§40. Control of Microfluid Devices towards Mass Production of IFE Targets

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Precise mass production of fuel capsules is required for inertial fusion energy system [1]. The use of microfluid device is a promising technology in the target fabrication [2]. In this year, we provide precise fabrication of monolithic low density metal oxide using a microfluid device [3].

The advantage of the electrospinning sol-gel method is that the microstructure of the metal oxide fiber sheet can be designed and fabricated repeatedly to meet the demand of the target in a very convenient way. In the case of the previous study on SnO_2, the diameter of the fiber is a function of the concentration of $SnCl_4$ in the precursor [4]. By increasing the concentration from 2.5% to 7.5%, the diameter of the SnO_2 fibers increase from 180 nm to 460 nm with densities of 0.825 g/cm^3 to 0.214 g/cm^3, respectively. When the fabrication parameters were fixed, both the morphology and the density of the mat were fixed, and the mass of SnO_2 mat per unit area only correlated with the thickness of the film. In order to obtain lower density than those of the previous report of SnO_2, we prepared nanofiber containing smaller concentration than those for SnO_2. But in such cases the shrinkage during the calcination was too large to obtain the density lower than 50 mg/cm^3. In order mitigate the shrinkage, the metal sources increased in comparison with the case of tin, then the optimized conditions were different from the scalability for the case of SnO_2.

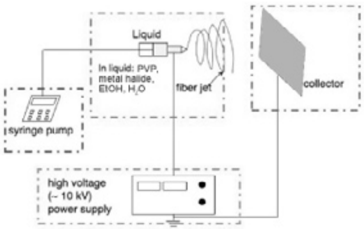


Figure 1. Schematic illustration of the basic setup for electrospinning.

Although $SnCl_4$ is soluble in ethanol, other metal chlorides are sometimes difficult. PVP can be dissolved in water, while aqueous PVP does not easily give electrospinning nanofiber due to the low vapor pressure. In this study for other metals, ethanol/water mixture is chosen as solvents in order to satisfy the two necessary conditions, 1) high solubility of metal chloride, and 2) complete evaporation of solvent during the flight from the injection nodule to the nanofiber collector of the counter electrode. When the solvent remained on the counter electrode, severe shrinkage happened and density increased. For the vanadium, the water content reached to 12.5 wt%.

Another requirement is viscosity of precursor solution. In the present study, Mw was chosen to 44,000.

Figure 2 shows obtained laser targets of copper and vanadium oxides. The area are well controlled to be 1.5 x 2.0 (mm)^2 for both cases. This area is typical for laser targets of Gekko XII experiments. The densities are 27$\pm$2 and 40$\pm$5 mg/cm^3 for copper and vanadium oxides, respectively, which agrees to the specifications of the target design at the experiments. Furthermore, these low density of copper and vanadium oxides are difficult using other fabrication technique such as aerogel method.

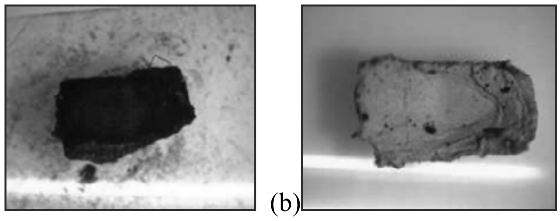
(a)  (b)

Figure 2. The optical images of the monolithic and low-density (<50 mg/cc) metal oxides. CuO of 1.0^d x 1.5^w x 2.0^h (mm)^3 (left) and V_2O_5 of 0.6^d x 1.5^w x 2.0^h (mm)^3 (right).

In order to determine the chemical composition of them, the weight of the metal component was measured using ICP (induced coupled plasma) analysis. These values supports the compositions of $CuO(H_2O)_{0.75}$ and V_2O_5. The x-ray diffraction patterns also agreed to those in the previous reports of CuO and V_2O_5. The SEM images shown in Fig 3 are quite crystalline shape and different from the cases of SnO_2. In the case of V_2O_5, it is anisotropic and its length was ~5μm (a). The CuO did not show such large size and was ~100 nm crystals which continuously connects one-dimensionally (b). Both anisotropic morphologies imply the formation of the crystals based on the initial nanofibric structures.

To summarize, by the use of electrospinning technique, metal halide containing PVP nanofiber film was obtained for cupper and vanadium. The nanofiber mats can be cut to centimeter-sized monolithic films. The films were converted to monolithic low-density metal oxides by calcination. The density was less than 50 mg/cm^3. The metal oxides had anisotropic structures.

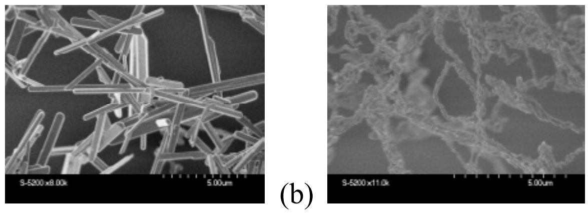
(a)  (b)

Figure 3. SEM images of calcinated low-density metal oxide: (a) V_2O_5 (b) CuO.

1) Norimatsu, T. et al, *Fusion Sci. Technol.*, **49** (3), 483-499, (2006).
2) Nagai, K. et al., *Nuclear Fusion*, **49** (9), 095028 (9 pages), (2009).
3) Nagai, K., et al., *Fusion Sci. Technol*, **59** (1), 216-220, (2011).
4) Pan, C., et al., *J. Appl. Phys.*, **100** (1), 016104, (2006).