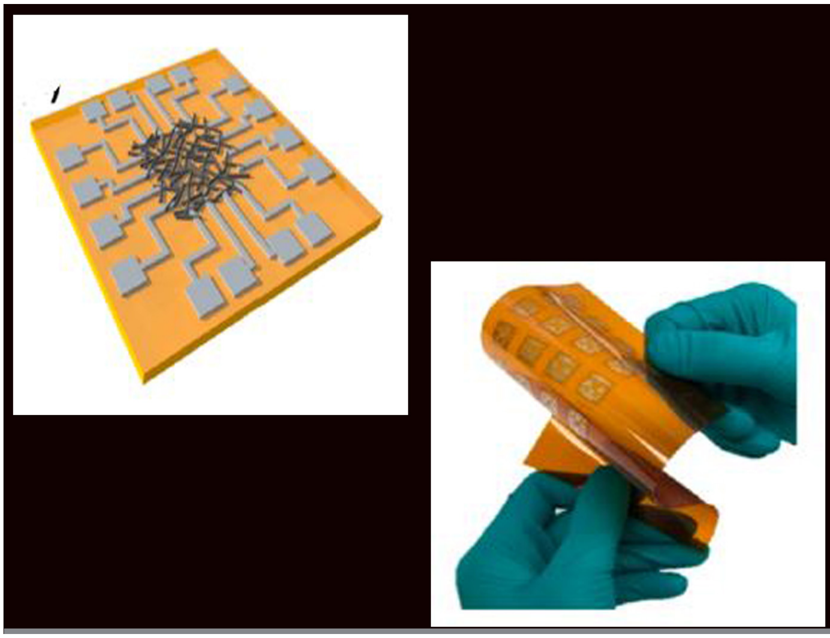


National Aeronautics and Space Administration

TECHNOLOGY SOLUTION

Electrical and Electronics

Highly secure all-printed Physically Unclonable Function (PUF) electronic device based on a nanomaterial network

Leveraging inherent variability in nanomaterial networks to create a simple, low-cost, durable, and easy to manufacture PUF for secure authentication

Assets are traditionally secured so important information can only be accessed when a key is placed in a lock (physical or electronic). Given the tremendous increase in the number of devices in the era of Internet of Things (IoT), direct access between things without human intervention is ideal. IoT related devices require unique identification codes that can be safely stored for security and that are resistant to physical attacks and exposure to harsh environments. As a solution, NASA Ames has developed a Physically Unclonable Function (PUF) electronic device using an all-printed nanomaterial network , such as a Carbon Nanotube (CNT) network. The invention leverages the intrinsic, random, and unique features of CNTs in a network for authentication, which can be used as a secret, stable, and robust key for high-level hardware security.

BENEFITS

- Low-cost fabrication
- Durable
- Easy to manufacture
- Stable, resistant to environmental impacts and tampering
- Includes a method of reading multiple resistances by placing multiple electrodes around a single CNT network
- Inter-device and intra-device (device-to-device) variability is harnessed here for the PUF application
- Flexible and printable electronics for portable or wearable devices will be networked to meet the IoT era demands
- Security key cannot be duplicated or identified without access to the secure device

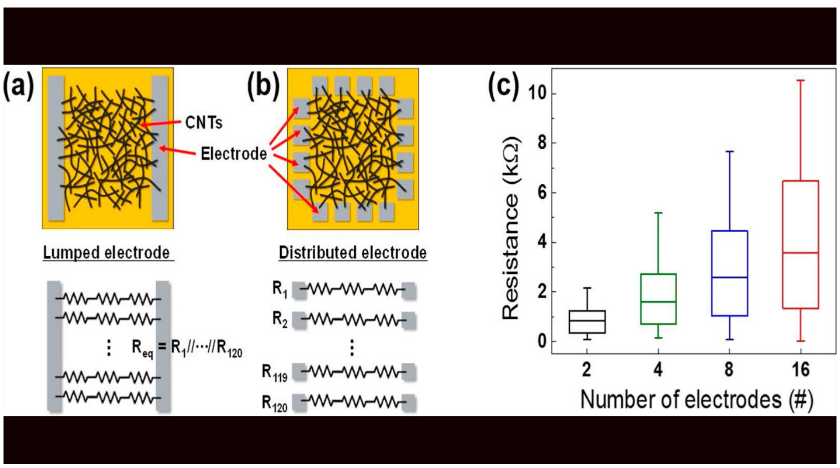
APPLICATIONS

The technology has several potential applications:

