Technical Paper

mobiCARE™ +Cardio

Conductive Adhesive Material for Bio Patch

seers
Glossary

**Acrylates adhesive polymer**: Acrylate polymers belong to a group of polymers that could be referred to generally as plastic. They are noted for their transparency, resistance to breakage, and elasticity. They are also commonly known as acrylics or polyacrylates. Acrylate polymers are commonly used in cosmetics, such as nail polish, as an adhesive.

**Hydrophilic colloid**: In chemistry, a colloid is a mixture in which one substance of microscopically dispersed insoluble particles is suspended throughout another substance. Sometimes the dispersed substance alone is called the colloid.

**PDMS (polydimethylsiloxane)**: Polydimethylsiloxane (PDMS) belongs to a group of polymeric organosilicon compounds that are commonly referred to as silicones. PDMS is the most widely used silicone-based organic polymer and is particularly known for its unusual rheological (or flow) properties. PDMS is optically clear and, in general, inert, non-toxic, and non-flammable. Its applications range from contact lenses and medical devices to elastomers.

**PEDOT:PSS**: poly(3,4-ethylene dioxythiophene) polystyrene sulfonate is a polymer mixture of two ionomers. One component in this mixture is made up of sodium polystyrene sulfonate, which is a sulfonated polystyrene. Part of the sulfonyl groups are deprotonated and carry negative charges. The other component, poly(3,4-ethylene dioxythiophene), or PEDOT, is a conjugated polymer that carries a positive charge and is based on polythiophene. Together, the charged macromolecules form a macromolecular salt.

**Polyolefin foam**: Polyolefin foam, a plastic with independent cells, is characterized by its excellent elasticity. In particular, with air cells formed in the independent cells, it has various functions, such as heat insulation, waterproofness, and buffering. In addition, it can be used in food containers, as the material is not toxic. [Source] The polyolefin foam of Youngbo Chemical Co. Ltd. brought a new sensation to the interior market (studies by Epsilon Emboss).

**Flexible printed circuit board (FPCB)**: This is a base plate of a circuit board coated with flexible copper foil (copper film). A three-layer structure, in which a copper foil and a polyimide (PI) film are bonded together using glue, has been widely used up to now, but two-layer FCCL, in which the PI film is directly die-cast or adheres to the copper foil at a high temperature, has been newly released. Two-layer FCCL is easy to use for forming a fine pattern and is excellent in flexibility, so it is widely used in display products, such as mobile phone folders, liquid-crystal display products, and PDP modules.

**Energy Harvesting**: Energy Harvesting is a technology that allows individual devices to collect energy from natural energy sources, such as the sun, vibration, heat, wind, etc., and transforms it into useful electric (e.g., solar power generation).
1. Problems with Bio Patch materials used in detecting vital signals

Currently, Bio Patches used for detecting bio-signals are mainly composed of acrylate adhesive polymers, natural rubber latex, and hydrophilic colloids. When patients use the Bio Patches for long periods, they sometimes damage their skin.

The Bio Patch may also cause fatal side effects, especially for newborns or elderly people with weak skin tissues.

For these reasons, most of the materials in Bio Patches do not meet the requirement of maintaining stable adhesion to the skin for a long time for the purpose of detecting diseases, such as arrhythmia. Therefore, the need to develop new patch materials is increasing.

![Figure 1. Side effects of adhesive materials used in medical patches](image)

2. Industry trend of patch material development

Recently developed adhesive materials using PDMS, which is known as a biocompatible polymer, are superior to the glue-type acrylate adhesive polymer used in the past. To improve the adhesion, the surface of the newly applied material is being developed in the form of a mushroom-shaped small projection or a lizard-paw shape.

In most cases, when an electrocardiogram (ECG) is measured, motion artifacts occur due to the unstable adhesion between the conductive patch electrodes and the skin, and this is the biggest obstacle to detecting stable ECG signals. Therefore, to detect bio signals stably without noise, it is very important to develop electrode materials featuring flexibility and stretchability.

