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From: National University Corporation Kyoto Institute of Technology

Title: <u>A new development of textile pressure sensor – a five-layer structure produce made by knitting</u>

1. Source of the announcement:

Annie Yu (Assistant Professor, Faculty of Fibre Science and Engineering, Kyoto Institute of Technology)

Yuya Ishii (Associate Professor, Faculty of Fibre Science and Engineering, Kyoto Institute of Technology)

2. Noteworthy points of the discovery/invention:

◆ This work is novel. It differs from conventional/previous work in that the textiles sensor is directly made from yarns into a five-layer structure by knitting.

◆ The surface of the textile sensor is non-conductive and can be directly come into contact with human body.

◆ No additional lamination, chemical coating or after-treatment is needed in the production. Therefore, the problem of delamination or loss of chemical after washing can be solved.

◆ This discovery is expected to contribute to the development of wearable electronics and support IoT development.

3. Summary of the discovery/invention:

Assistance Professor Annie Yu and Associate Professor Yuya Ishii and his/her colleagues at the School of Science and Technology, Kyoto Institute of Technology, have shown that using knitting to create a five-layer fabric structure for using as a capacitive pressure sensor. As the sensor is entirely made of yarn, it is soft to touch and easily cuts into different shapes or sews onto apparels or other textiles products. By applying the fabric pressure sensor, apparels that can help to monitor our health or sport activities can be developed.

By changing the yarn using it the middle connective layer, the compression stiffness of the fabric sensor can be significant changes. With this characteristic, the sensitivity and the sensing range of the fabric sensor can be customized.

Only a knitting machine can produce this fabric sensor. No chemical treatment and lamination are required. The difficulties in the production of fabric sensors the processing time and procedures and energy consumption can be largely reduced. It is hoped that the developed fabric pressure sensor can support the development of wearable electronics and IoT.

4. Content of the announcement:

<u>Research background</u>

The Internet of things (IoT) has been rapidly developing and expanding in recent years. One of the important elements of the IoT are wearable sensors which can be used for motion detection, vital sign and ubiquitous health monitoring, etc. Due to the development of wearable electronics, the demand for soft and flexible textile sensors has subsequently increased. Strain, temperature, electromagnetic, and pressure sensors made with textiles have been the

subject of interest in many research studies. However, the fabrication method of textiles sensors can be complicated. The conductive yarns or materials that are used on the surface of fabric sensors can directly come into contact with the human body when the body touches or compresses the sensors. The conduction of an electrical current to and through the body could affect the pressure sensing of the sensor. When used to detect human motion, additional insulating fabrics are needed to cover the fabric sensor. Combined with several layers of chemical coating or printed material makes the fabrication process more complicated and delamination may occur after repeated uses or washes.

Associate Professor Yuya Ishii is the expert in smart textiles and the development of functional polymer nano/micro fibers. Assistant Professor Annie Yu has done extensive studies on textiles product development. She is also an expert in knitted structure design, especially spacer fabric (Note 1). They see the potential of using knitting to produce a textile pressure sensor by taking spacer fabric structure as a basis. Together with two post-graduate students Yota Matsui and Kazuki Tonomura, a team is formed to carry out the development of spacer fabric capacitive pressure sensor.

Description of Research

In this study, a new spacer fabric capacitive sensor which consists of five layers of materials is developed. The proposed fabric sensor was constructed on a double-bed weft-knitting machine. The surface layers are two layers of knitted fabrics produced on the front and back beds of a knitting machine, while the ,monofilament yarns produce the front and back tuck stitches to connect the two layers of fabrics and form the connective layer. The proposed fabric sensor used a plating technique in addition to the three layers of conventional weft-knitted spacer fabric. The surface layers were fabricated by using two yarn carriers that carried an insulating yarn and a conductive yarn respectively. During the knitting of the surface layer, the two yarns are plated with the insulating yarn going in the front of the conductive yarn. This allows the insulating yarn to be always shown on the fabric surface, thus embedding the conductive yarn in the spacer fabric, and forming a five-layer structure (Figure 1). Therefore, only the insulating yarn is in contact when touched or pressed. The monofilament yarns can help to support the 3D structure and create space between the conductive yarns of the upper and lower surface layers. With the proposed structure, two parallel electrode plates made of conductive yarn can be separated by the spacer fabric to form the compressible dielectric layer (Figure 2). When the fabric being compressed, the capacitance between the upper and lower conductive layers would change. By identifying the relationship between the capacitance variation and the pressure applied (Figure 3), the fabric can be used as a pressure sensor.

By using different filament yarns in the connective structure, the fabric stiffness and thickness would change and hence capacitance. This allow the range of pressure sensing of the textiles can be adjusted through the use of a suitable monofilament yarn.

