Supplementary Information

Materials

Liquid gallium, citric acid, sodium hydroxide (NaOH), and di-sodium hydrogen phosphate dodecahydrate ($Na_2HPO_4 \cdot H_2O$), sulfuric acid (H_2SO_4), ethanol, were purchased from Sigma-Aldrich, USA. Beta-cyclodextrin and hydrogen peroxide (H_2O_2) were purchased from TCI, Japan. Dulbecco's Modified Eagle's medium (DMEM) and sodium chloride (NaCl) were purchased from Merck Biochrom (Berlin, Germany). Paraformaldehyde was purchased from Boster Biological Technology (California, USA). Sample of the human cervix adenocarcinoma HeLa cell line were purchased from the American-Type Culture Collection (ATCC, USA). All the reagent and buffer solutions were prepared with deionized (DI) water (18.2MΩ).

Methods

GaOOH nanoparticle synthesis by varying the oxidizing agent concentration

To synthesize GaOOH nanoparticles, a probe sonicator (SONICS VCX130, USA) was used which has a power rating of 130 watts and frequency of 20 kHz. Synthesis was carried out in 10 ml of DI water containing 1, 2 and 5% hydrogen peroxide respectively for 0.1 g of liquid gallium.

GaOOH nanoparticles synthesis by varying pH

To synthesize GaOOH nanoparticles, 10 ml of 2% hydrogen peroxide was used to which 1 M H_2SO_4 was added to make a final solution with pH 2 or 5. To generate an alkaline solution, 1 M

NaOH was used to adjust the pH to a value of 9. Sonication was then undertaken for 25 min at 40% power amplitude.

Preparation of GaOOH before characterization

All samples were initially centrifuged and washed with DI water after synthesis. Then 0.01 gram of GaOOH nanoparticles powder was redispersed in water via sonication and centrifuged at 2000 rpm to remove large particles.

Cyclodextrin conjugation with GaOOH nanoparticles preparation

To conjugate GaOOH nanoparticles with cyclodextrin, ***β***-cyclodextrin, Sodium phosphate dibasic, citric acid, and gallium oxide nanoparticle are required in this experiment. For solution preparation, 15 ml of DI water, 1.5 g of citric acid, and 0.9 g sodium phosphate dibasic were combined and stirred until dissolved. Afterwards, 1.5 g of ***β***-cyclodextrin and 1 g of synthesized GaOOH nanoparticles were added and sonicated for 30 minutes at room temperature and then dried at 100℃ followed by incubating at 180℃ until the substance swells and the color turned to light brown.

Characterization

Material characterization was performed using a field-emission scanning electron microscopy (FEI Nova NanoSEM 450, BRUKER at an operating voltage of 10 kV under high vacuum), X-ray diffraction (XRD, BRUKER AXS D8 Discover operating at 40 kV and 40 mA by using Cu Ka radiation with a Goebel mirror (for parallel beam) and Nicolet 6700 Attenuated total reflection – Fourier Transform Infrared (ATR-FTIR) (Thermo Scientific, Waltham, USA). Transmission electron microscopy (TEM) and scanning transmission electron microscopy (STEM) images were

taken at an accelerating voltage of 200 kV using a JEOL 2100 instrument equipped with a high-sensitivity silicon drift X-ray detector and a Gatan Orius SC1000 CCD camera. UV−visible characterization was performed using NanoDrop™ (Thermo Scientific, Waltham, USA). Fluorescence spectra was obtained using FP-6200 fluorescence spectrophotometer (Jasco, Tokyo, Japan). NIKON TI-S inverted fluorescence microscopy, Japan was used to obtain the optical and photoluminescence images. SZ-100 Dynamic light scattering (Horiba Ltd., Japan) was used to determine the average size of nanoparticles. Moreover, super-resolution laser scanning confocal microscopy (SR-LSCM) CarlZeiss LSM800 with AiryScan used to investigate cellular uptake and fluorescence property under cells uptake.

