Needle type temperature probe for both diagnosis and treatment of musculoskeletal pain

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Abstract

In this study, we developed multi-functional needle that provides the temperature measurement and medicine injection for both diagnosis and treatment of musculoskeletal pain syndrome (MPS). In the case of MPS, trigger points where from the pain originates are present in the musculoskeletal body and their size vary from several micrometer to millimeter. Therefore, it is needed to develope a medical device that is capable of not only finding the trigger points which present at human body, but also injecting medicine in the exact location for treatment. To challenge this difficulties, a thermocouple was fabricated on the surface of a needle for injecting medicines using metal deposition process. Special type of stainless-constantan thermocouple was achieved with the stanless body of a needle itself and deposited constantan metal film. In particular, parylene coating before constantan deposition enables to limit the temperature sensitive area to the end of the needle tip, whereas the rest of the needle body was electrically insulated. Fabricated needle type temperature probe produces 3.25 mV/℃ of thermoelectric sensitivity. Finally, conventional T-type thermocouple wire and needle type temperature probe were inserted in close to the animal muscle sample and temperature was recorded with thermoelectric voltage when the sample was heated on the hot plate. Needle type temperature probe will be applied to identify the trigger points of MPS from temperature distribution and then, inject medicine at the exactly same points. Furthermore, this surface fabrication technology can be applied to different kinds of medical devices that require temperature measurement.

1. Design and fabrication

1.1 Temperature probe

Needle type temperature probe measures the temperature at the tip of needle end. There are several types of designs to utilize syringe needle as temperature sensor. Cui *et al* [1] were proposed needle tempeature microsensor to measure underneath skin temperature in real-time. Thermistor was inserted into needle body and filled with epoxy resin glue. It causes low temperature sensitivity due to the indirect contact to target surface. Furthermore, it is impossible to inject medicine. To overcome these problems, Watanabe *et al* [2] suggested micro-thermocouple probe. Metal deposition process was used to fabricate thermocouple on the surface of pulled glass pipette. Thermocouple junction was formed on the tip using focused ion beam etching. It requires two steps of metal deposition and dielectric coating, respectively. Furthermore, weak terminal adapter may cause noise or durability probelm in the use of musculoskeletal system instead of bio cell. Therefore, we proposed new needle type temperature probe that is capable of measuring temperature as well as injecting medicine for both diagnosis and treatment of musculoskeletal pain.

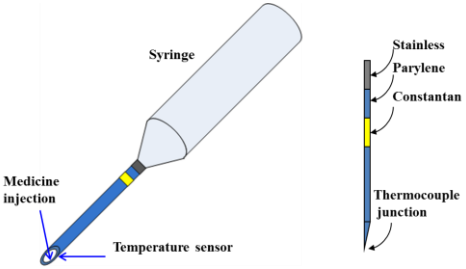

Figure 1. A schematic of needle type temperature probe

Figure 1 shows a schematic of developed temperature probe. Needle body was utilized as one of thermoelectric material (stainless) to reduce fabrication step as well as to improve electrical and mechanical stability. Parylene vapor coating was applied before deposition of constantan (Cu-Ni) to restrict electrical contact on the tip of needle. Parylene thin film has enough dielectric property with 1.5 ㎛ of thickness providing chemial, physical and biological stability. Tip of needle was covered during parylene coating to make single contact junction which could be temperature measurement area. Then, constantan was deposited using 300W DC sputtring process

as 0.2 μm of thickness to make special type of thermocouple. Constantan has -35.1 μV/℃ of negative Seebeck coefficient compared to stainless steel (4.4 μV/℃) that generates the thermoelectric performance the same as T-type thermocouple.

1.2 Connection pad

Needle type temperature probe should have been biocompatible with human body. Parylene coating is beneficial for both chemical and mechanical protective layer of thin film, and it is biocompatibe by covering whole exposed surfaces. However, it is impossible to connect each thermocouple layers because all the layers are stacked in the same area. A sequential covering of each layers were able to expose thermocouple connection pad on the needle body for signal processing and external measuring equipment. Electrically conductive epoxy provides stable and damageless connections for lead wires on thin and weak constantan film.

2. Experiments

2.1 Calibration

Thermocouple generates thermoelecric voltage proportional to the relative temperature on contact junction. Needle type temperature probe was calibrated with T-type commercial thermocouple in the heated water. Thermoelectric performance has its own non-linear characteristics in the wide range of temperature. AD594 IC provides linearization of calibration data and and 3.25 mV/℃ of sensitivity was achieved.

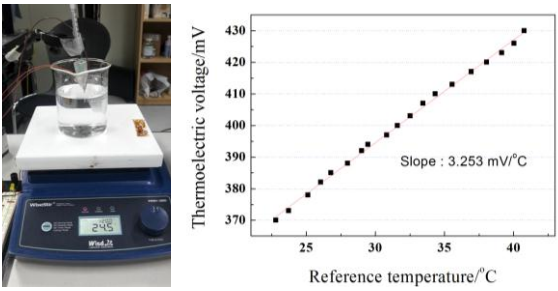

Figure 2. Calibration process

2.2 Real-time experiment

Needle type temperature probe is intended for inserting musculoskeletal system. Probe tip was inserted into animal muscle to demonstrate the real-time experiment. T-type commercial thermocouple was placed near the probe tip for reference temperature. Figure 3 shows the results of real-time experiment when applying heat. Thermoelectric voltage well represents the reference temperature.

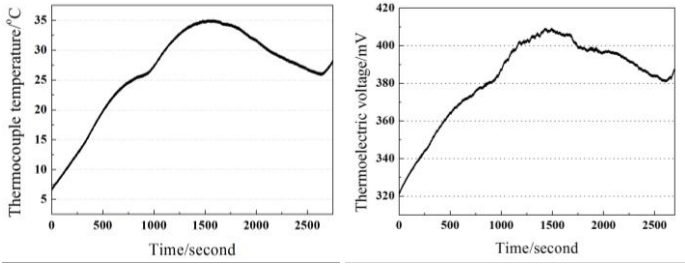

Figure 3. Real-time experiment in animal meat

3. Conclusion

Surface fabrication technology enables to fabricate thermocouple on syringe needle maintaining its own function. Needle type temperature probe can measure inside temperature of musculoskeletal system as well as injecting medicine on detected trigger point exactly. Furthermore, this surface fabrication technology can be applied to different kinds of medical devices that require temperature measurement.

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