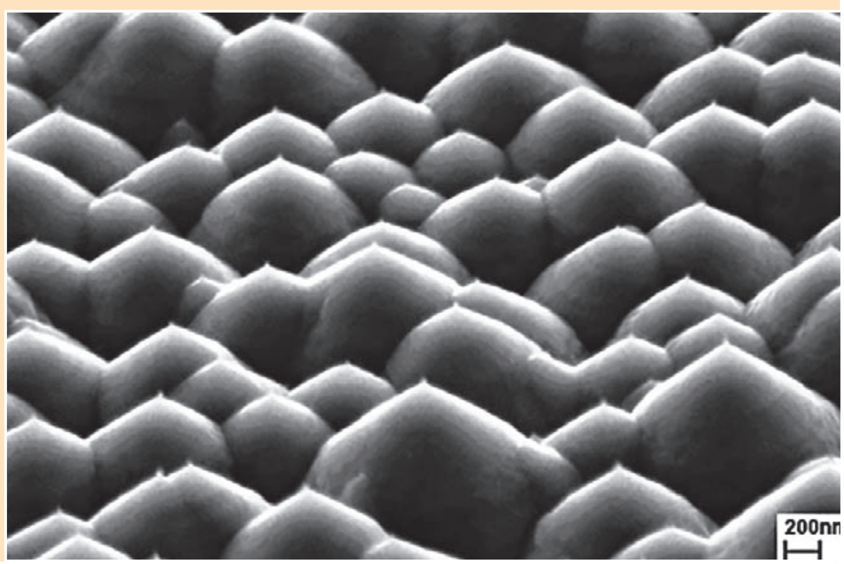


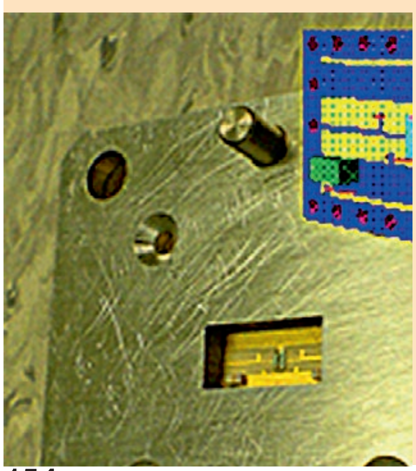
Figure 3: Nanostructured surface of graphite grains

development of technologies, devices and products, consultation, training for innovative personnel or the joint use of equipment and organisation of joint development groups. During company visits I frequently stress that they have done well if they have come to us for knowledge, but here they will not acquire it just like that. The point is, we will only arrive at real knowledge through joint work. The Institute also facilitates help for companies in becoming involved in international projects and networks. Each year we participate in around 180 European projects, but sadly to date only a minimal number of Slovenian companies have taken part in them. All these projects are tied to companies abroad, so we suggest to Slovenian companies that they should also seek opportunities for breaking into the European technological arena through us.

What desires do entrepreneurs have most frequently in making contact with you, or what do companies lack most of all? How can you help them?

Usually this does not involve projects where we would develop a product in its entirety. Most commonly they have technological problems which they cannot resolve themselves, and they want to know how they could improve an existing product, whether this involves better materials, new technology or automation. We as an institute are keener on having them work with us and our ideas to develop products that will be successful on the market and will create among buyers the need for such products.
Cooperation with industry takes various forms. The first has been a kind of sponsorship, where the Insti-

Figure 2: Photo and schematic representation of a unitary phase-shifting cell.



Prof Dr Marija Kosec
Head,
Electronic Ceramics Department
Jozef Stefan Institute

Planar antennas based on ferroelectric thin films

Dr. Barbara Malič

As part of the EU FP6 RETINA project, we have collaborated with HYB, d.o.o. in developing and fabricating a planar low-cost antenna, which will enable broadband access to the Internet aboard mobile platforms, such as aircraft.
The antenna is composed of a mesh of ferroelectric phase-shifters allowing beam steering of an electromagnetic signal in a selected direction i.e. towards a dedicated satellite.
The ferroelectric capacitor, which is the active component of the phase-shifter, is a (Ba,Sr)TiO3 (BST) thin film deposited on a ceramic substrate by Chemical Solution Deposition. The BST film is less than 1 μm thick, with electrodes patterned by lift-off photolithography and wire-bonded in the phase-shifting cell.