HeLa cells uptake GaOOH and GaOOH-CD nanoparticles preparation

For in vitro imaging with GaOOH, the human cancer cell lines HeLa were cultured in Dulbecco minimum essential media (DMEM) with 5% fetal bovine serum (FBS) and 1% penicillin, and 1% streptomycin. The day before treatment, cells were seeded in 35 mm culture dishes at a confluency of 70-80 %. On the treatment day, the cells in serum-supplemented media were treated with the CD conjugated GaOOH at a final concentration of (50 ng/mL) for one hour at 37°C. Control dishes were incubated without CD-GaOOH. Unconjugated GaOOH were incubated with HeLa cell lines and served as additional control. After one hour, the cells were washed thrice with PBS and fixed by 4% paraformaldehyde in PBS for 20 min at room temperature then washed thrice with PBS again and directly imaged using a confocal microscope.

Lastly, Confocal Microscopy images were obtained using a confocal laser microscope (LSM 800 with Airyscan; Carl Zeis, Oberkochen, Germany) high resolution with laser excitation at 488 nm, controlled with Zen Blue software (version 2.6). Images were acquired using 40x oil-immersion

objective and z-stack sections of 1 μm. All images are taken in exact same conditions of laser power, aperture, gain, offset, scanning speed, and scanning area.

Results

The XRD data shows that the round nanoparticles from the sonication of Gallium in 5% H_2O_2 by 130 watts and 20 kHz for 25 minutes at 40% power sonication are poorly crystalline GaOOH nanoparticles.

