Introductory Course

Medical Applications for Micromachines, Part 4

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Micro-Electrodes: Data Interface with Living Organisms

Mechanical industries tend to view electronic systems as borrowed systems. With the human body, however, we must consider contact points between an electronic system and nerves in the human information system as a complex system from the beginning. The development of an interface between neural circuits and external instruments is essential as a base technology for micromachines. Recently Japan has been presented with a golden opportunity to make up lost ground in pacemaker development.

Forty years have passed since development began on pacemakers, now the most widely used artificial organ. The pacemaker is also a good example of the increased use of micromachines, achieving complex control and high compatibility with the human body. Pacemakers that have until recently been developed to treat bradycardia are starting to be incorporated as implanted defibrillators for treating tachycardia.

We are just now developing other methods of applying micromachines to the nervous system. In addition, diseases brought about by the nervous system of the heart and diseases brought about by nerves in the cerebral/peripheral nervous system have many common points in the form of electric signals. A great number of regions controlling human body functions can be manipulated electrically, and engineers have shown an interest in this field. However, we have tried to provide interface with macro-instruments located external to the body to provide a less invasive operating method. As a result experiments in Japan using the approach of installing a micro-electrode into the body have unfortunately been limited to animal experiments in our engineering departments. Although many approaches in a clinical setting have been proposed, there has been little research aimed at making this practical. Nowadays, researchers of neural systems have begun to assert that the 21st century is not only the age of gene research, but also of brain research.

Studies on micro-electrodes implanted in the human body have increasingly been conducted in the areas of visual and auditory systems, wherein multichannel needle electrodes are implanted to directly stimulate sensory areas in the brain. Some clinical achievements have been observed in the auditory field. A strong potential has also been seen in approaches to stimulate afferent nerves between sensory organs and the brain and in direct stimulation of sensory cells. In the auditory field, cochlear implants have found practical uses, while in the visual field there have been repeated experiments conducted to stimulate optic nerves using electrode, with inclined needle array. Japan has also been recognized for its advanced medical technology on implanting multichannel microsensors in the cranium to sample signals from the brain and determine functional regions. Many clinical examples that have been conducted are now common in health insurance coverage.

Many approaches have been developed for treating peripheral nerves, such as microsleeve electrodes and nerve growth electrodes that incorporate the fiber-growing region of the nerve stump in an electrode. Studies are being conducted to create an interface between nerves and artificial devices, both internal and external to the body. Studies on both of these micro-electrodes and electronic devices must cover such medical engineering issues as the compatibility of micromachining methods and materials with the body tissue, and the intervention of nerve growth factors, such as endocrine substances. We must create new areas of research.

Micro Fluid Devices: an Essential Micromachine Technology for Medical Measurements

It is well known that the object of medicine, the human body, comprises 70% water. Many medical instruments operate using an aqueous solution or a solution containing cells or micro-particles. It is a well-known historical fact that the first idea for creating an automated biochemical analyzer, called an auto analyzer, came during the development of tabletop chemical plants. With these devices, methods of pumping, cleaning devices, separating samples, and detecting reactions were studied at dimensions near the micro-level to enable a drastic size-reduction in the plants.

Although there have been various proposals for developing micro-fluid devices since the beginning of micromachine development, even today these devices only function as a single component. We must reinvestigate and reconstruct all system components with the aim of versatility. To do this, we must begin by acquiring base technologies for designing micro-fluid systems, including theories for analyzing fluid behavior at high viscosity and approaching particle transport and the need for rheological analysis, which knowledge can help us zero in on the essence of living matter. It would not be an exaggeration to say that developing technical elements as systems will influence tomorrow's sample testing apparatus. However, we must still develop numerous components and study them as microsystems in order for micro-instruments used in sample measurement, such as micro-TAS (total analysis system) and on-chip labs, to become the next-generation of auto analyzers useful in medical treatment.

New Medical Industries Created from an On-site Demand for Micro-Instruments

In order to popularize medical products and their use in the home, we must develop technologies for manufacturing cheaper and smaller products. By taking up each instrument one by one, perhaps we will see the need to explore the feasibility and significance of manufacturing them at a micro-size. Most conventional medical equipment is manufactured manually one product at a time, resulting in high prices that have stifled the market. Manufacturing this equipment at micro-sizes would give rise to industrialization and lower costs, which could generate a large demand. Blood sugar testing apparatus that are already used in the home have generated a new direction for diabetes control and have generated an enormous market. Micro-syringes for use in the home, which have helped reform conventional methods of administering medicine, and the much smaller catheter, have the potential to radically change medical treatment in the future. Obviously in either case it will be necessary to develop impartial ideas with much consideration for the clinical sites. It is clear from experience that the more widespread the micromachine system can be used, the more likely the system may become Japan's original industry. The objective of our efforts is most likely to develop common equipment of widespread use aimed primarily at treating lifestyle-related diseases.

Since the components of micromachine systems are small, we have a tendency to think it difficult to mount circuits for information systems therein. However, the smaller the devices become and the more widely they are used, the more indispensable it is to automate data processing in devices and elements. If our research does not include the study of somewhat fixed distributed data processing systems in micromachines and their integration as systems, there will probably be less possibility of micromachines becoming an essential technology in the medical industry.