Dr Barbara Malič

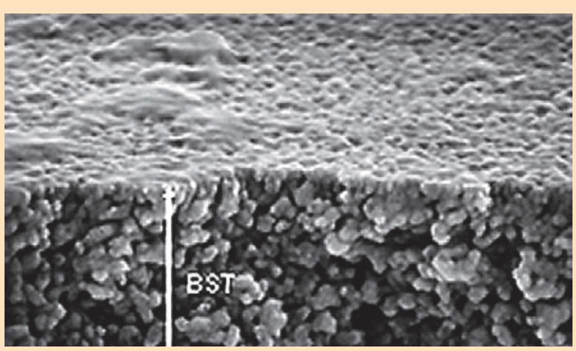


Figure 4: Cross-section microstructure of a BST thin film on a ceramic substrate

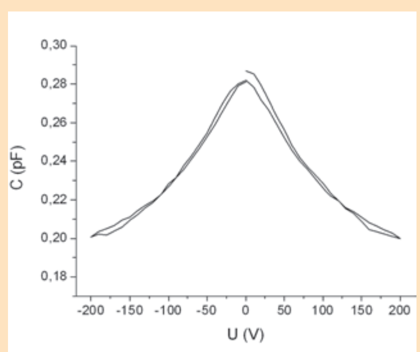


Figure 3: Capacitance-voltage response of a BST thin-film capacitor

The Ceramic-MEMS is the result of research activities on materials, construction, design, electronics, and fabrication and characterisation of materials and devices. The research activities were carried out by research organisations HIPOT-RR, d.o.o. and the Jožef Stefan Institute. Part of this research was funded by the national "Hybrid Micro Electro Mechanical Systems" (L2-6462-1704) project and part by the EU FP6 MINUET (FP6-505657) project. Both were also financially supported by the Slovenian company HYB, d.o.o.

Ceramic MEMS

Micro-electro-mechanical systems (MEMS) can be fabricated with a variety of technologies and from a range of materials. MEMS are normally made by micro-machining silicon, but in some applications ceramic materials are a very useful alternative. The laminated 3D structures made using low-temperature cofired ceramics (LTCC) are especially practical for ceramic micro-electro-mechanical systems (Ceramic MEMS). Pressure sensors, which are an important segment in the MEMS market, can be based on different technologies and principles. Thick-film ceramic pressure sensors are typically larger (in the meso size range) and mostly used in a physically and/or chemically demanding environment. Sensor elements made with thick-film technology on a deformable diaphragm are most common in ceramic pressure sensors. Diaphragm dimensions must be chosen and material must be selected very carefully to, on the one hand, maximise the sensor's signal and, on the other, to stay within the elastic limits of the diaphragm material and avoid fracturing the diaphragm. For this purpose, several construction details were studied and then verified using a simulation of test structures with the ANSYS finite-element-analysis software package. An example of such analysis is shown in Figure 1.

Darko Belavič
Head, HIPOT-Research group
HIPOT-RR, d.o.o.
c/o Jožef Stefan Institute

The sensing principles of the thick-film ceramic pressure sensors are piezoresistance, capacitance and resonance. The piezoresistive pressure sensor is made with four thick-film resistors on the diaphragm. Each thick-film resistor acts as a strain gauge that is capable of translating a strain into an electrical signal. The working principle is piezoresistivity – the property of resistor materials to change their resistivity under strain. The capacitive sensor is based on changes of the capacitance values between two electrodes. One electrode is fixed and the other is movable and made on the diaphragm. The displacement of the movable electrode depends on the applied pressure. The piezoelectric resonant pressure sensor is based on the piezoelectric properties of ferroelectric thick films on the deformable diaphragm. The ferroelectric structure works as an actuator and generates stresses in the diaphragm, and these induce vibration of the diaphragm at its resonant frequency. The applied pressure bends the diaphragm and shifts the resonant frequency, which can be used as the output signal of the piezoelectric resonant sensor. The thick-film piezoelectric resonant pressure sensor is a relatively new device made with new thick-film PZT material. Two types of piezoelectric resonant pressure sensor are shown in Figure 2.