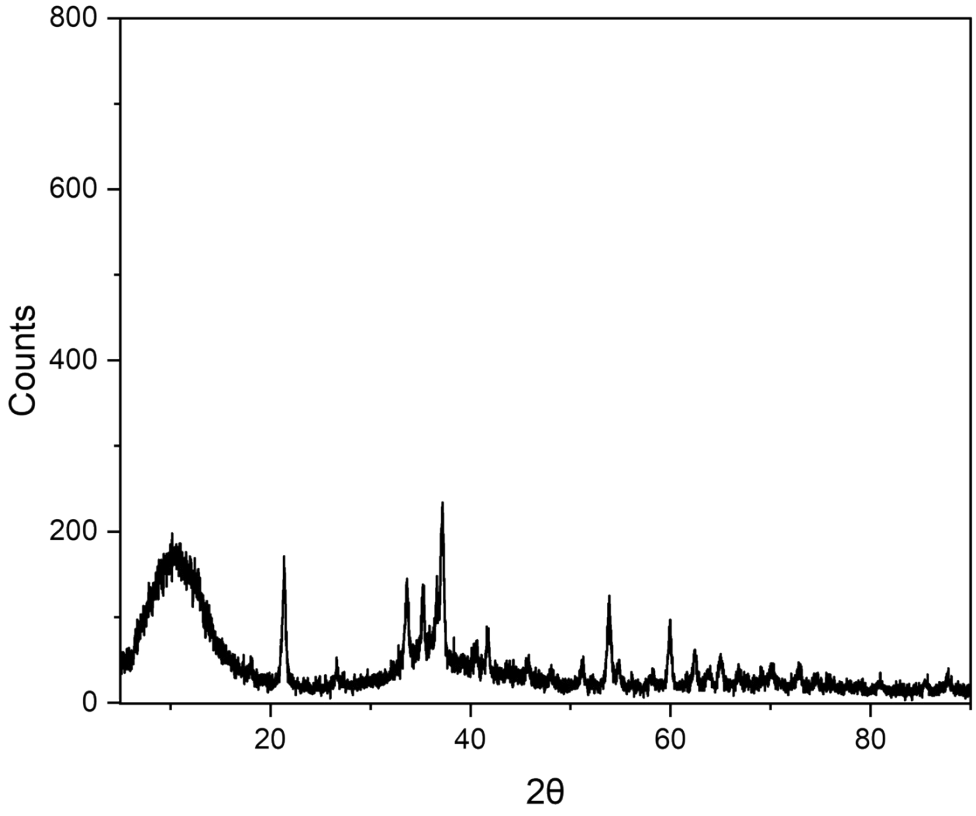


Figure S1. XRD spectrum of gallium in 5% H_2O_2

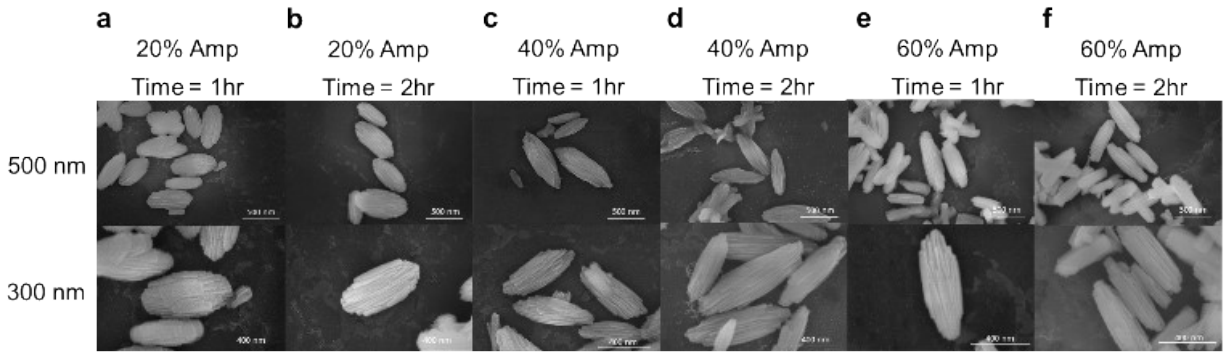


Figure S2. SEM images of GaOOH nanoparticles when amplitude and time of probe sonication was varied.

The histogram graph to presented that the sonication power affects more elongated structures and aspect ratio of the GaOOH nanoparticles while the sonication time has less of impact.

