News From Japan

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Development of a Braided Piezoelectric Cord for Wearable Sensors

Modern society is supported by various technologies such as AI (artificial intelligence), IoT (internet of things), 5G (fifth generation technology standard for cellular networks), etc. Indispensable key components within these technologies are, of course sensors that detect and monitor various physical, chemical, and biological parameters. To monitor mechanical movements, such as vibration and bending, piezoelectric materials can effectively be used. Piezoelectricity is a phenomenon that is observed in a certain kind of dielectric materials and many academic papers in scientific conferences and journals have been devoted to this phenomenon, including publications of IEEE DEI Society [1, 2].

Piezoelectricity appears in both inorganic and organic dielectrics. Lead zirconate titanate (PZT) and polyvinylidene fluoride (PVDF) are respective typical examples. Compared to inorganic piezoelectric ceramics, organic piezoelectric polymers have several advantages, including light weight, thickness, and flexibility. Thanks to these advantages, several piezoelectric polymers have been used for many years in various applications, for example as ultrasonic devices and microphones. Although the usage of piezoelectric devices makes a strong point for polymers, it is still within the scope of conventional ways of applications of piezoelectricity. Prof. Yoshiro Tajitsu (Figure 1) of Kansai University in Japan has, over the recent years, developed new innovative piezoelectric polymers and proposed emerging ways of using them for generating large piezoelectric signals. This short article introduces Prof. Tajitsu and his above-mentioned achievements.

Yoshiro Tajitsu obtained a Ph.D. degree from Waseda University in 1978 for his experimental and analytical research on dielectric relaxation of insulating polymers. Afterwards he worked at Yamagata University and then moved to Kansai University in 2004. At that time, his research interests concentrated on practically useful properties of functional polymers. Typical examples are the optical chirality of polymers, such as poly-L-lactic acid (PLLA), and the use of this effect for light modulation [3]. By deepening his knowledge on molecular structures and, associated with it, the physico-chemical properties of various polymers, he has expanded his research topics to various fields that are important for industrial applications and to our daily lives. One example is his research on biodegradable polymers as insulating materials. Tajitsu was awarded the IEEE James Melcher Prize Paper Award by the Electrostatic Process Committee of the Industrial Applications Society, as shown in

Figure 1. Prof. Yoshiro Tajitsu.

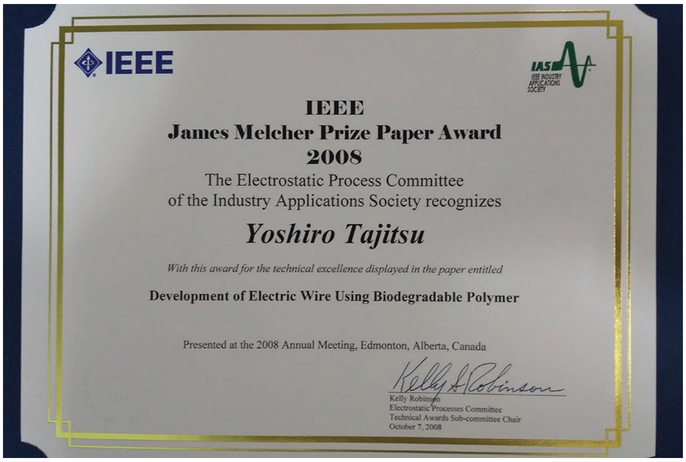

Figure 2. Tajitsu was awarded IEEE J. Melcher Prize Paper Award.

(a) (b) (c)

Figure 3. Three typical decorative knots of Japanese kumihimo (= braided cord); Kicchyo (a), Kame (b), and Awaji (c) knots.

Figure 2, for the development of electric wire using biodegradable polymer.

He also attempted to develop new methods for widening the applications of polymeric piezoelectric materials. Kansai University is located in a suburban area of Osaka, the second largest megalopolis next to Tokyo, which is only about 40 km (25 miles) from Kyoto. As is well known, Kyoto is rich in traditional culture and one among its cultural heritages is "kumihimo" or braided cords. There are several methods for braiding cords, typically with three different decorative knots, as shown in Figure 3. Tajitsu adopted this idea for developing PLLA piezoelectric braided cord, which is known to exhibit high anisotropy of its piezoelectricity as a function of the direction of mechanical stress applied to it. Normally PLLA fiber does not show any piezoelectricity when it is stretched. However, when the fiber is bent, it induces a strong piezoelectric signal.

