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A new strategy to realize the three-dimensional functional metal oxide nanostructured electronics

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Transition metal oxides (TMOs) possess unique functionalities, such as ferroelectric, ferromagnetic, and superconducting properties, that are absent or inferior in other materials. These nanostructures are indispensable factor to achieve the nanoscale electronic devices. In order to realize such the specific nano-functionalities, reliable and versatile methods for controlling the shape, size, position, and spatial period of three-dimensional (3D) nanostructures is essential. Since, TMOs are generally hard figuring materials, it is still difficult to strike a balance between achieving the resolution on the order of 10 nm and controlling the size, shape, and position under the artificial design. To overcome these difficulties, we have been developed a novel nanofabrication technique by combining inclined pulsed laser deposition (PLD) with nanoimprint lithography (NIL), namely "3D nanotemplate PLD" technique [1-5]. In this method, target materials are deposited onto the sidewalls of a well-defined patterned template (Fig. 1(a)). The key advantage of this technique is that the smaller nanostructures than the size of a lower limit in NIL process can be fabricated while maintaining the original pattern shape and position. Importantly, this method is essentially free from charging effects; the resolution limit is not affected by the conductivity of the system, in contrast to conventional electron- and ion beam-based lithography methods. Figure 1(b) shows the relationship between the width (*w*) of the nanostructure and the PLD deposition duration. Their clear proportional relation guarantees the systematic control of *w*. The height and length are able to be controlled by adjusting NIL condition.

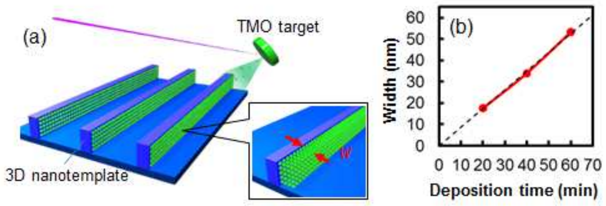

Figure 1 (a) Schematic drawing of 3D nanotemplate PLD.
(b) Dependence of *w* on deposition duration.

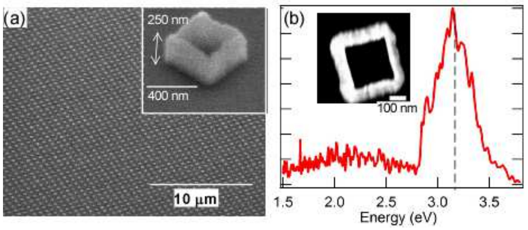

Figure 2 (a) Typical SEM image of ZnO nanobox structures. (b) CL spectrum at RT from a single ZnO nanobox shown (inset).

We have successfully produced various 3D nanostructures by 3D-nanotemplate PLD method. Figure 2(a) and 2(b) show highly ordered ZnO nanoboxes [1, 2] with a width of ~20 nm, and cathodoluminescent (CL) spectrum from a single ZnO nanobox at room temperature (RT), respectively. The strong ultra-violet emission at 3.25 eV (λ=380 nm) and little visible emission in CL spectrum indicate the high quality of the ZnO nanostructures with little defects. The brilliant luminescence from the single ZnO nanobox guarantees the excellent nanoscale optical functionality of the single ZnO nanostructures. Figure 3(a) shows the epitaxial $(Fe,Zn)_3O_4$ (FZO) nanowall wire grown on the 3D MgO nanowall substrates with the lateral heterointerfaces [3]. FZO is a ferromagnetic semiconductor at RT and one of the candidate materials for spintronics applications. The single FZO nanowall wire exhibited essentially identical magnetic resistance (MR) properties (Fig. 3(b)) to those of the thin film [3, 4]. We also succeed to produce a nanoscale bottleneck structure: nanoconstriction of FZO which would produce the MR enhancement due to the domain wall pinning effect. Figure 3(c) shows the FZO nanoconstriction with a bottleneck width of 65 nm and a length of 53 nm, fabricated by utilizing a nanoscale shadowing effect [5]. The 3D degrees of freedom in production of the metal oxide nanostructures are an essential advancement towards realizing metal oxide based electronics incorporating their diverse and unique physical properties.

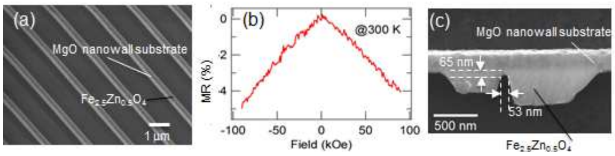

Figure 3 (a) FZO epitaxial nanowall wires and (b) MR curve at 300 K. (c) SEM image of a FZO nanoconstriction.

The nanostructures of the strongly correlated electron material $(La,Pr,Ca)MnO_3$ which exhibits colossal MR, could be also produced. Here, we revealed the individual physical properties of the single nano electronic domains, whose ensemble is observed in general bulk and film system. In the presentation, we will show the details of 3D nanotemplate PLD technique, the TMOs nanostructures, and their nano physical properties, and will discuss our approaches for the realization of the nanostructured electronics.

References

[1] A. N. Hattori, A. Ono, and H. Tanaka, Nanotechnology **22** (2011) 415301.
[2] A. N. Hattori, M. Ichimiya, M. Ashida, and H. Tanaka, Appl. Phys. Express **5** (2013) 125203.
[3] Y. Fujiwara, A. N. Hattori, K. Fujiwara, and H. Tanaka, Jpn. J. Appl. Phys. **52** (2012) 015001.
[4] T. Kushizaki, K. Fujiwara, A. N. Hattori, T. Kanki, and H. Tanaka, Nanotechnology **23** (2012) 485308.
[5] T. Kushizaki, K. Fujiwara, Y. Fujiwara, A. N. Hattori, H. Tanaka, Appl. Phys. Express **6** (2013) 035201.