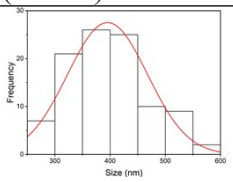
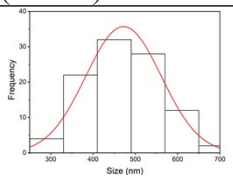
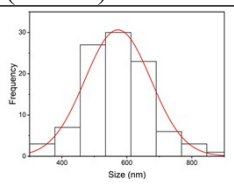
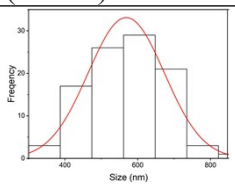
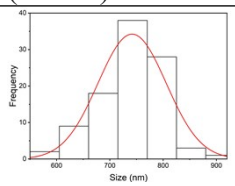
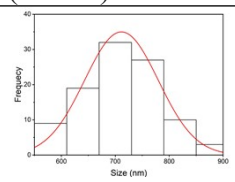
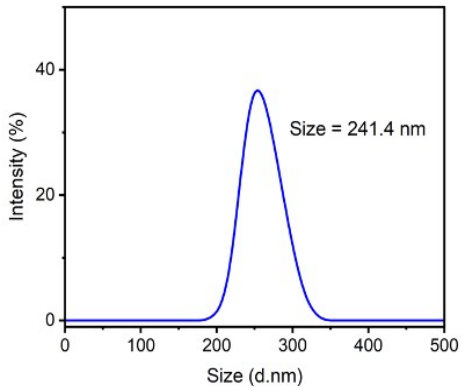
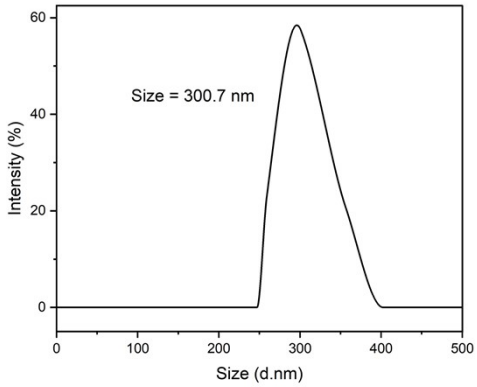
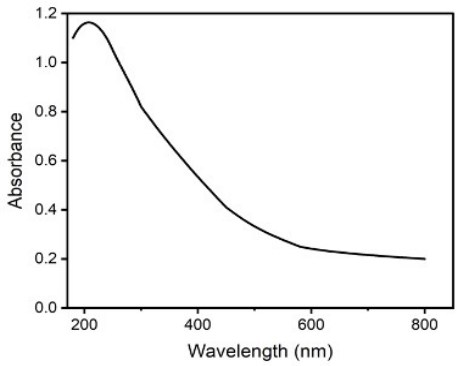
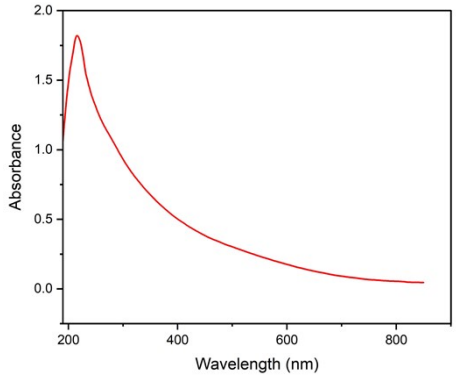
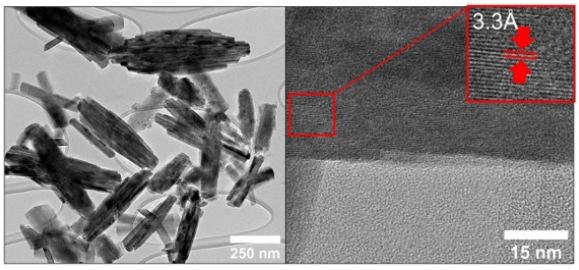
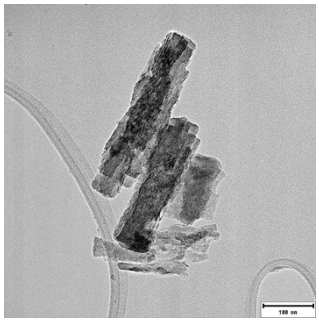
20% Amp Time = 1hr	20% Amp Time = 2hr	40% Amp Time = 1hr	40% Amp Time = 2hr	60% Amp Time = 1hr	60% Amp Time = 2hr
Aspected ratio 20 particles L/W= 1.81 (n = 20)	Aspected ratio 20 particles L/W= 1.96 (n = 20)	Aspected ratio 20 particles L/W= 2.52 (n = 20)	Aspected ratio 20 particles L/W= 2.73 (n = 20)	Aspected ratio 20 particles L/W= 3.43 (n = 20)	Aspected ratio 20 particles L/W= 3.35 (n = 20)
					

Figure S3. The comparison statistic of GaOOH nanoparticles at difference sonication power and time.

The characterization data of GaOOH and CD-GaOOH nanoparticles including size of nanoparticles, UV-visible absorption spectra, Transmission electron microscopy, X-ray diffraction, fluorescence property when detected with inverted fluorescence microscopy and laser scanning confocal microscopy when incubated with HeLa cells.

