Narrative Report

1. **PRF#:**56840-DNI-7
2. **Project Title:** Electrically Responsive and Locally Programmable Hydrogel Composites
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Report Period: 2017/09/01 – 2018/08/31

The main goals of this grant are to design and synthesize a novel type of hydrogel composite which is electrically responsive and locally programmable, and to study its mechanical properties, electrical responsiveness and local actuation abilities.

During the first year (**2016/09/01 – 2017/08/31**) of the project, we have 1) synthesized thermal responsive hydrogel of Poly(N-isopropylacrylamide) (PNIPAM), 2) designed and fabricated compliant ultra-thin heaters in open mesh format, 3) successfully integrated the ultra-thin heaters with the PNIPAM hydrogel; and 4) investigated the interfaces between hydrogel and mesh heaters.

During the second year (**2017/09/01 – 2018/08/31**), we have 1) studied the material interfaces between the hydrogel and thin open mesh electronics with polyimide encapsulation, 2) designed a new hydrogel with significantly improved mechanical toughness while holding thermal responsiveness based on double cross-linked PNIPAM hydrogel as the previous hydrogel is very brittle thus fragile, 3) integrated mesh electronics with such hydrogel, 4) deformed the hydrogel/electronics composite and investigated coupled mechanical and thermal stimulations and local actuation properties, and 5) extend the composite material design strategy to other electrically programmable material systems.

Those progresses have allowed us to successfully testify our hypotheses of this project that 1) the electronic mesh is able to be embedded into hydrogel and concurrently deform with it, 2) the embedded electronic mesh has minimum or negligible constraint on the expansion and shrinkage of the hydrogel, 3) the tensile modulus of the electrically responsive hydrogel composite are almost the same as that of the thermal responsive PNIPAM hydrogel, 4) the hydrogel composite is able to actuate locally through the rational design of the electronic mesh and also the hydrogel, and 5) the material design strategy is applicable to other material systems, such as liquid crystal elastomers.

While achieving the novel electrically responsive and locally programmable hydrogel composite, we also developed locally programmable thermal responsive liquid crystal elastomers using a similar approach. Such hybridized liquid crystal elastomer with deformable sensing and actuating electronic network has allowed us to develop a novel fully soft robot that can perform inchworm-like locomotion. The research results have been selected as a cover story on the journal of *Advanced Materials* (Fig. 1), and this work has been reported by many news outlets.

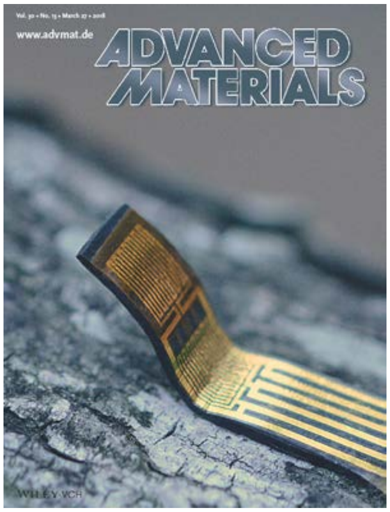

Figure 1. Cover of Advanced Materials in March 2018, Issue 13.