

EXPERIMENTAL SECTION

Chemicals and reagents. All chemicals used in this research are of analytical grade. Tin(II) chloride, nitrobenzene, ethanol, sodium hydroxide were purchased from Merck, Darmstadt, Germany. Ultrapure water (Elix and Synergy, Millipore, Bedford, MA, USA) was used throughout the work.

Synthesis of 1D-Sn(IV) hydroxide nanofluid. 10.0 g of $\text{SnCl}_2 \cdot 2\text{H}_2\text{O}$ was refluxed at 90 °C for 6 h in a mixture containing 8.0 g of nitrobenzene, 30 mL of concentrated HCl solution (37%) and 40 mL of ethanol. Then the refluxed mixture was cooled to room temperature and 4M NaOH solution was added dropwise to reach a neutral pH. Nitrobenzene was added in excess, with respect to tin (II) chloride, and the resulting aminobenzene byproduct was washed off with ethanol, producing a light-yellow coloration. The washing step was repeated until the discarded ethanol remains colorless. The resulting gel was vigorously shaken with water and again collected by centrifugation three times to significantly reduce the concentration of chloride ions. Following this washing process, water could not be separated from the highly stable nanofluid. To prepare the transparent metal hydroxide (TMHO) film, a cleaned glass slide was placed inside a petri dish. Then, 3 mL of the as-prepared nanofluid was casted on the glass slide and a beaker was flipped over to prevent dust contamination. The TMHO films were collected after 24 h of slow solvent evaporation.

Thermal conductivity and viscosity measurements. The effect of concentration, temperature, pH and ageing period of the 1D-Sn(IV) hydroxide nanofluid on the thermal conductivity and viscosity was investigated carefully. The thermal conductivity of 1D-Sn(IV) hydroxide nanofluid was measured by a thermal conductometer Digiton 3750K, PA HILTON LTD, United Kingdom, using a standard volume of 50 mL per sample. A viscometer Brookfield DV-I was used in all viscosity-related experiments. To measure the volume fraction of nanofluid vs thermal conductivity, a total of 13 samples (0.25 % - 5.00 %) were prepared by appropriately diluting the as-prepared nanofluid with water. The same 13 samples were used to correlate volume fraction and viscosity. To study pH vs thermal conductivity and pH vs viscosity, the pH of the nanofluid was adjusted by mixing an appropriate volume of 1M HNO_3 and 1M NaOH solutions. For the investigation of temperature vs thermal conductivity and temperature vs viscosity, a heating bath (B-491, BUCHI, Switzerland) was employed to set the nanofluid temperature at 30, 40, 50, 60, 70 and 80 °C.

Other characterization of nanofluid. The size, shape, surface morphology and surface texture were investigated with an ultrahigh-resolution FE-TEM, (JEOL, JEM-2100F, Tokyo, Japan). Dynamic light scattering (DLS) was performed on a Zen 3600 Malvern, UK equipped with a zeta potential analyzer. A PHILIPS PW 3040 X'pert PRO X-ray diffractometer was employed to evaluate the crystallinity. The surface texture was observed with a field emission scanning electron microscope (FE-SEM) (JSM-7600F, JEOL, Tokyo, Japan). An optical microscope ME300TZ-3M (40X-1000X EPI) was used to capture images of transparent metal hydroxide (TMHO) at the Pilot Plant and Process Development Centre (PP & PDC), Bangladesh Council of Scientific and Industrial Research (BCSIR) Laboratories, Bangladesh. A Thermo Scientific Escalab 250Xi X-ray photoelectron spectrometer (XPS) equipped with a monochromatic Al $K\alpha$ (1486.6 eV) X-ray source was used to quantitatively determine the composition of the Sn(IV) hydroxide