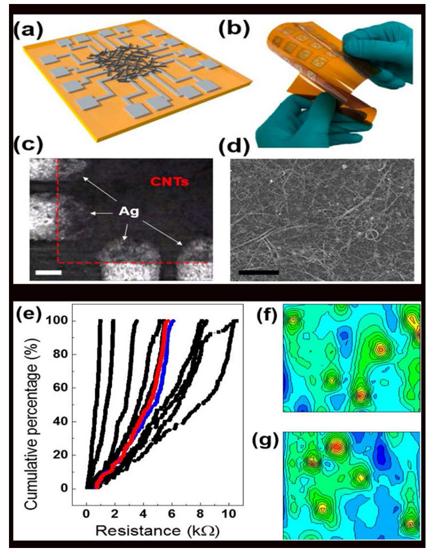
- Thin film transistors
- Energy storage devices
- Displays and sensors
- Portable or wearable devices
- Internet of Things (IoTs)

THE TECHNOLOGY

The technology is an all-printed Physically Unclonable Function (PUF) electronic device based on a nanomaterial (such as single-walled carbon nanotube) network. The network may be a mixture of semiconducting and metallic nanotubes randomly tangled with each other through the printing process. The all-printed PUF electronic device comprises a nanomaterial ink that is inkjet deposited, dried, and randomly tangled on a substrate, creating a network. A plurality of electrode pairs is attached to the substrate around the substrate perimeter. Each nanotube in the network can be a conduction path between electrode pairs, with the resistance values varying among individual pairs and between networks due to inherent inter-device and intra-device variability. The unique resistance distribution pattern for each network may be visualized using a contour map based on the electrode information, providing a PUF key that is a 2D pattern of analog values. The PUF security keys remain stable and maintain robustness against security attacks. Although local resistance change may occur inside the network (e.g., due to environmental impact), such change has little effect on the overall pattern. In addition, when a network-wide resistance change occurs, all resistances are affected together, so that the unique pattern is maintained.



Range of CNT resistances depending on the number of electrodes in a single network. (a) Conventional lumped electrode configuration. (b) Distributed electrode configuration. (c) Box plot with whiskers from minimum to maximum. The middle line of the box plot represents the median of the CNT resistances.



All-printed PUF based on a single CNT network (a) Schematic of the proposed PUF with one CNT network (black) and 16 electrodes (gray) on a flexible substrate (brown). The CNT network is located at the center of the chip, and the electrodes are arranged along the periphery of the CNT film. The contact pads connected to the electrodes are located at the edge of the chip for measurement. (b) Image of the fabricated devices on a polyimide substrate showing mechanical flexibility. (c) Microscope image of the CNT PUF showing the boundary between the silver (Ag) electrode and the CNT film. The scale bar is 200 micrometre. (d) Scanning electron microscope image of the inkjet printed CNTs showing a random network. The scale bar is 1 micrometre. (e) Cumulative percentage versus resistance from 11 different PUF devices. Each device has 120 resistance values, and the range and distribution of resistance vary widely. (f,g) Contour maps of the CNT PUFs having the red and blue data set in (e), respectively. The two devices have similar resistance distributions, but their contour maps show a different pattern due to the introduction of electrode information.

PUBLICATIONS

Patent No: 11,244,775

https://pubs.acs.org/doi/10.1021/acsaelm.9b00166

"Patent only, NO software available."

More Information

National Aeronautics and Space Administration

Agency Licensing Concierge

Ames Research Center

MS 202A-3
Moffett Field, CA 94035
202-358-7432
Agency-Patent-Licensing@mail.nasa.gov

www.nasa.gov

NP-2015-05-1898-HQ

technology.nasa.gov

NASA's Technology Transfer Program pursues the widest possible applications of agency technology to benefit US citizens. Through partnerships and licensing agreements with industry, the program ensures that NASA's investments in pioneering research find secondary uses that benefit the economy, create jobs, and improve quality of life.

ARC-18241-1, TOP2-317