Ergen et al., J Biotechnol Biomater 2022, 12:4

Journal of Biotechnology & Biomaterials

Letter to Editor Open Access

Wearable Sensors Based on Aerogel for Human Motion Tracking

Onur Ergen[1,2,3]*, Ecem Celik[1,2,3] and Ahmet Hamdi Unal[1]

[1]*Department of Electrical and Electronics Engineering, Koc University , Sarıyer, Istanbul, 34450, Turkey*
[2]*Graduate School of Science and Technology, Koc University, Sarıyer, Istanbul, 34450, Turkey*
[3]*Surface Science and Technology Center, Koc University, Sarıyer, Istanbul, 34450, Turkey*

Letter to Editor

Wearable bioelectronics systems are one the most important tools for human health and motion monitoring. However, there is still a great challenge to fabricate high-performance flexible devices with a conformal integration of the human body. We recently developed a new method to build aerogel based strain sensors that can effectively extract information from involuntary human motion due its gradient functionalities. These sensors provide good mechanical integrity and allow high density power generation during subtle human motion.

The design and development of wearable bioelectronics devices, for measuring and quantifying physiological human motions, have always been very attractive to researchers and gaining tremendous attention in recent years. This wearable technology is now paving the path towards personalized preventative healthcare (PPH) and provides a significant opportunity to extract direct information from simple human motion, which promotes early diagnosis, health monitoring, and personalized treatment [1-4]. Signals generated by the human body can be classified into two categories; voluntary and involuntary. Voluntary motions work according to one's desire or under control, such as joint flexion movements, whereas involuntary motion, such as respiratory, alimentary, or muscle activation, work reflexively. Today's technological advancements, such as big data analytics, artificial intelligence, the internet of Things etc., makes continuous tracking of involuntary motion very crucial. Thus, it can explore the possible underlying mechanism of many diseases, which can assist with future diagnosis and treatment. Therefore, numerous efforts have been made to develop wearable devices through the use of nanomaterial's, including nanowires, carbon nanotubes, 2D materials , etc. In particular, grapheme has been extensively studied for wearable applications due to its exciting electrical and mechanical properties. Especially, the development of 3D graphene based sensor architectures, such as conductive foam, nano-papers, etc.[18-21] However, all geometries still struggle with inadequate fit with the human body, conformal integration, and sensitivity.

Here, we demonstrate a new method to build aerogel based strain sensors that can effectively extract information from involuntary human motion. Graphene aerogels (GA) were uniquely reinforced with carbon nanotubes (CNTs) to generate 3D hybrid frameworks. These frameworks provide stretchable characteristics, that the conductive pathways can be maintained under high strain or stress conditions. Maintaining the conductive pathways is very important to produce reliable information and it is one of the challenging problems for strain sensor designs. However, GA and CNTs mixture provides an excellent framework for reliable data gathering and also their material functionalization properties provide great opportunity to produce highly sensitivity sensors. In this work, a strain sensor was prepared from highly functionalized GA and CNTs by reconstruction and dispersing technique, which is simple, low cost, and scalable. PDMS @ silk composites were also embedded in GA/CNTs to achieve piezoelectric properties and produce a sensor that can be directly applied to the surface of the skin, while exhibiting high stretch ability and sensitivity to subtle body motions.

The fabrication process of the strain sensor is illustrated in. GA is synthesized using precursors of grapheme oxide, which is cross-linked via organic sol-gel chemistry, followed by super critical dying and carbonization, which is achieved through pyrolysis at 1050 ˚C under nitrogen, as previously reported by Resulted aerogel is then reconstructed; first it is grinded down by using a vibrational ball while loading it with functionalized carbon nanotubes. Then, the solution is vacuum filtered and annealed at 600˚C. As a result, CNTs produced a conformal coating on the surface of the aerogel with a pyramid shape). The selective grinding and reconstruction is very necessary to form good GA/CNTs interfaces, which is a very critical step to have a sensitive strain sensor that can respond to even the most subtle environmental disturbances, almost with a hair and skin relation.

Electrical conductivities of GA/CNT hybrid structure. It is well known in the literature that increasing GA concentration significantly increases polymer electrical conductivity by more than 10 orders of magnitude. Similar a conductivity improvement trend can clearly be seen when CNT content is added. CNT loading can result in more than 1.5 orders of magnitude improvement, however, further increase in CNT content beyond 0.44 wt % results in saturation and beyond 0.55 wt. % results in CNT fractures and breakage, thus conductivity slightly degrades, which is also in line with the literature.

