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Electronic Supplementary Information

Ultrafine-fiber thermistors for microscale biomonitoring

Tomohiko Nakajima* and Tetsuo Tsuchiya

Advanced Manufacturing Research Institute, National Institute of Advanced Industrial Science and Technology, Tsukuba Central 5, 1-1-1 Higashi, Tsukuba, Ibaraki 305-8565, Japan.

Preparation procedure

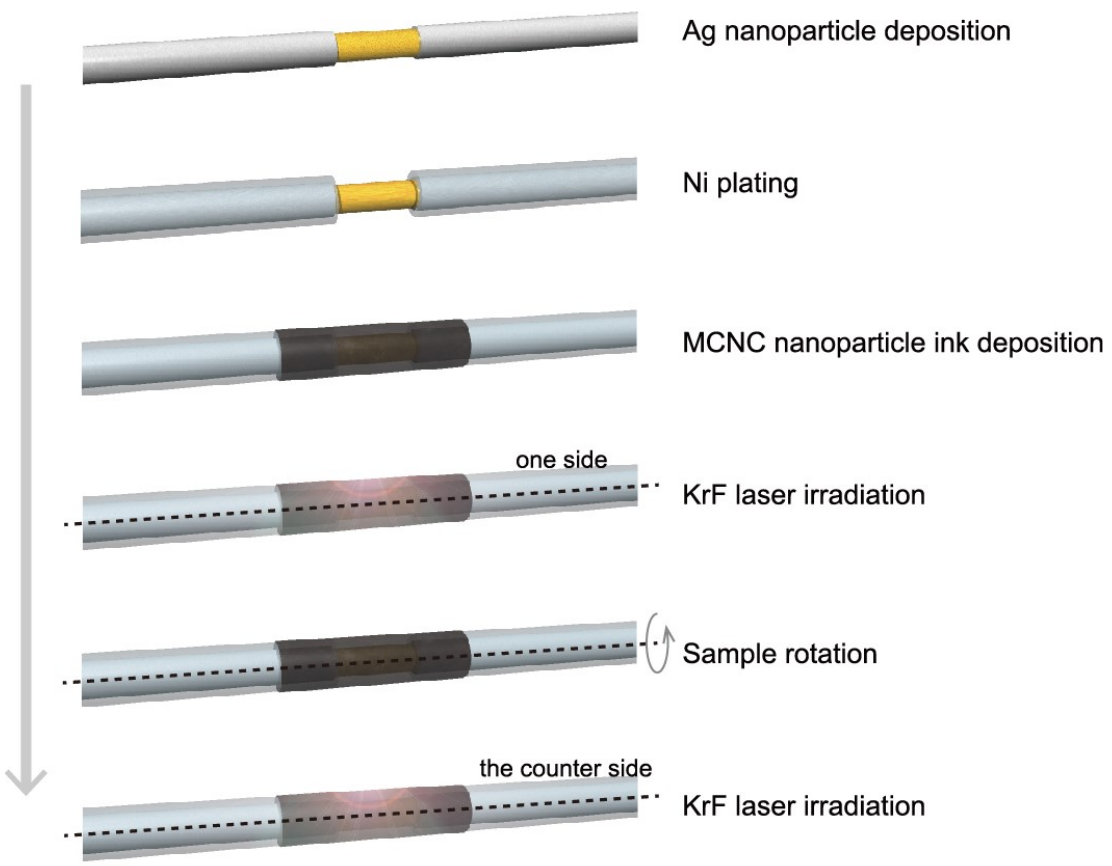

Fig. S1: Sample preparation procedure for the MCNC fiber thermistor.

