Ni-P, Cu and Ag Microcoils Prepared from Helical Structures in Plant Fibrovascular Bundles by Electroless Plating

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Microstructures responding to electromagnetic waves in a frequency region of GHz – THz have attracted much attention due to their potential applications in electronics devices. For example, Motojima et al. propose carbon microcoils for applications in electromagnetic wave absorbers to avoid radio interference.[1)] In theory, when an electroconductive microcoil is irradiated by an electromagnetic wave, induction current runs in the microcoil. As a result, the induction current is converted into heat by resistance. The carbon microcoils with 2 – 10 μm coil diameter and 0.1 – 3 mm coil length have been successfully fabricated by a chemical vapor deposition (CVD) method. Both of left- and right-handed carbon microcoils are mixed in a powder state.

In this study, we noticed that a plant fibrovascular bundle only contained a left-handed helical structure, as shown in Figure 1. If the left-handed helical structure would be utilized as a template for preparing a chiral electroconductive microcoil, novel materials responding to an electromagnetic wave with unilateral circular polarization could be developed. Here, we report on preparation of Ni-P, Cu and Ag microcoils by a template synthesis using the helical structures collected from several plants through electroless plating. Methods to separate the helical structures from plant organization as well as to cover them with electroless depositions and morphologies of resulting metallic microcoils were described.

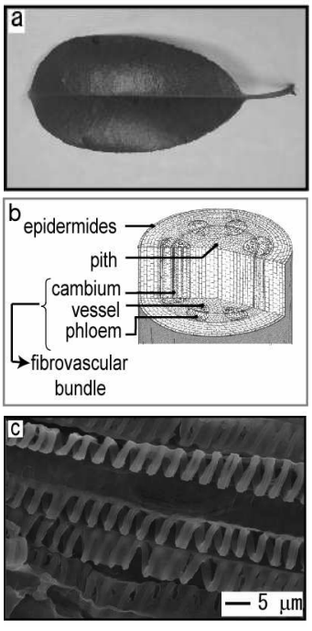

Figure 1. (a) Photograph of a Red robin leaf, (b) illustration of a leaf vein fracture, and (c) SEM image of helical structures in fibrovascular bundles.

Left-handed helical structures could be separated from a leaf of Red robin in major proportions by immersing the leaf in a saturated KOH ethanol solution and a dilute H_2SO_4 aqueous solution under ultrasonic irradiation, followed by filtration. The helical structures were dispersed in a $PdCl_2$ aqueous solution and immersed in Ni-P and Cu plating baths containing $H_2PO_2^-$ ion as reductant and an Ag bath containing $C_6H_{12}O_6$ as reductant. Electroless depositions on the coiled template were investigated by EDX and XRD analyses.

Figure 2 shows SEM images of a left-handed helical structure after each electroless plating, with results for Ni-P, Cu and Ag shown in its parts a, b and c, respectively. Ni-P and Ag microcoils were composed of particles with 100 nm diameter on average, exhibiting an amorphous Ni-P phase with a broad peak of $2\theta = 44.5^o$ and a crystalline Ag phase with major sharp (111) and (311) peaks of $2\theta = 38.1$ and 77.5^o, respectively. In the case of Cu plating, relatively large Cu cubic crystals with 1 μm side length were observed for a plated surface of the coiled template. In this way, we could only prepare left-handed microcoils of Ni-P, Cu, and Ag by the template synthesis through electroless plating. Using helical structures separated from a leaf of Red robin, the metallic microcoils with 5 – 15 μm coil diameter, 50 – 100 μm coil length and 5 – 10 μm wiring gap were obtainable.

To prepare metallic microcoils with different sizes, we separated additionally two helical structures from a flower petal of Lathyrus odoratus and a root of Nelumbo nucifera. The helical structures of Lathyrus odoratus could be obtained in a manner similar to Red robin. The helical structures of Nelumbo nucifera were obtainable by cutting helical structures existing in a fracture surface of the root. Ni-P microcoils with 5 – 10 μm coil diameter, 50 – 100 μm coil length and 5 – 10 μm wiring gap could be prepared from flower petal of Lathyrus odoratus. Larger Ni-P microcoils with 50 – 100 μm coil diameter, 500 – 5000 μm coil length and 50 – 70 μm wiring gap could be obtained from Nelumbo nucifera. It was found that the morphologies of metallic microcoils prepared by this methodology were tunable by choice of the kind of plants. We will discuss electroconductive properties of thus obtained metallic microcoils.

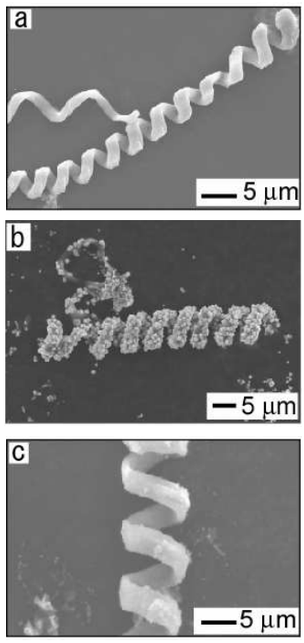

Figure 2. SEM images of helical structures plated by (a) Ni-P, (b) Cu and (c) Ag.

[1] S. Motojima, et al., *J. Appl. Phys*, **94**, 2325 (2003).