The resistance change, $\Delta R/R_0$ as a function of the applied strain under quasi-static loading was investigated. The relative change in resistance linearly increases with the applied strain up to failure. The gauge factor $\Delta R/(\varepsilon R_0)$ is the highest for the reconstructed GA/CNTs nanocomposite structure, which strongly indicates that sensitivity of the sensor is directly related to how the nanocomposite is prepared. Gauge factor versus CNT loading of reconstructed GA/CNTs exhibits a peak value of 94 with CNT concentration of 0.4 wt %. The stress-strain curves of GA/CNTs also show clear dependence on GA/CNT nanocomposite preparation and CNT loading. The reconstructed GA/CNTs exhibit higher modulus, good elongation, and strength. Also, beyond 0.44 wt % the crack propagation becomes predominant due to GA and CNT segregation, which is consistent with the above results. The resistance change time from 1%, 5%, and 10% is shown in, $\Delta R/R_0$ is rising with strain, as expected, and there are no irreversible resistance changes observed for reconstructed GA/CNTs. shows typical stress-strain curves of different GA architectures and different CNTs loadings

***Corresponding author:** Onur Ergen, Department of Electrical and Electronics Engineering, Koc University, Sarıyer, Istanbul, 34450, Turkey, E-mail: oerge@ku.edu.tr

Received: 13-Apr-2022, Manuscript No. jbtbm-22-60613; **Editor assigned:** 15-Apr-2022, Pre QC No. jbtbm-22-60613 (PQ); **Reviewed:** 20-Apr-2022, QC No. jbtbm-22-60613; **Revised:** 22-Apr-2022, Manuscript No. jbtbm-22-60613 (R); **Published:** 27-Apr-2022, DOI: 10.4172/2155-952X.1000269

Citation: Ergen O, Celik E, Unal AH (2022) Wearable Sensors Based on Aerogel for Human Motion Tracking. J Biotechnol Biomater, 12: 269.

of reconstructed GA/CNTs. It is very clear that reconstructed GA/CNTs exhibits higher modulus, elongation, and strength compared to other geometries. Also, the modulus of the reconstructed GA/CNTs increases by increasing CNT concentration; however, beyond 0.5 wt. % it starts to decrease due to GA and CNT segregation, which is also in line with the above results. Shows cyclic performance of reconstructed GA/CNTs, which exhibits linear characteristic at low strain values, then it plateaus and exhibits exponential changes, as described in the literature. It can also be clearly seen that when GA/CNTs are released, the curve almost return to its original position, which strongly indicates complete recovery. It is very clear that reconstructed GA/CNTs exhibit superior properties with minimum deformation, which implies its structural robustness.

We constructed some field tests using reconstructed GA/CNTs/PDMS@Silk, finger flexion, when the finger is flexed at angles 120 ^{0}, 130 ^{0}, and 140 ^{0}, GA/CNTs sensors produce signals with different intensities, basically, the larger the degree of flexion the larger the elongation. This indicates GA/CNTs sensors have great ability to detect and quantify the applied strain. Shows successful pulse detection from the wrist, sensor directly touches the skin and is attached by adhesive tape. The pulse movement is recorded as 78 beats per minute (bpm), which is within the normal resting heart rate of 70 and 100 bpm.

In summary, we demonstrated GA/CNTs based highly sensitive and robust strain sensors. The findings suggest that the concentration of CNT loading and GA reconstruction during fabrication plays a crucial role for tuning the sensor's sensitivity. Moreover, the synergy effect, between GA and CNTs, is also very critical to reach desirable electrical performance and gauge factor, especially during stretch and hold cycles. Proper CNT loading resulted in superior electrical conductivity, robustness, and stretch ability. Reconstructed GA/CNTs may provide insight into the potential future development of next generation wearable electronic devices for continuous human motion monitoring.

Acknowledgements

This research was supported in part by TUBITAK, which provided for the design of the experiment and electrical measurements; Surface Science and Technology Center at Koc University provided material and electrical characterization.

Conflict of interest

No.

References

1. Rogers JA, Somey T, Huang Y (2010) Materials and mechanics for stretchable electronics. Science, 327(5973): 1603-1607.
2. Wang Y, Wang L, Yang T (2014) Wearable and highly sensitive grapheme strain sensors for human motion monitoring. Adv Funct Mater 24(29): 4666-4670.
3. Segev-Bar M (2013) Flexible sensors based on nanoparticles. ACS Nano 7(10): 8366-8378.
4. Son D, Lee J, Qiao S (2014) Multifunctional wearable devices for diagnosis and therapy of movement disorders. Nat Nanotechnology 9(5): 397.