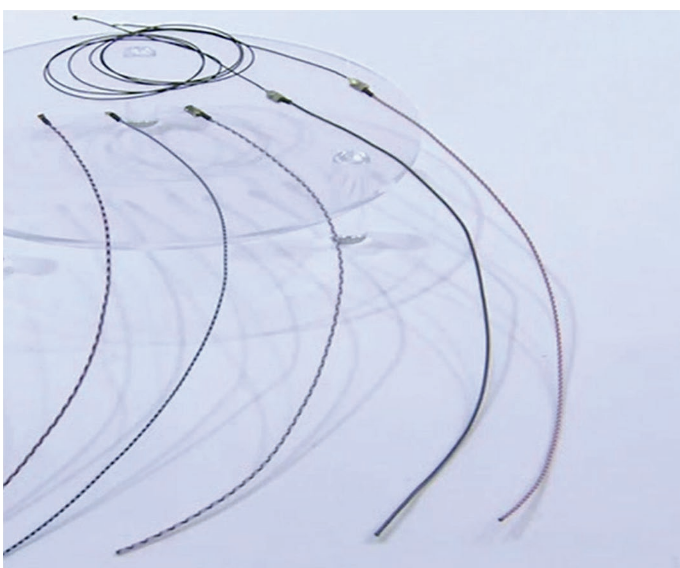

Figure 4. Braided piezoelectric PLLA cords.

Detail of the following description was already published in our society's Transactions on Dielectrics and Electric Insulation in 2018 [4]. Therefore, we introduce here only a brief outline. Figure 4 shows a piezoelectric PLLA braided cord developed by Tajitsu with the assistance of Teijin Co. Ltd. It consists of PLLA fiber yarn, conducting fiber yarn as a winding core and as an outer conductor, and poly(ethylene terephthalate) yarn as shown in Figure 5. Then, a traditional braid artist weaved three chokers made of the piezoelectric PLLA braided cord, each with a different decorative knot, as shown in Figure 6. A lady wrapped the choker around her neck and Tajitsu measured the piezoelectric signals of the wearer when breathing. As shown in Figure 7, the three knots produce clearly different signals. He found that the shape of the signal acquired by the Kicchyo knot corresponds well with the standard shape of an electrocardiogram when a human is breathing. The piezoelectric signals induced by the chokers are different between the occasions of coughing and swallowing by the wearer. This means that the PLLA piezoelectric cord can be used as a wearable sensor of a

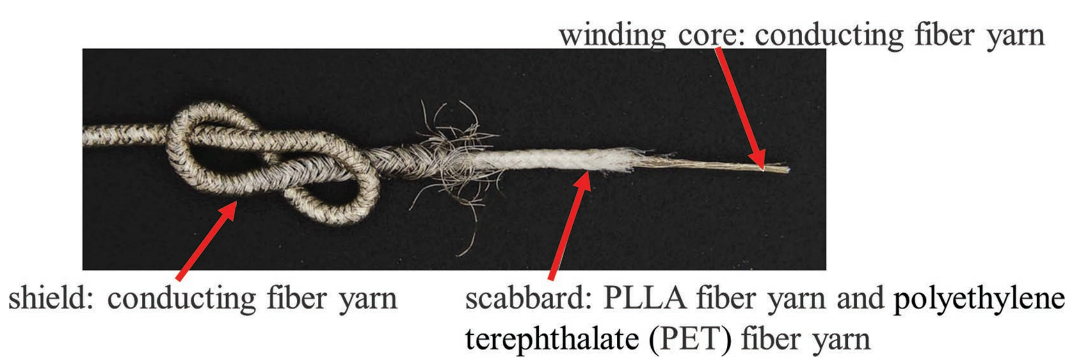

Figure 5. Inside of the braided piezoelectric PLLA cord.

(a) (b) (c)

Figure 6. Piezoelectric chokers with different decorative knots. (a) Kicchyo, (b) Kame, and (c) Awaji.

