Silk Fibroin Based Biocompatible, Flexible, and Biodegradable Microwave Devices for Wireless Communication and Stress Sensing

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Abstract

Flexible electronics, especially electronic skin, is deemed as a great promising tool that seamlessly connects humans with electrons in order to monitor human health, sharpen human perception of the external environment and even expend human senses1. However, the growing mismatch between traditional materials used in electronic skin and human applications is prompting the development of innovative biocompatible, skin attachable and biodegradable materials to fabricate electronic skin more suitable for the human body. Among all those alternative natural materials, silk fibroin, with its natural abundance, excellent biocompatibility, controllable biodegradability, appropriate mechanical features and comfortable attachment2, is a suitable substrate material electronic skin. Here, we made a silk fibroin based biocompatible biodegradable and ultra-flexible microwave device that exhibits good magnetic properties, sensitive microwave characteristics, and sensitive response to stress and strain. First, due to internal structure of silk fibroin, ultra-thin and flexible films based on B. mori silkworm cocoons was fabricated. In addition, nanoscale CoFeB metal layer was deposited on the silk fibroin film by magnetron sputtering, which shows well-established magnetic properties. Furthermore, we verified the microwave performance of the device by electron paramagnetic resonance (EPR) and broadband ferromagnetic resonance (FMR). Also, a great of FMR frequency shift was obtained during the bent test of flexible microwave device, under external mechanical tensile stress (R=5 mm), which provides sensitive stress-strain detection for microwave devices. This work provides new material possibilities for flexible microwave devices, further narrowing the distance between humans and electronic devices.

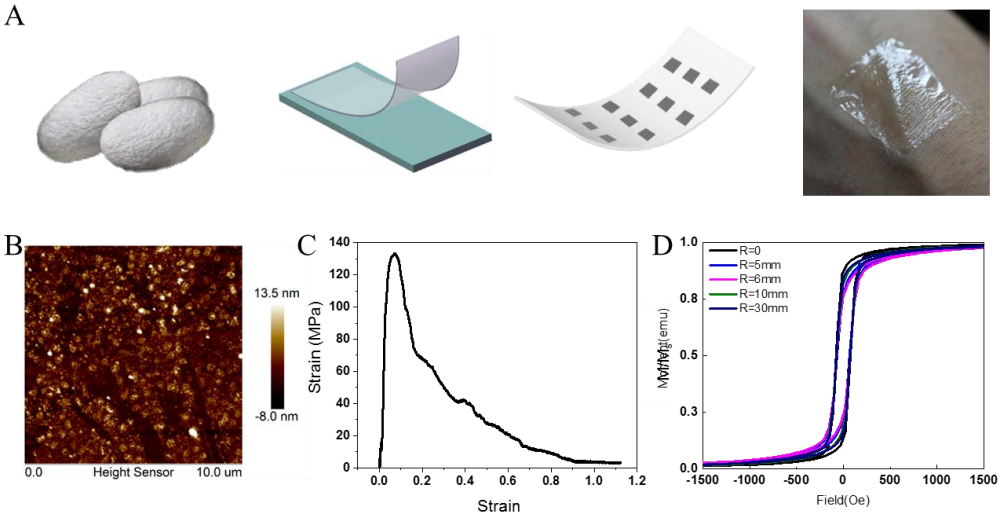

Figure 1. Schematic of silk fibroin based microwave device manufacturing process and basic characterization. A. the schematic of fabrication process for flexible silk film based microwave device. B. The AFM image for the surface of device, the surface roughness is around 10 nm. C. Stress-strain curve of the device. D. M-H loops along the in-plane direction under different bending radii.

1 Oh, J. Y. & Bao, Z. Second Skin Enabled by Advanced Electronics. *Advanced Science*, 1900186, doi:10.1002/advs.201900186 (2019).

2 Huang, W., Ling, S., Li, C., Omenetto, F. G. & Kaplan, D. L. Silkworm silk-based materials and devices generated using bio-nanotechnology. *Chem Soc Rev* **47**, 6486-6504, doi:10.1039/c8cs00187a (2018).