TOYOHASHI UNIVERSITY of TECHNOLOGY
Hibarigaoka, Tempaku, Toyohashi, Aichi, 441-8580 Japan
PHONE: +81-532-44-6577 FAX: +81-532-44-6557
E-mail: press@office.tut.ac.jp

PRESS RELEASE

Source: Toyohashi University of Technology, Japan, Committee for Public Relations

Title: High-refractive-index material retains high transmissivity after annealing at 850°C
Subtitle: Successfully combined with magnetic garnet to yield ten times enhanced performance

Full text:
Toyohashi University of Technology researchers in collaboration with Massachusetts Institute of Technology (MIT), have developed a new material capable of retaining high transmissivity after thermal treatment at 850°C and successfully applied the material to optical devices. The researchers alternately laminated film of this high-refractive-index material and film of a low-refractive-index material to form a dielectric mirror[1)] and then used the mirror for magneto-optical device production, which requires thermal treatment at high temperatures.

The amount of information we handle daily has been skyrocketing, and development and research of information processing devices is an urgent task. Meanwhile, recent research has started to show that combining well-known, superior materials can yield new materials that have a greatly enhanced performance compared to conventional materials. However, combining different materials often proves to be a challenge; a material with good properties when used alone can cause new problems when combined with another material. Among these new problems, heat-related problems are easy to understand. For example, when a material that requires thermal treatment at a certain temperature is combined with another material that degrades at that temperature, the resulting product’s performance is degraded, making such a combination pointless.

In this study, the research group of Toyohashi University of Technology in collaboration with Massachusetts Institute of Technology (MIT) alternately laminated a high-refractive-index material and a low-refractive-index material to form a dielectric mirror and combined the dielectric mirror with transparent magnetic garnet[2)]. The magnetic garnet requires thermal treatment at about 750°C during formation, and therefore the dielectric mirror needs to withstand this temperature. It is well-known that tantalum oxide[3)], which is widely used as a high-refractive-index material in dielectric mirrors, crystallizes[4)] and loses much of its transmissivity at about 700°C.

This study uses “amorphous tantalum yttrium oxide” [5)], which has been studied for use as an insulate material[6)], as a high-refractive-index material. Amorphous tantalum yttrium oxide is formed by adding a trace amount of yttrium oxide[7)] to tantalum oxide, and retains transmissivity after thermal treatment at 850°C, making it suitable for combination with magnetic garnet. With this discovery, the research group overcame the problem of performance degradation caused by thermal treatment, and

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succeeded in enhancing the performance of an integrated device composed of a dielectric mirror and magnetic garnet by about ten times.

“We used amorphous tantalum yttrium oxide to form a dielectric mirror and combined it with magnetic garnet. Actually, other than magnetic garnet, there are more materials that have not been combined with dielectric mirrors because of the high-temperature thermal treatment that is required. I hope that our findings will help make such materials usable too,” says Assistant Professor Taichi Goto.

The new material “amorphous tantalum yttrium oxide” contains tantalum oxide as its major constituent and about 14% yttrium oxide. The presence of yttrium oxide molecules between tantalum oxide molecules prevents crystallization, resulting in an increase in the crystallization temperature to about 850°C or higher. Tantalum oxide loses its transmissivity when crystallized, but in the study the crystallization temperature was increased and thus the loss of transmissivity of tantalum oxide was successfully prevented. The study provides a new material that is capable of giving enhanced performance to optical devices.

“Magnetic garnet has a wide range of applications, such as ultra-fast displays, spin wave[8)] devices, and lasers. Performance of these devices can be greatly enhanced by combining magnetic garnet with dielectric mirrors containing our high-refractive-index material,” says Takuya Yoshimoto, a Ph.D. student in charge of sample preparation for the study.

The new material amorphous tantalum yttrium oxide is producible and stable at room temperature, and is promising for future application to spin wave devices, compact laser devices containing magnetic garnet, and so on.

This study was conducted by Associate Professor Hiroyuki Takagi, Associate Professor Yuichi Nakamura, Professor Hironaga Uchida, and Professor Mitsuteru Inoue (all at Toyohashi University of Technology) in collaboration with Professor Caroline A. Ross at Massachusetts Institute of Technology (MIT).