Cu co-doping effect on the electrical resistivity

A resistivity comparison between MCN and MCNC is shown in Fig. S2. Both of film were prepared on polyimide sheet substrates by photocrystallization process. KrF laser irradiation conditions were two-step irradiation at 30 mJ·cm^{-2} for 300 pulses and 55 mJ·cm^{-2} for 300 pulses in air at room temperature. The MCN nanoparticle dispersion ink was prepared by same procedure with the previous work.[1]

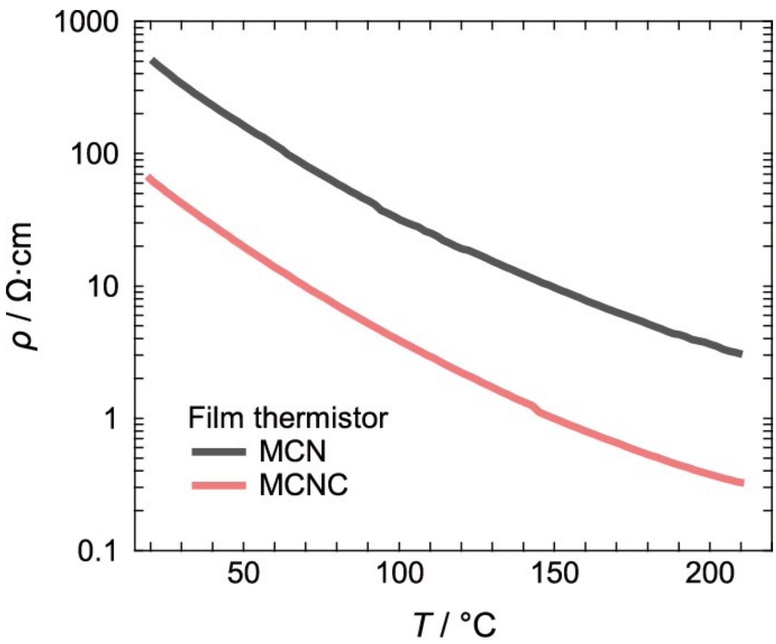

Fig. S2: Temperature variation of ρ in the MCN and MCNC sheet thermistors.

Simulations for temperature variation during pulsed laser irradiation

Temperature variations during laser irradiation were simulated by the heat diffusion equation simplified for two-dimensional heat flow:

$$\rho C\frac{\partial T}{\partial t} = \frac{\partial}{\partial x}\left(\kappa\frac{\partial T}{\partial x}\right) + \frac{\partial}{\partial z}\left(\kappa\frac{\partial T}{\partial z}\right) + q,$$

where T is the temperature at time t and depth z, ρ is the mass density, C is the specific-heat capacity, κ is the thermal conductivity, and q is the heat supply. To evaluate the heat diffusion under laser irradiation, we obtained the value of q provided by the pulsed-laser energy ($q = I(z,t)$) from the following:

$$I(z,t) = I_0(t) \cdot (1 - r) \cdot \exp(-\alpha z),$$

where R is the reflectance. In the calculation, the irradiated laser light is assumed to be absorbed at the MCNC film. We carried out numerical simulations for the temperature variation during irradiation by the excimer laser using a finite-difference approximation to the above equations. We used the finite-element analysis program ANSYS Mechanical 2020 R1 (ANSYS Inc.). The boundary conditions used were T = 25 °C at t = 0 s (the initial substrate temperature), T = 25 °C at the bottom of the substrate, and at the interfaces (adiabatic condition). The thermal and physical properties for the numerical simulations are listed in Table S1. The properties of Mn_3O_4 were partly used in place of MCNC.

Table S1 Thermal and physical properties for the numerical simulations.

Materials	α (cm^{-1})	R	κ (W cm^{-1}K^{-1})	ρ (g cm^{-3})	C (J g^{-1}K^{-1})
Polyimide	–	–	0.0012	1.42	1.1
Aramid	–	–	0.0014	1.39	1.088
MCNC	95800	0.191	0.057 [a]	4.856 [a]	0.624 [a]