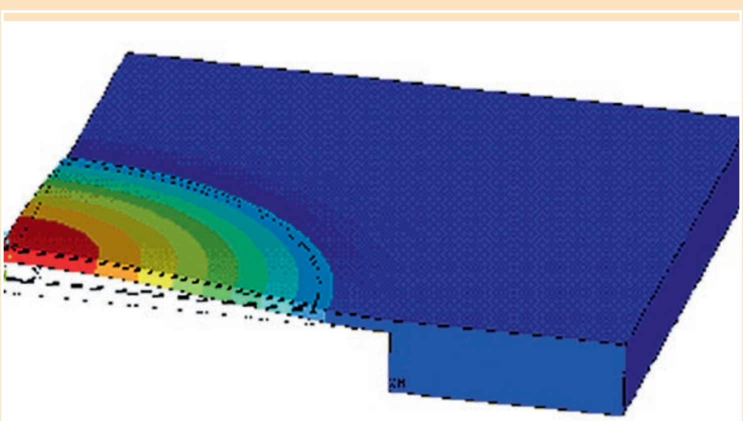


Figure1: Bent diaphragm of ceramic pressure sensor analysed using finite elements

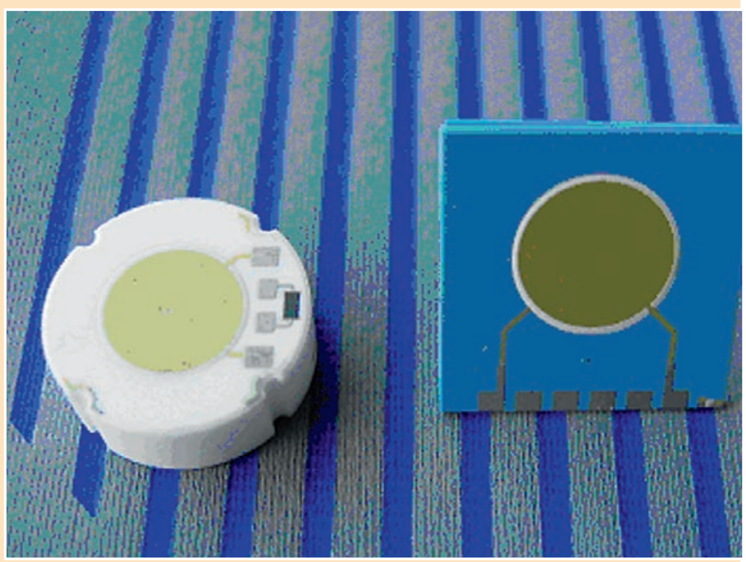


Figure2: Thick-film piezoelectric resonant pressure sensors made by thick-film PZT material on an alumina capsule (left) and on a 3D LTCC

tute received a sum of money from a company and used it for a project where it was more or less all the same whether it succeeded or not. At that moment this was good, but negative consequences soon became evident. Whoever receives the money usually does not produce any major results, and the company itself is not interested in what happens with the money, so the project usually ends with a report, and rarely with a prototype. This form of cooperation is undoubtedly the worst, since it usually causes more harm than benefit. The next method is what I call buy-sell. A company has a technological problem, and wants new materials or development. The Institute fulfils the company's order and is paid for the service. Yet in this case, too, we cannot speak of real cooperation. Good cooperation is partnership, in other words when we arrive together at the concept of how to deal with a problem, and we are somehow mutually dependent. In addition to the concept, we also exchange people, their technological knowledge comes to us and vice versa. A long-term partnership is created, since both sides know what they can offer each other and that only together can they arrive at the final result.

Entrepreneurs from which sectors most commonly approach you?

Most companies are from manufacturing, such as the car industry. It is true, however, that they could also come from entirely different sectors, but they don't. For instance we have tried to establish contacts with retail, but have not succeeded. They see no advantage in science and technology, although I believe that at the Institute they still have considerable opportunities, whether we are talking about product control, logistics or internet sales. The possibilities on which in a few years their lives will depend are great.

What criteria do you use to decide on cooperation?

It happens that we might not have mastered some field or we lack sufficient knowledge. Occasionally there are complications with money. Many people still believe today that we are financed from the budget and that our services are free. But IJS does not live off the national budget. The Institute's operations are financed through projects for which we tender in the national and European market, both in the public and private sectors. Equally, we have no funds to implement a project for free which is not part of the projects through which we are financed. It is true, however, that at IJS we do not embark on projects where the basics would be learned. We only accept projects where we can sell the knowledge we have, and which for individual projects we also enhance appropriately.

Has IJS in the past worked in cooperation with domestic or foreign companies on such a far-reaching project that it has ranked as a breakthrough on the world scale?

