Highly deformable piezoelectric nanotruss for tactile electronics

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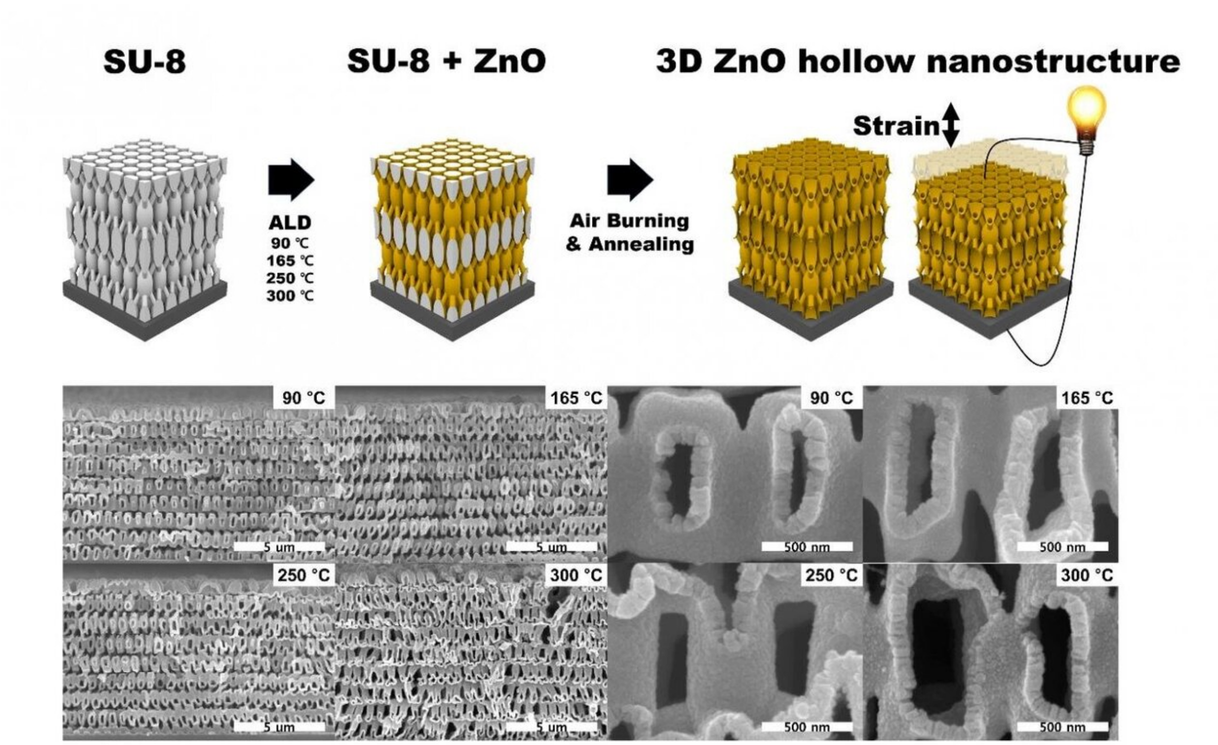

Conceptual schematics and SEM images of 3D ZnO hollow nanostructure deposited at 90, 165, 250, and 300 ℃ after removal of the epoxy template. Credit: KAIST

With the importance of non-contact environments growing due to COVID-19, tactile electronic devices using haptic technology are gaining traction as new mediums of communication.

Haptic technology is being applied in a wide array of fields such as robotics or interactive displays. Haptic gloves are being used for augmented information communication technology. Efficient piezoelectric materials that can convert various mechanical stimuli into electrical signals and vice versa are a prerequisite for advancing high-performing haptic technology.

A research team led by Professor Seungbum Hong confirmed the potential of tactile devices by developing ceramic piezoelectric materials that are three times more deformable. For the fabrication of highly deformable nanomaterials, the research team built a zinc oxide hollow nanostructure using proximity field nanopatterning and atomic layered deposition. The piezoelectric coefficient was measured to be approximately 9.2 pm/V and the nanopillar compression test showed an elastic strain limit of approximately 10%, which is more than three times greater than that of the bulk zinc oxide one.

Piezoelectric ceramics have a high piezoelectric coefficient with a low elastic strain limit, whereas the opposite is true for piezoelectric polymers. Therefore, it has been very challenging to obtain good performance in both high piezoelectric coefficients as well as high elastic strain limits. To break the elastic limit of piezoelectric ceramics, the research team introduced a 3-D truss-like hollow nanostructure with nanometer-scale thin walls.

According to the Griffith criterion, the fracture strength of a material is inversely proportional to the square root of the preexisting flaw size. However, a large flaw is less likely to occur in a small structure, which, in turn, enhances the strength of the material. Therefore, implementing the form of a 3-D truss-like hollow nanostructure with nanometer-scale thin walls can extend the elastic limit of the material. Furthermore, a monolithic 3-D structure can withstand large strains in all directions while simultaneously preventing the loss from the bottleneck. Previously, the fracture property of piezoelectric ceramic materials was difficult to control, owing to the large variance in crack sizes. However, the research team structurally limited the crack sizes to manage the fracture properties.

Professor Hong's results demonstrate the potential for the development of highly deformable ceramic piezoelectric materials by improving the elastic limit using a 3-D hollow nanostructure. Since zinc oxide has a relatively low piezoelectric coefficient compared to other piezoelectric ceramic materials, applying the proposed structure to such components promised better results in terms of the piezoelectric activity.

"With the advent of the non-contact era, the importance of emotional communication is increasing. Through the development of novel tactile interaction technologies, in addition to the current visual and auditory communication, mankind will enter a new era where they can communicate with anyone using all five senses regardless of location as if they are with them in person," Professor Hong said.

"While additional research must be conducted to realize the application of the proposed designs for haptic enhancement devices, this study holds high value in that it resolves one of the most challenging issues in the use of piezoelectric ceramics, specifically opening new possibilities for their application by overcoming their mechanical constraints.

More information: Hoon Kim et al, Breaking the elastic limit of piezoelectric ceramics using nanostructures: A case study using ZnO, *Nano Energy* (2020). DOI: 10.1016/j.nanoen.2020.105259

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