Reservoir computing enhancement in three-dimensional porous CNT-POM network

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[Introduction] Artificial neural networks (ANN) and artificial intelligence (AI) have been getting tremendous attention in recent years. Although there has been a significant development in such systems, they are limited by current transistor-based devices' computational powers and efficiency. As a result, researchers have been working on new approaches by performing computational tasks using nanomaterials and nanotechnology. Carbon nanotubes (CNTs) and polyoxometalates (POM) networks have been extensively studied and exhibited properties [1] that are ideal for performing reservoir computing (RC) benchmark tasks such as waveform generation and nonlinear autoregressive moving average (NARMA) [2]. The template technique has recently been getting much attention, though it is mostly investigated in sensor technology. The template technique is undoubtedly an underrated method, maybe due to the rapid expansion of research work that overwhelms almost anyone. Nonetheless, the template technique is an excellent method for fabricating a device that requires a specific topology for improved performance.

Herein we wish to present the prospect of using a three-dimensional (3D) porous structure that, due to its network topology, would allow us to fabricate devices with consistent arrangement and patterns that would ideally resolve the mentioned issues and improve the reservoir performance.

[Method] Single-walled carbon nanotubes (SWNTs) (1 mg) was dispersed in 10 mL of IPA via sonication for one hour. Simultaneously, 2 mg phosphomolybdic acid hydrate (PMo_{12}) was dissolved in 1 mL acetonitrile and added to SWNTs dispersion. The mixture was sonicated for 4 hours and then filtered using a 0.1 μm PTFE filter paper and dispersed in 10 mL IPA via sonication. Two 3D devices were prepared by cutting the melamine sponge into 0.5 × 0.5 × 1 cm pieces, immersing them in cellulose dispersion of 0.01 and 1 wt%, and sonicating for 1 minute. After drying in an oven at 50 °C, the porous 3D network was immersed in CNTs-POM dispersion and sonicated for 2 minutes before drying. The reservoir performance of devices was evaluated by waveform generation task and NARMA 2 task.

[Results and discussion] The I-V characterization of each device indicate semiconductive behavior in both samples. The observed nonlinearity is one of the main required properties in reservoir devices. The Lissajous plot that indicates the input-output relationship confirms the nonlinearity in the 3D CNT-POM network (Fig. 1a). The waveform generation and NARMA 2 benchmark tasks indicate that the sample containing more cellulose fiber performs better in the reservoir task. These results indicate that the reservoir performance was improved by increasing the porosity and subsequent topological recurrent network formation. Furthermore, we can conclude that the CNT-POM network's actual physical structure has the utmost importance in reservoir dynamics.

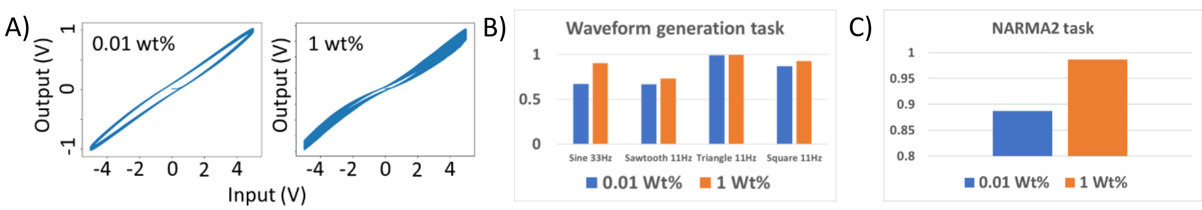

Figure 1. A) Lissajous plot; B) Waveform generation task (Input 11 Hz Sinusoidal wave; Target 33 Hz Sinusoidal wave and 11 Hz Sawtooth, Triangle and Square waves); C) NARMA 2 task

References

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