Characterization method	GaOOH	CD-GaOOH
DLS		
UV-vis spectra		
TEM		

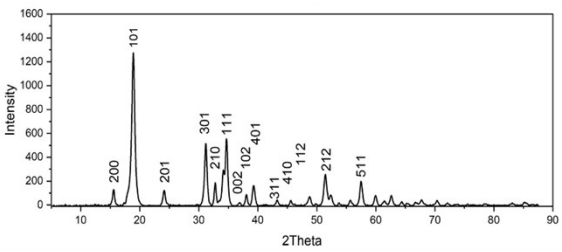
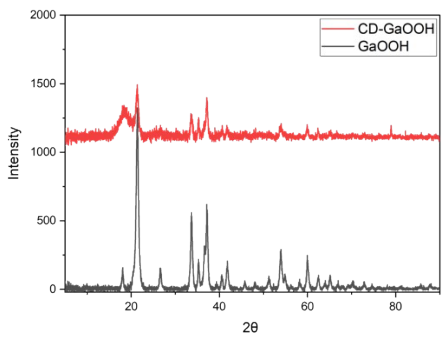
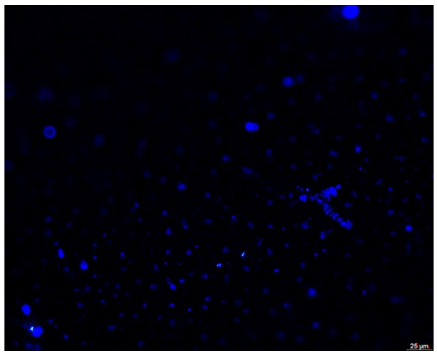
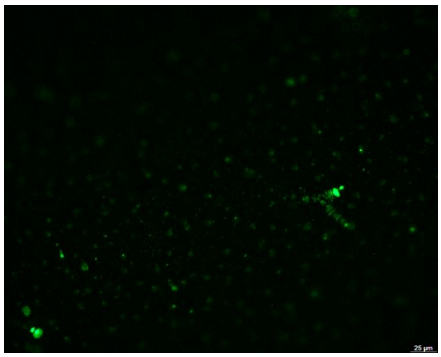
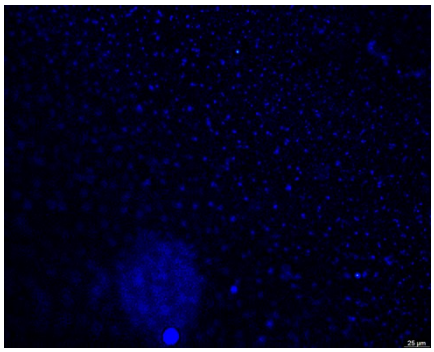
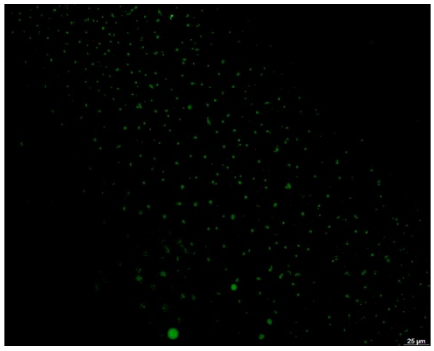
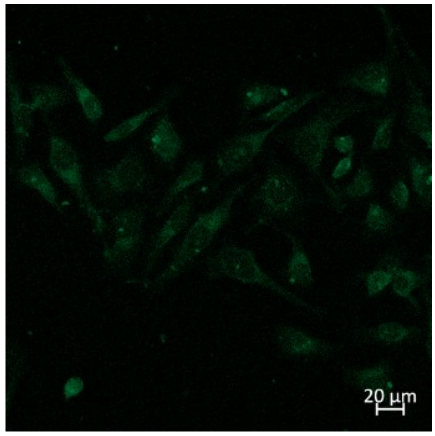
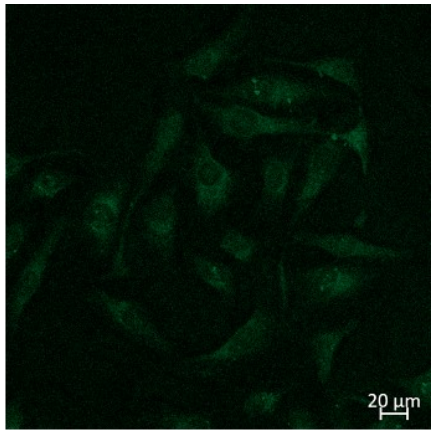
XRD		
Inverted fluorescence microscopy	 	 
Confocal laser scanning microscopy when incubation with HeLa cells		

Figure S4. The full characterization data of GaOOH and CD-GaOOH nanoparticles.