Extended abstract

Polyl-L-lactic acid (PLLA) exhibits piezoelectricity, which is the ability of certain dielectric materials to generate an electric displacement in response to mechanical stress [1,2]. We have developed a piezoelectric PLLA fabric for sensing applied stress and strain using piezoelectric PLLA fibers, and tailored smart clothing having the function of sensing complex human motion using the piezoelectric PLLA fabric. Note that PLLA exhibits only shear piezoelectricity [1,2]. Therefore, a piezoelectric signal from a PLLA fiber cannot be observed when the fiber is stretched. On the other hand, we have reported that bending a PLLA fiber while fixing one of its ends generates a piezoelectric signal from the fiber [3,4]. On this basis, to capture the displacement of a PLLA fiber in a weave owing to its piezoelectricity, the existence of a fixed point during the bending motion of the PLLA fiber is required. To realize a piezoelectric PLLA fabric that enables the sensing of human motion, the motion of a single PLLA fiber in three primary fabrics with plain, twill, and satin weaves was analyzed by the finite element method (FEM). As a result, we found that when the plain weave was bent, the PLLA fiber in the plain weave was bent by almost the same amount as the PLLA fiber with one end fixed. In other words, in this case, a piezoelectric signal is generated by a PLLA fiber in the plain weave. In the case of a twill weave, when the weave was twisted, the PLLA fiber in the twill weave was bent effectively as if one of...
its ends were fixed, and a piezoelectric signal was generated. In the case of the satin weave, when the weave expanded and contracted, the PLLA fiber in the satin weave was also bent effectively as if one of its ends were fixed. Also, when the satin weave was twisted by a large amount, the PLLA fiber was similarly bent. On the basis of the simulation results, three piezoelectric PLLA fabrics with plain, twill, and satin weaves were produced by Teijin Limited, Japan, a joint research company, as shown in Fig. 1.

To demonstrate the sensing of human motion using piezoelectric PLLA fabrics, we developed a prototype system that allows human movement, detected through the motion sensing of smart clothing obtained by sewing together pieces of piezoelectric PLLA fabric, to be linked with that of a humanoid robot, as shown in Fig. 2. The piezoelectric response signal generated by the movement of the subject’s arm was processed by an analog signal-processing unit and amplifier and filter circuits. Then, the processed signal was sent to the circuit system controlling the arm motion of the android robot through a wireless local area network (LAN) communication system. That is, the human arm motion could be instantaneously linked to the motion of the robot arm. Through the prototype system in Fig. 2, simple procedures such as bending of the arms and twisting of the wrists were replicated by the humanoid robot but not complex movements of the arms.

**Figure 2.** Prototype system linking motion of a human arm to that of a humanoid robot using the piezoelectric PLLA fabric sensing system through a wireless communication system.
We are currently developing a new version of the smart piezoelectric fabric to improve the reproducibility of measurement accuracy and realize easy-to-wear and comfortable clothing by modifying the structure and materials of the electrodes in the piezoelectric PLLA fabric. Furthermore, using the new version of the smart piezoelectric fabric, we will attempt to realize smart clothing that can sense the complicated motion of the upper half of the human body, as shown in Fig. 3.

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Figure 3. New version of smart piezoelectric clothing under development using piezoelectric PLLA fabric.

References

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