Given that each year we have many more than 100 projects, it is hard to highlight any one in particular. I should mention perhaps just two companies, Domel, d. d., and Droga Portorož. For the first company our researchers developed a cell for laser testing of the quality of engines, which was a very important achievement on the world scale. For Droga we provided automation, IT support and robot operation for the tea production line. A special feature of this was that we provided it as a turnkey project.

If an entrepreneur visits you and you determine that you cannot help him, do you contact other domestic and foreign institutions of knowledge?

We cooperate with all the universities and institutes in Slovenia and numerous institutions of knowledge abroad. In recent years our portfolio has been dominated by European projects, with about 200 going on each year. Last year we signed a cooperation agreement with the Austrian technological institute Joanneum Research, which deals primarily with development for industry. Through them we are linked to the biggest technological institute, TNO, which is headquartered in the Netherlands. This involves enormous synergies, with them seeking from us primarily basic knowledge and us seeking technological knowledge from them.

This means that through IJS Slovenian knowledge is being increasingly transferred to the economies of other European countries.

Of course. Direct cooperation with industry abroad is increasing by around 50 percent annually. We are not talking big numbers, just a few percentage points of our total revenue, but it is significant that it is increasing so much. We are being approached most of all by Austrian and German companies. And across the pond we have primarily scientific links. The USA is a traditional area of cooperation for us, but in terms of the number of bilateral projects in recent years (alongside the USA) we have cooperated most with Japan.

Finally, a question which is not entirely connected to the Institute's cooperation with industry. How in your opinion could IJS market its intellectual property even better?

The field in which Slovenians are certainly not present in the European and world map is that of spin-off, that is, companies created from knowledge or ideas. There are very few such companies in Slovenia. In this field Europe is significantly better, since it has determined that our main lag behind America is in the establishing of small companies created on the basis of technological discoveries.
A little time ago I started developing an idea that I called "from doctorate to company". In Slovenia each year there are between 20 and 30 new doctoral graduates. The basic concept was to provide for all these young researchers at the Institute an incubation period and funds, so that the idea they developed in their doctorates – if of course they wanted to – could be developed up to the founding of a company and the sales of their first products. This preliminary period would last three to five years, and then the company would relocate to a technology park. We would facilitate work through our equipment and personnel and also our monetary fund, which we would set up for this purpose. The doctoral graduate would be the majority owner of the company, and we would be co-owners. Once the company was on its own two feet, IJS would sell its share. Unfortunately my idea has run into numerous formal problems, so I have shelved it for the moment.

