Experimental Analysis of Laser-Assisted Microfabrication Using TiO_2 Nanoparticles

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Abstract

Recently, tiny structures around micrometers which consist of metal or dielectric are increasing interest that they can be applied to particular optical devices, such as photonic crystals or THz meta-materials. In order to make such applications, structures are often needed to be small around several or tens of micrometers, be three-dimensional, and have electrical or optical characters. We propose a new method which is able to fabricate three-dimensional micro structures which may satisfy those conditions.

1 Concept of microfabrication using TiO_2 nanoparticles

The main point of our method is extraction of metal using photocatalyst, TiO_2 [1]. We prepare the particular solution which contains Ag^+ and TiO_2 nanoparticles. Then TiO_2 is excited by UV-beam, emits electron, and Ag^+ gains the electron and extracts into Ag. As shown in Figure 1, this reaction happens only near the beam waist, so three-dimensional structure is fabricated as we scan the beam waist.

2 Fabrication System

We have developed the microfabrication system based on the principle mentioned above [2]. Figure 2 shows the schematic of the system. We use 405nm laser diode as a beam source. The objective lens with 0.90NA focuses the beam into a cell which holds the solution while beam power in the cell is adjusted at 1.4 mW. In order to scan the beam waist relatively, we use three-axis motorized stage with 100 nm moving step. The cell is composed of two cover slips separated by 100 μm film, and filled by the solution which consists of $AgNO_3$, NH_3, and 10 nm TiO_2 nanoparticles dispersion: NTB-01 (Showa Titanium).

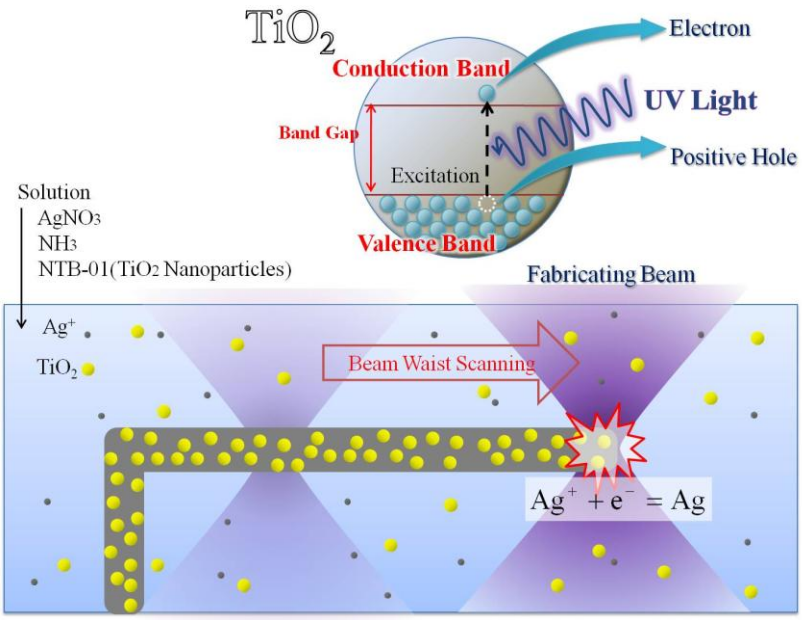

Figure 1: Concept of microfabrication using TiO_2 nanoparticles

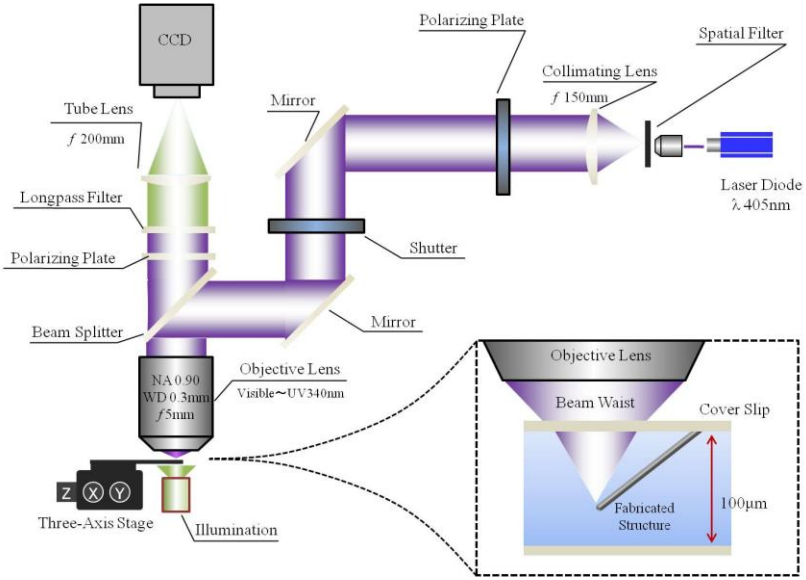

Figure 2: Schematic of laser-assisted fabrication system

3 Controlling fabricated structure's properties

When we bring the structure to the vapor phase, it will be broken by surface tension of the solution. To avoid this, after we fabricate the structure, we brought it out by supercritical drying. The fabricated structure contains both Ag and TiO_2 spreading at random. This randomness may make hard to design the structure's electromagnetic or optical characteristics.

