Textile inductive energy converter based on 3D-spacer fabric

Increasing functional integration into textile products leads to new applications and textile developments called “Smart Textiles”. In particular, there is a growing demand for mobile power supplies [1] in the areas of communication, sports and leisure, occupational health and safety, and personal health care, as well as medical technology (e.g. sensors for vital signs monitoring). As a result of miniaturization the use of mobile electronic devices continually increases.

Components of Smart Textile systems

Fig. 1 shows general components of “Smart Textile” systems. The only chance to realize maximum comfort, tactile quality and minimal manufacturing cost, is to design additional components (such as sensors etc.) as complete textile solutions. In addition to ecological reasons, a self-powered textile-integrated energy converting system is necessary to substitute for foreign battery systems. Energy can be harvested from different energy sources such as kinetic energy, thermal energy, pressure fluctuations etc., to obtain the required energy [1].

Previously known products such as shoes use piezoelectric crystals or reverse electrowetting [3] for energy transformation. These approaches, however, are limited to the integration in shoe soles. Furthermore, additional energy conversion elements and additional manufacturing processes (e.g. integration of the piezoelectric crystals) are required. Other known approaches include embroidery of electrical conductors [4-6] or incorporation of piezoelectric yarns [7, 8].

Inductive energy converter based on 3D-spacer fabric

While running, arms, legs and feet carry out oscillating motions. The yellow lines on the feet, legs and arms visualize the movement (Fig. 2). The blue 2-sided arrows indicate the oscillation. If this oscillating movement is transferred to a magnet inside a coil, an AC voltage is induced. The amount of induced voltage depends essentially on the number of turns of the coil and the rate of change in magnetic flux density [9]. The alternation of the magnetic field change is caused by the step frequency. Moreover, the induced voltage depends on the magnetic flux density as well as on the size of the area in the normal direction of the magnetic field.

The Institute of Textile Technology at RWTH Aachen University (ITA), Aachen/Germany, has developed a manufacturing process of an inductive energy converter which is automatically integrated within a 3D-spacer fabric without the need of any additional processing steps (Fig. 3).

The basis of the energy-converting textile is a conventional textile spacer fabric with a homogeneous distribution of pile threads. The pressure behavior can be customized by pile thread material, pile thread density and pile thread angle to cover surfaces [10]. The surfaces of the 3D spacer fabric may have closed or open pores. Thus, the haptic as well as the heat and fluid transport properties of the fabric can be adjusted. Due to the omission of pile yarns, recesses are introduced which serve as a cavity for the magnetic material. By a partial weft, an electrical conductor is integrated at the lower surface and connected to the upper surface around the recess. Another partial weft follows in the upper surface. The connection to the lower area completes a round (Fig. 3 top right). By repeating the cycles at a superimposed linear production speed, the rounds form a coil around the recess. In principle this “textile coil” can be manufactured by the equipment normally used for the production of conventional spacer fabrics. However, by adjusting the parameters of the process quality and production speed may be optimized.

The integration of a cylindrical magnet in-
produces a voltage. Due to a redundant arrangement of several inductive energy converters the energy yield can be increased.

**Resulting strategy**

With respect to the components of a smart-textile-system shown in Fig. 1, the inductive energy converter can be part of the resulting strategy, which is shown in Fig. 4. Due to the converted alternating voltage a rectifier is needed. For energy storage, fully integrated textile solutions are the object of research [11]. Alternatively, the use of conventional capacitors is possible. For connection e.g. silver-coated textile yarns can be employed. Due to the use of functional fibers as capacitors a completely integrated textile solution is feasible.

The table gives an overview of typical magnitude of power demand of various mobile electronic devices.

In particular, energy consumption of medical devices and sensors is small in comparison to the energy need of other devices.

The resulting strategy can be integrated in footwear, arm pockets, shirts or pants. However, further studies are required for a better understanding of the orientation and positioning of the presented inductive energy converter.

**Conclusions**

At the ITA a concept for automated manufacturing of an energy-converting textile based on a 3D-spacer fabric has been developed and validated. The inductive energy converter consists of a textile coil, which is integrated in a spacer fabric. A magnet converts the kinetic energy of oscillating movements during running into an electric energy. The first "textile coil" was produced with a silver-plated polyamide yarn. Possible fields of usage of such an energy converter are the integration in shoes, shirts or pants or in pockets (e.g. cell phone or MP3 pouches). Due to the fully automated manufacturing process, the textile inductive energy converter is suitable for a large scale series production.

**References**