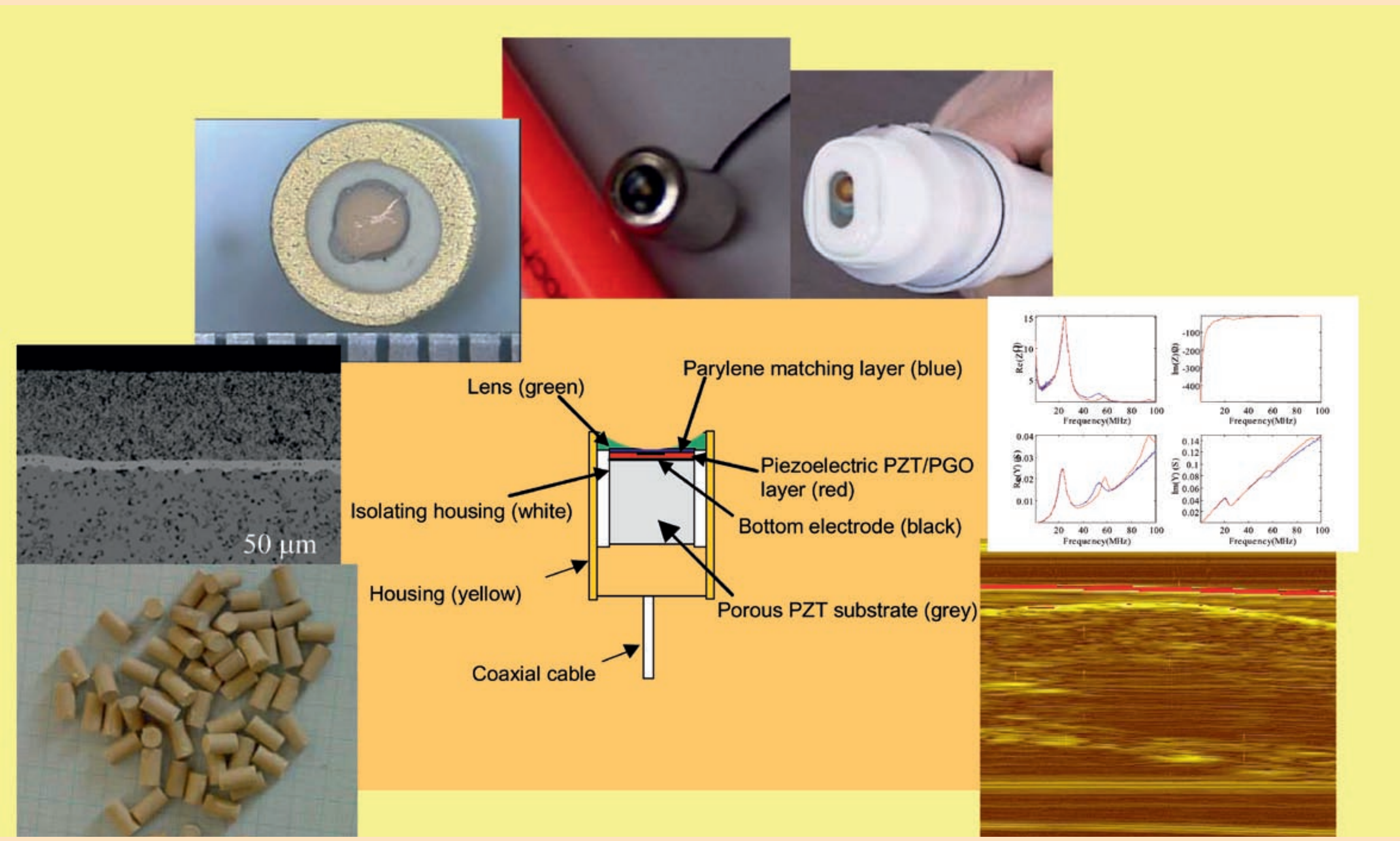
Medical transducers based on ferroelectrics thick films

Recent development trends in piezoelectric devices are towards smaller size, higher resonant frequencies and a low driven voltage. For high-frequency transducers in medical imaging applications, thin (i.e. <50 µm) piezoceramic elements are necessary. These are usually produced by lapping and machining. However, the elements tend to chip and break, and this is a major problem when joining the element to the backing. This problem may be avoided by an integrated device with a thick piezoelectric layer on a suitable substrate that also serves as a backing. To provide this function, porous PZT ceramics were chosen for the substrate.

Piezoelectric lead-zirconate-titanate, Pb(Zr,Ti)O3, PZT-based thick films were processed by screen printing and firing on porous PZT. To lower the firing temperature of the PZT layers to 800–900 oC, the composition was modified with lead germanate (PGO) that forms a low-temperature liquid phase.

A structure composed of PZT/PGO thick films, a gold bottom electrode, PZT barrier layer and porous PZT substrate delivers the best performance in terms of electromechanical properties of the active layer and acoustical properties of the substrate (acoustical impedance and attenuation). This has allowed us to determine the dimensions and final structure for fabrication of the transducer. In co-operation with GIP Ultrasons of Tours, France, within the EU FP5 PIRAMID project, the integrated thick-film transducers have been fabricated. The image obtained with the PZT/PGO thick film has a very good axial resolution and good sensitivity, which make this integrated thick-film structure promising for medical imaging transducer applications.

Dr Janez Holc



A) Schematic of the integrated thick-film transducer.
B) A substrate with the function of backing was produced from PZT powder and a pore former to obtain the defined porosity after sintering.
C) Cross section of the thick film structure after sintering of PZT/PGO layer.
D) Front of the transducer after thick-film processing, sputtering of the top gold electrode and poling. Diameter of transducer is 5 mm.
E) Transducer in metal housing after processing of parylene matching layer and lens (made by GIP Ultrasons).
F) Transducer in medical ultrasonic probe (made by GIP Ultrasons).
G) Real and imaginary part of electrical impedance of PZT/PGO thick-film structure (measured at GIP Ultrasons).
Image of a forearm obtained with an integrated PZT transducer. It has very good axial resolution and sensitivity compare to a classic bulk transducer (measured at GIP Ultrasons).