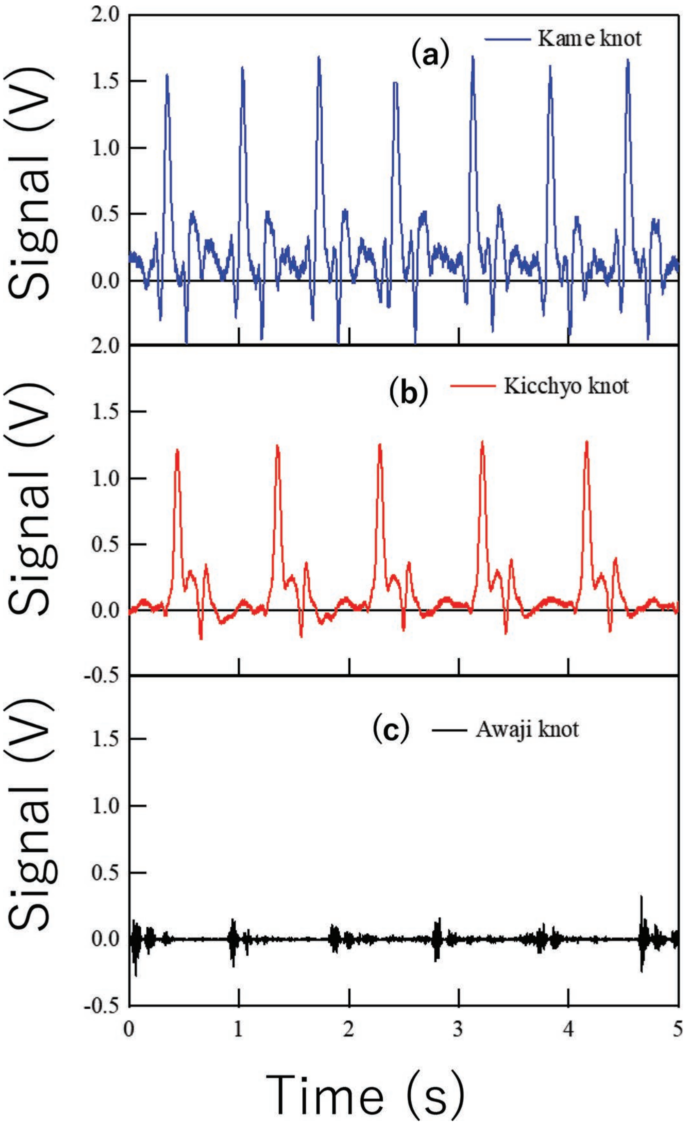

Figure 7. Piezoelectric signals induced by the breathing of the wearer when she wrapped the three chokers with different decorative knots; (a) Kame, (b) Kicchyo, and (c) Awaji [4].

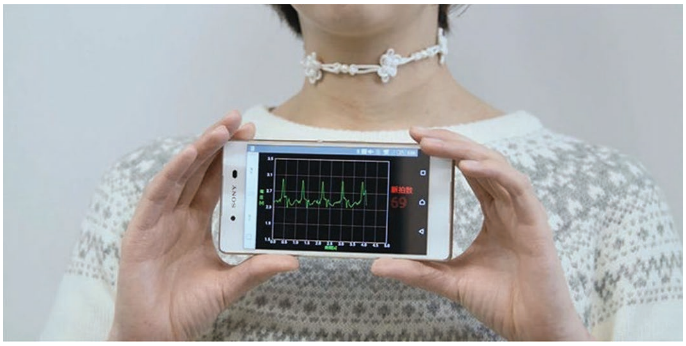

Figure 8. Health monitor using the wearable PLLA piezoelectric cord as a remote sensor.

telemetric health monitor as shown in Figure 8. If we wrap the piezoelectric PLLA braided cord around the waist or wrist, it can be used as a wearable switch or controller of various devices, such as a smartphone [5]. In addition, if the cord or similarly woven piezoelectric cloth is put underneath a floor mat, we can harvest electricity when walking on it [6].

This article was completed in cooperation with Professor Yoshiro Tajitsu of Kansai University.

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