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5. Academic journal(s) publishing the work:

Journal: Mechanics of Advanced Materials and Structures

Title of article: Development of knitted capacitive pressure sensor with spacer fabric structure

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6. Explanation of Terminology:

(Note 1) Spacer fabric – A kind of knitted fabric that consists of two surface layers connected by a layer of pile yarns. It is good to provide cushioning and commonly found in car seats, backpack, beddings and paddings.
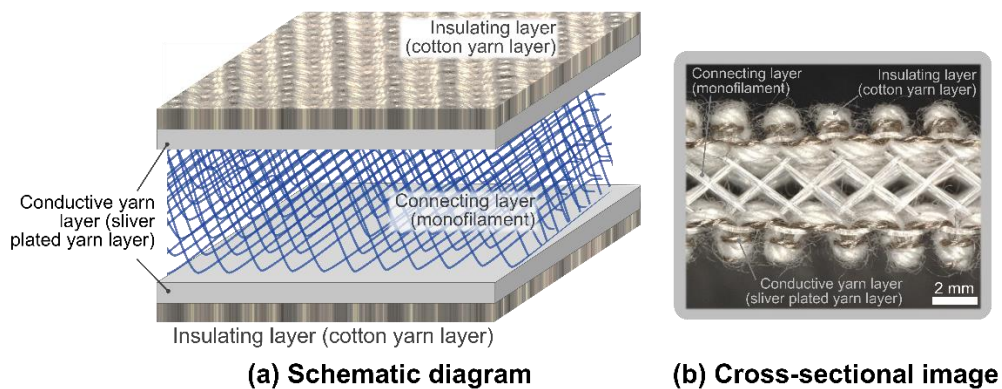
7. Attachments:

(a) Schematic diagram　　**(b) Cross-sectional image**

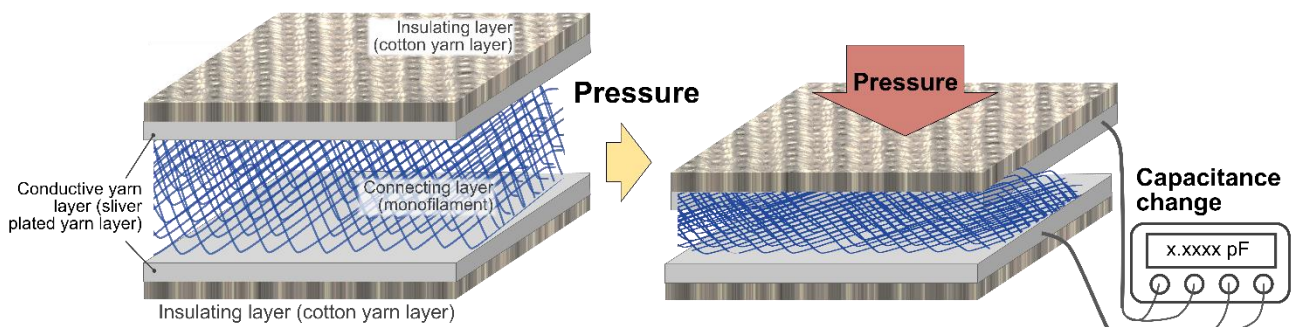**Figure 1**. Five-layer structure of the textiles pressure sensor

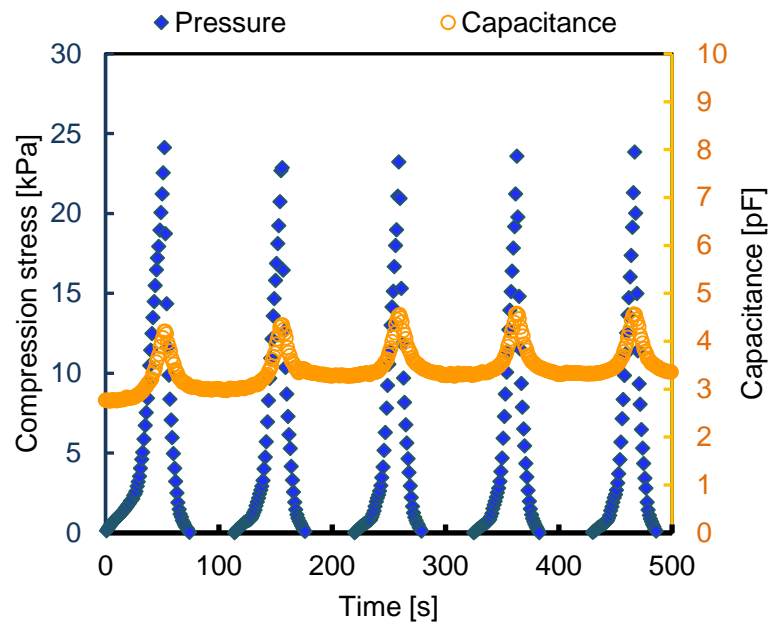**Figure 2**. Fabric is compressed to change the capacitance to use for pressure detection

Figure 3. Relationship between pressure and capacitance