[a] Mn_3O_4

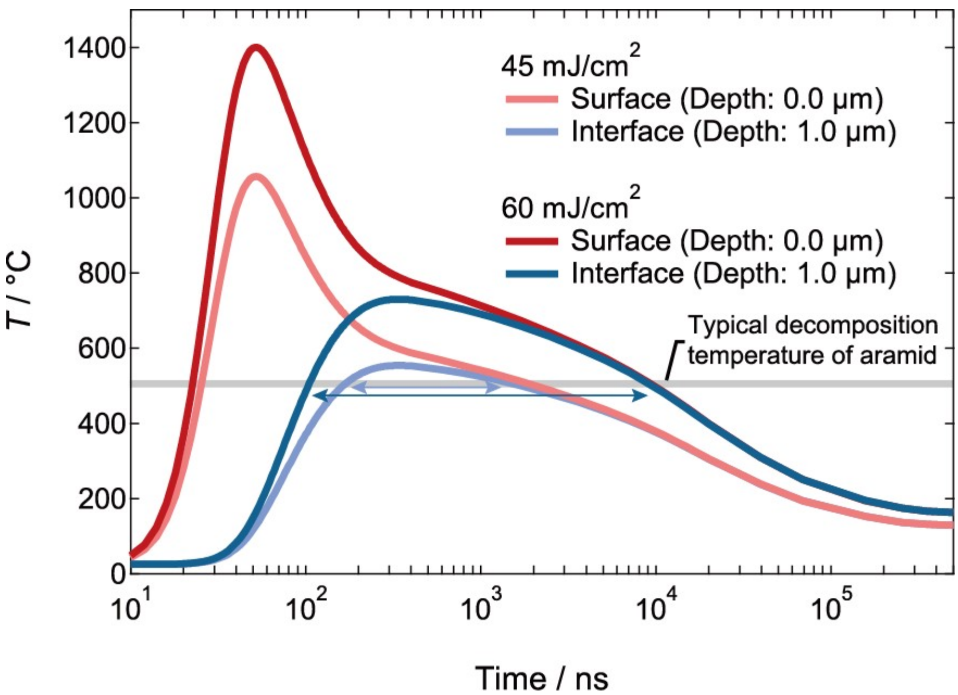

Fig. S3: Time variations of the temperature under laser irradiation at 45 and 60 mJ·cm^{-2} at the surface of the MCNC film and at the interface between the thermistor and the aramid fiber.

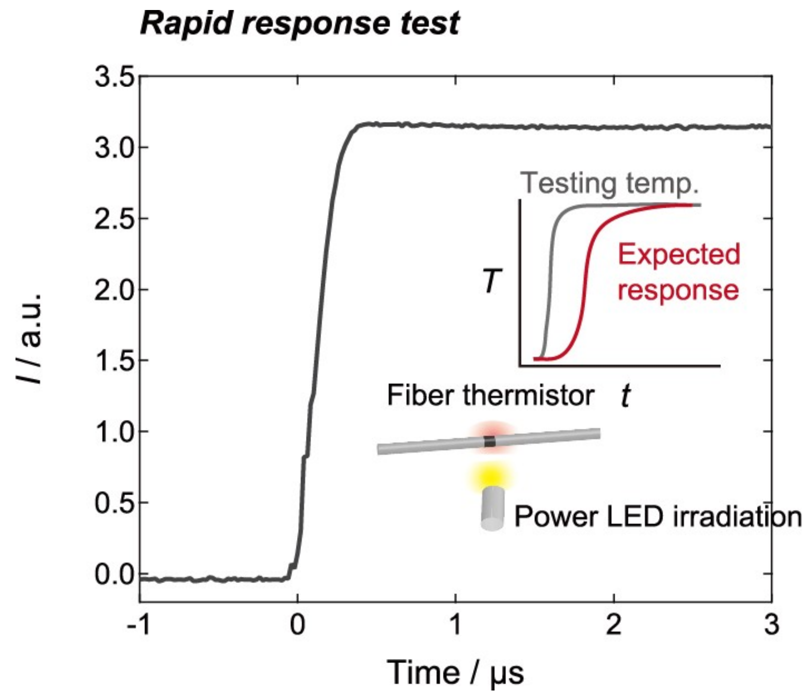

Fig. S4: Light intensity variation as a function of time at turning on the UV-LED, and schematic of temperature response test concepts.

Reference

1. T. Nakajima and T. Tsuchiya, *J. Mater. Chem. C*, 2015, 3, 3809–3816.