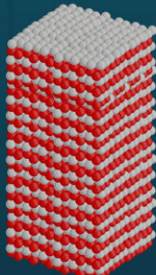


Novel nanowire fabrication technique paves way for next generation spintronics

November 3 2022


Novel Method for Direct Fabrication of Ferromagnetic Nanowires on Silicon Substrates

Ferromagnetic nanowires with $L1_0$ crystal structure and high coercivity are promising candidates for future spintronic devices



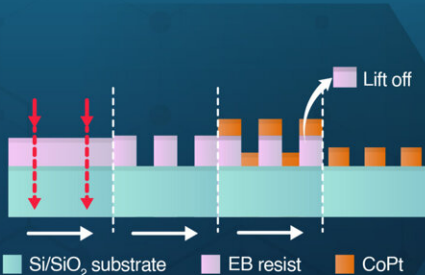
■ Pt
■ Fe

But, thus far, there has been no method to directly fabricate $L1_0$ -ordered nanowire spintronics on substrates using only annealing, due to droplet formation during annealing



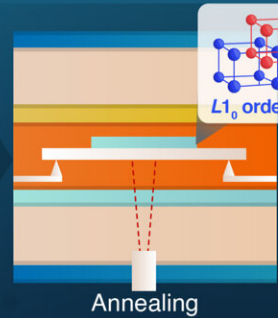
Droplet formation

Direct fabrication using nanostructure-induced $L1_0$ -ordering of twinned single-crystals in CoPt ferromagnetic nanowires on Si/SiO₂ substrates



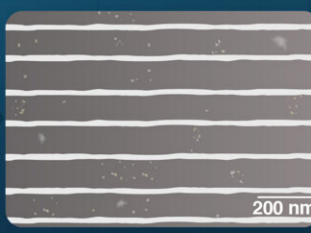
Si/SiO₂ substrate EB resist CoPt

Lift off



Annealing

$L1_0$ ordering



200 nm

- ✓ Lift-off process comprising electron-beam (EB) lithography and EB evaporation, followed by annealing

- ✓ $L1_0$ ordering driven by atomic interdiffusion, surface diffusion, and large internal stress at ultrasmall curvature radii

- ✓ 30 nm-scale ultrafine ferromagnetic nanowires with large coercivity (10 kOe)

The nanostructure-induced ordering method allows the direct fabrication of high-coercivity CoPt nanowires, making it a significant technology for future spintronic devices

Nanostructure-induced $L1_0$ -ordering of twinned single-crystals in CoPt ferromagnetic nanowires

Toyama et al. (2022) | *Nanoscale Advances* | 10.1039/d2na00626j



Graphical abstract. Credit: Tokyo Tech

As our world modernizes faster than ever before, there is an ever-growing need for better and faster electronics and computers. Spintronics is a new system which uses the spin of an electron, in addition to the charge state, to encode data, making the entire system faster and more efficient. Ferromagnetic nanowires with high coercivity (resistance to changes in magnetization) are required to realize the potential of spintronics. Especially $L1_0$ -ordered (a type of crystal structure) cobalt–platinum (CoPt) nanowires.

Conventional [fabrication](#) processes for $L1_0$ -ordered nanowires involve [heat treatment](#) to improve the physical and chemical properties of the material, a process called annealing on the crystal [substrate](#); the transfer of a pattern onto the substrate through lithography; and finally the chemical removal of layers through a process called etching.

Eliminating the etching process by directly fabricating nanowires onto the [silicon substrate](#) would lead to a marked improvement in the fabrication of spintronic devices. However, when directly fabricated nanowires are subjected to annealing, they tend to transform into droplets as a result of the internal stresses in the wire.

Recently, a team of researchers led by Professor Yutaka Majima from the Tokyo Institute of Technology have found a solution to the problem. The team reported a new fabrication process to make $L1_0$ -ordered CoPt nanowires on silicon/[silicon dioxide](#) (Si/SiO₂) substrates.

Talking about their research, published in *Nanoscale Advances*, Prof. Majima says, "our nanostructure-induced ordering method allows the direct fabrication of ultrafine $L1_0$ -ordered CoPt nanowires with the

narrow widths of 30 nm scale required for spintronics. This fabrication method could further be applied to other $L1_0$ -ordered ferromagnetic materials such as iron–platinum and iron–palladium compounds."

In this study, the researchers first coated a Si/SiO₂ substrate with a material called a "resist" and subjected it to [electron beam lithography](#) and evaporation to create a stencil for the nanowires. Then they deposited a multilayer of CoPt on the substrate. The deposited samples were then "lifted off," leaving behind CoPt nanowires. These nanowires were then subjected to high temperature annealing. The researchers also examined the fabricated nanowires using several characterization techniques.

They found that the nanowires took on $L1_0$ -ordering during the annealing process. This transformation was induced by atomic interdiffusion, surface diffusion, and extremely large internal stress at the ultrasmall 10 nm scale curvature radii of the nanowires. They also found that the nanowires exhibited a large coercivity of 10 kiloOersteds (kOe).

According to Prof. Majima, "the internal stresses on the nanostructure here induce the $L1_0$ -ordering. This is a different mechanism than in previous studies. We are hopeful that this discovery will open up a new field of research called 'nanostructure-induced materials science and engineering.'"

More information: Ryo Toyama et al, Nanostructure-induced $L1_0$ -ordering of twinned single-crystals in CoPt ferromagnetic nanowires, *Nanoscale Advances* (2022). [DOI: 10.1039/D2NA00626J](https://doi.org/10.1039/D2NA00626J)

Provided by Tokyo Institute of Technology

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