Funding agency:
JST PRESTO No. JPMJPR1524
JSPS KAKENHI Nos. 26220902, 15H02240, 16H04329, 17K19029
JSPS Program for Advancing Strategic International Networks to Accelerate the Circulation of Talented Researchers No. R2802
Yazaki Memorial Foundation for Science and Technology
NAF ECCS No. 1607865

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Reference:

Takuya Yoshimoto, Taichi Goto, Hiroyuki Takagi, Yuichi Nakamura, Hironaga Uchida, Caroline A. Ross and Mitsuteru Inoue, "Thermally stable amorphous tantalum yttrium oxide with low IR absorption for magnetophotonic devices", *Scientific Reports*, 7, 13805 (2017).
https://doi.org/10.1038/s41598-017-14184-4

Technical terms:

1) Dielectric mirror
   A type of mirror that reflects light with a specific wavelength composed of layers of high-refractive-index material and low-refractive-index material alternately laminated in the order of light-wavelength. Dielectric mirrors are used in filters that only allow transmission of light with a specific wavelength (color).
2) Magnetic garnet
   A type of garnet that is magnetic. The magnetic garnet in this study contains cerium, yttrium, and iron. Non-conductive material.
3) Tantalum oxide
   Oxidized tantalum.
4) Crystallization
   A phenomenon where randomly positioned atoms in a material become organized in a periodical manner and form a crystal.
5) Amorphous tantalum yttrium oxide
   An amorphous state refers to a non-crystalline state, and amorphous tantalum yttrium oxide refers to oxidized tantalum yttrium in an amorphous state. Abbreviated as aTYO.
6) Insulation material
   Non-conductive material.
7) Yttrium oxide
   Oxidized yttrium.
8) Spin waves
   Spinning refers to the rotation of electrons, and rotating electrons act as micromagnets. Spin waves are generated by a group of spinning electrons, and refer to a phenomenon where the top-like motion (precession) of respective spins is spatially displaced and propagates like waves.

Further information
Toyohashi University of Technology
1-1 Hibarigaoka, Tempaku, Toyohashi, Aichi Prefecture, 441-8580, JAPAN
Inquiries: Committee for Public Relations
E-mail: press@office.tut.ac.jp

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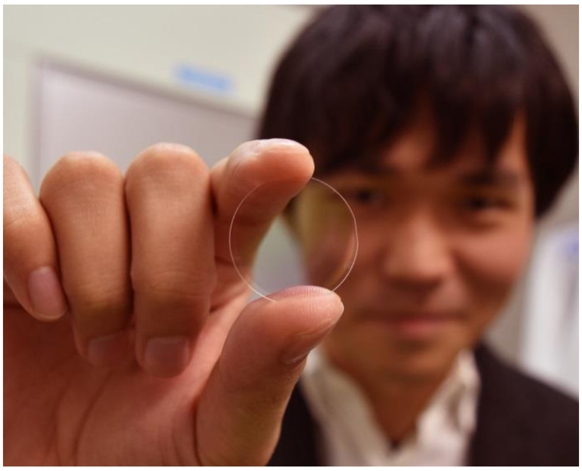
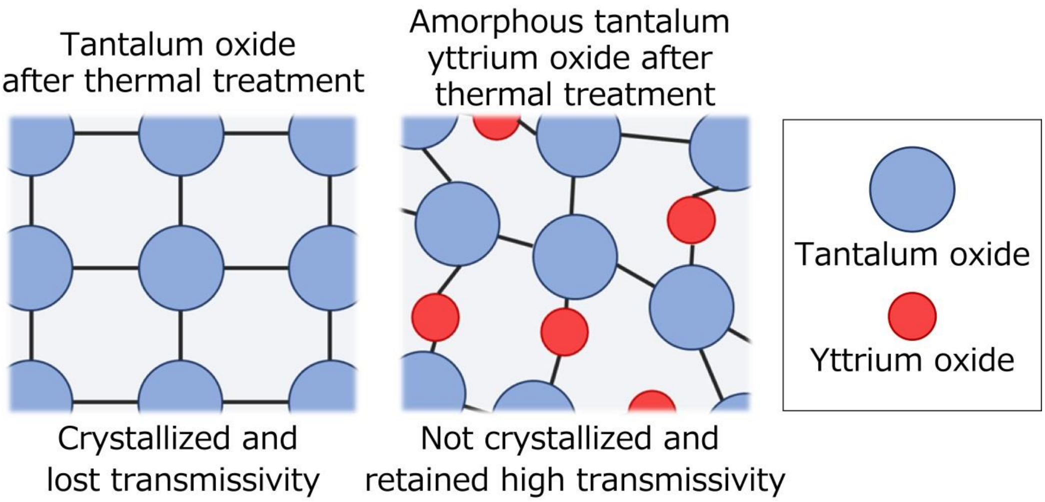
Figure 1:



Caption: Ph.D. student Takuya Yoshimoto holding a film of amorphous tantalum yttrium oxide

Figure 2:



Caption: Schematic views of atomic/molecular distribution in tantalum oxide and amorphous tantalum yttrium oxide. Even after thermal treatment at high temperature, amorphous tantalum yttrium oxide remains uncrystallized and retains the random distribution of atoms/molecules, which allows high transmissivity to be maintained.

Primary keyword: CHEMISTRY/PHYSICS/MATERIALS SCIENCES, ELECTROMAGNETICS, ENERGY/FUEL (NON-PETROLEUM), INDUSTRIAL ENGINEERING/CHEMISTRY, MATERIALS, NANOTECHNOLOGY/MICROMACHINES, OPTICS, PARTICLE PHYSICS