In order to solve this problem, we tried baking the structure with high temperature, 900 °C, and irradiating UV laser. The result is shown in Figure 3. Figure 3 (a) shows the schematic of fabricated structure. It is triangular pyramid with 60 μm edges and 49 μm height. Figure 3 (b) shows the image of baked structure and the result of spectrum analysis by SEM-EDS. The height of the structure is about 25μm so it is lower than we originally designed, but still keeping three-dimensional shape. The spectrum analysis shows that baked structure doesn't contain Ag. This result insists that we can fabricate three-dimensional micro structures with high permittivity.

The baked structure consists of TiO_2, photocatalyst, so it will be covered by metal using extraction of metal ion. In order to verify this idea, we put the baked structure into a sample cell which is filled with $AgNO_3$ aq. Then we irradiated it with 325 nm He-Cd laser. Figure 3 (c) shows the image of irradiated structure and the result of spectrum analysis. The irradiated structure is now coated by Ag, so it has dielectric core which is coated by metal. The result indicates the possibility that we can control optical or electromagnetic characteristics of fabricated structure by controlling region of metal and dielectric in it.

4 Conclusions

We proposed the new microfabrication method using TiO_2 nanoparticles. We have developed a unique system which can fabricate three-dimensional, 5-100μm structures consisting of dielectric and metal. We showed the possibility of controlling the characteristics of fabricated structures.

Acknowledgement

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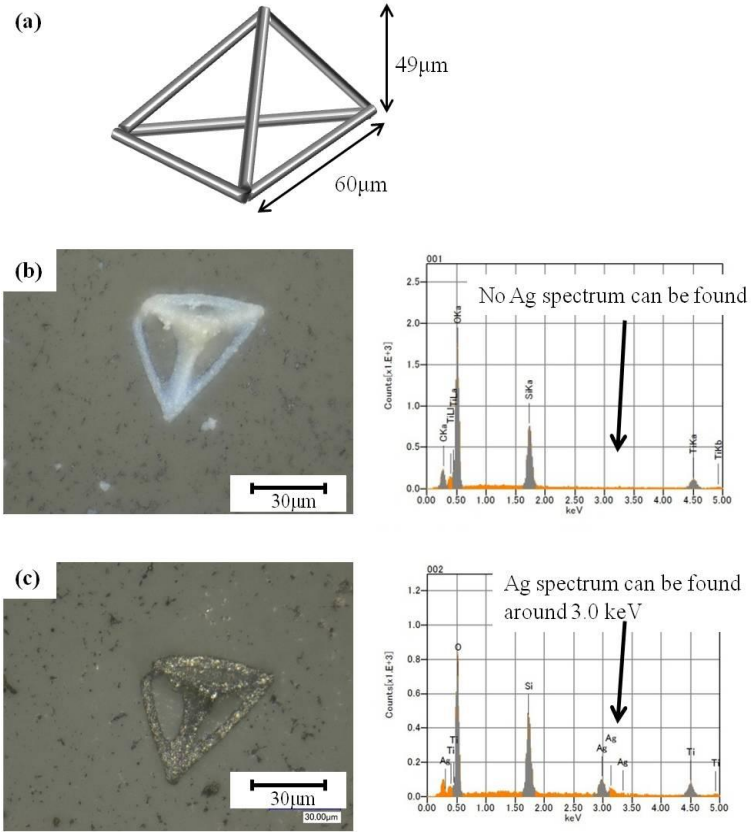

Figure 3: Controlling fabricated structure's properties (a)Original design: Triangular Pyramid (b)Baked structure with no Ag containing and its spectrum analysis (c)Irradiated structure coated with Ag and its spetrum analysis

References:

[1] Fujishima, A., Honda, K., "Electrochemical photolysis of water at a semiconductor electrode", Nature, Vol. 238, pp. 37-38, 1972

[2] Okuno, M., Aso, T., Takahashi, S., Takamasu, K., "A novel micrifabrication technique for three-dimensional metal structures by photocatalysis", Proceedings of the 21st American Society for Precision Engineering Annual Meeting, 301-304, 2006