As a new flexible and stretchable electrode material, the development that disperses carbon nanomaterials evenly on a polymer matrix to achieve a certain level of conductivity or that uses a conductive polymer known as PEDOT: PSS4 is actively underway. However, research results are still insufficient for overcoming the problems resulting from the attributes and structures of basic materials. Studies on minimizing motion artifacts should continue to detect biological signals more effectively.
3. Requirements for adhesive material to detect biological signals

The electrical conductivity of the human body is characterized by ion conduction. The conductive polymer currently used is a polymer material that maintains water, moisture, and electrolytes in a three-dimensional polymer matrix.

As mentioned above, the noise of the signal is an important factor to consider when measuring electrocardiograms, and maintaining moisture provides benefits such as 1) the ion conductivity of low source impedance, 2) high adhesive strength during the long period of use, and 3) maintaining the initial impedance value with no fluctuation. Figure 2 displays the requirements of the adhesive material for the Bio Patch.

![Figure 2. Requirements for Bio Patch material](image-url)
4. Development of Bio Patch material using conductive acrylic adhesive and silicone for wound treatment

To detect electrocardiogram signals for long periods, it is necessary to minimize the problems with existing patch materials and the noise issues generated during treatment.

SEERS used a two-part silicone used for treating scars or scratches on the skin for the skin-contacting part and used the Ag/AgCl electrode and acrylic ion-conductive material for the signal-detection part. Figure 3 shows the ECG electrodes used in the SEERS Bio Patch. Figure 4 shows the patch material with multiple electrodes for disposable and multi-sensor measurements.
4.1. Manufacturing disposable ECG electrodes using silicone adhesive

A disadvantage of widely used disposable ECG electrodes is that they cause skin problems for people with sensitive skin if used for extended periods of time. To overcome this, SEERS tried to minimize skin troubles by using a two-part silicone that is commonly used for scars and scratches on the adhesive part of the Bio Patch. The process of making a patch with a two-part silicone is as follows:

1) Polyolefin foam is processed into a circular shape.
2) An Ag/AgCl-plated snap button is tightened.
3) Acrylic conductive adhesive is attached to the Ag/AgCl.
4) The polyolefin foam is placed on the adhesive part.

4.2. Manufacture of adhesive part of multi-electrode patch

The adhesive part of the multi-electrode patch was also manufactured in the same manner as the disposable ECG electrode. The following materials were used to manufacture the adhesive part of the multi-electrode patch: 1) a polyolefin foam that can be processed according to the design shape of a built-in FPCB, 2) an acrylic conductive adhesive, 3) a medical nonwoven fabric tape, 4) a conductive gel sheet, and 5) a silicone adhesive coated with an even level of thickness on the surface.

The FPCB was fixed between the silicone adhesive and the nonwoven fabric tape, and the conductive gel sheet was adhered to the five terminals for sensing body signals. Other parts that come into contact with the skin were coated and turned into gel with a two-part type silicone in the same manner as the disposable ECG electrode.

5. SEERS’ development plan for patch material

SEERS is currently developing a Bio Patch material that is skin friendly and that can be used in a disposable form to reduce costs, minimize signal noise, and provide the ability to mount multi-functional sensors.

The following are some of the requirements that SEERS expects to be met in adhesive development through past development experience:

- It should be possible to shower with the patches on several times with a water-repellent structure rather than making it waterproof.
- It should be possible to adopt a structure that is as thin and flexible as possible.
- The adhesive capacity for the first use should be at least one week.
- The adhesive area of the skin should be as small as possible so that the user does not feel uncomfortable.
- It should be applicable via the silver electrode thin film process.

To meet the above requirements, SEERS focuses on:

1) The development of materials with no skin troubles, increased stability in conductivity, and high adhesiveness
2) The development of one-bodied materials with adhesive material for the skin, and conductive material for detecting electric signals
3) The development of disposable patch materials that form signal lines and electrodes by implementing conductive material on a nonwoven fabric via the thick film process.
4) The development of a stretchable conductive polymer material, which is a flexible/stretchable, then minimizes the motion artifact during the movements
5) The development of a conductive material capable of absorbing sweat
6) The development of a battery-free patch material with energy-harvesting technology

Reference

2) Dong Hae Ho, Jeong Ho Cho, “Recent Research Trend in Flexible and Stretchable Electrode for Wearable Device”, Industrial Chemical Outlook, Book 21 #1, 2018.