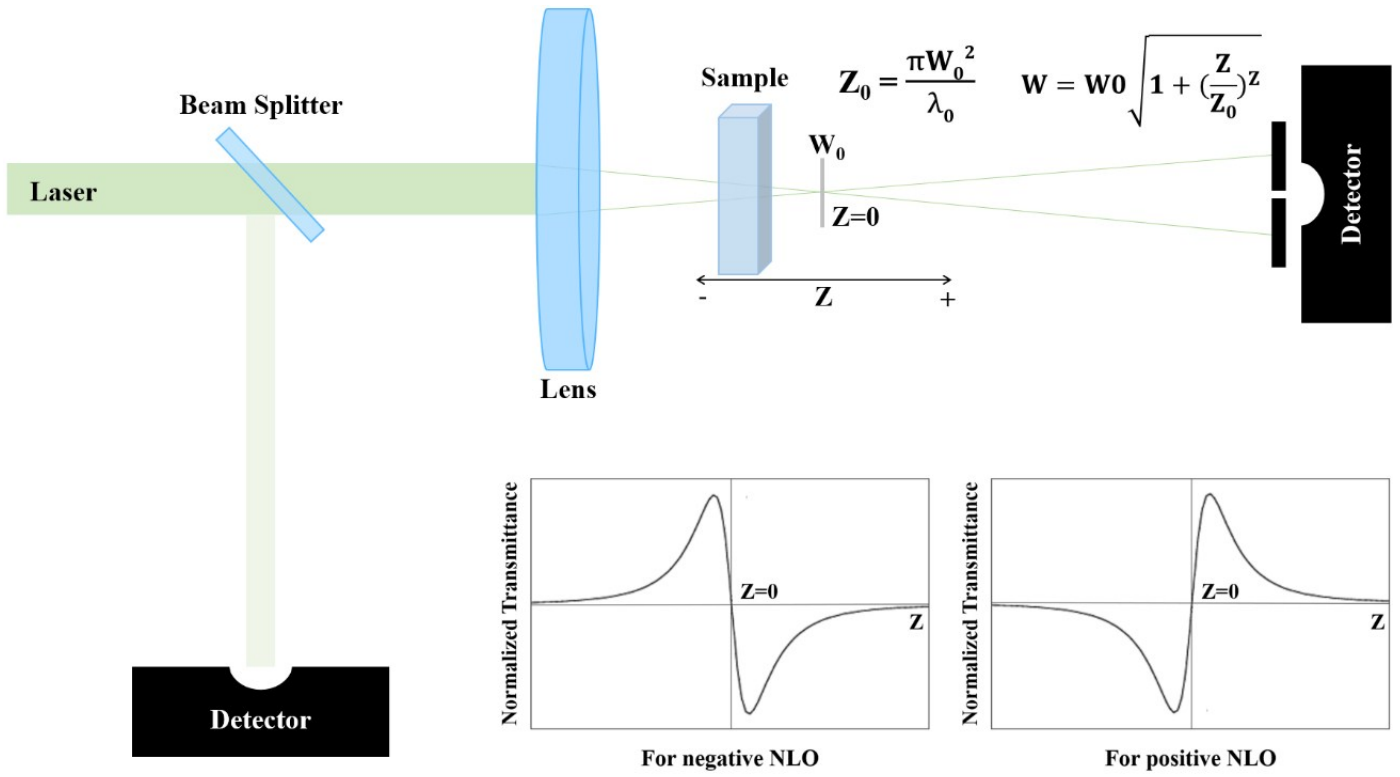
powders. FT-IR spectroscopy was performed on a Shimadzu Model Prestige-21 FT-IR spectrometer in the range 400-4000 cm^{-1} . UV-Vis absorption spectroscopy was obtained with a UV-1501 spectrophotometer, Shimadzu, Japan. The pH was measured with a pH meter (Oakton 35425-10).

NLO study. In the NLO experiments, operation, measurement and corresponding calculations were carried out as in our previously reported study.[S1] To measure the nonlinear phase shift of the incident laser beam, a continuous wave (cw) Ar-ion laser of 514 nm wavelength was used. Four scans were carried out with respect to four laser powers (50 μW , 500 μW , 1000 μW , and 5000 μW). The studied nanofluid was placed in a 2 mm quartz cuvette to ensure the optical path length to be 2 mm. During the Z-scan measurements, a Gaussian shaped (TEM00) laser beam was focused onto the sample through a convex lens of focal length 7.56 cm. Translation of the sample along z-axis was accompanied by a beam splitter (**Scheme S1**) and baseline correction was done by using water as background. For each Z-scan, five readings were recorded, and the standard deviation of the readings was used as experimental error. The sample was moved from left to right, with the focus of the convex lens in the center ($Z=0$) and using a far-field optical detector to record the fractional intensity change originating from the variable irradiance caused by the translation of the sample. The variation in transmittance was measured in the far-field optical detector (**Scheme S1**). This nonlinear transmittance (n_2) can be related to a nonlinear phase shift ($\Delta\phi$) by Equation (1).[S1]

$$n_2 = \frac{1}{kL_{eff}} \frac{\Delta\phi}{I_0} \quad (1)$$

Where $L_{eff} = \frac{1 - e^{-\alpha L}}{\alpha}$, α is the linear absorption coefficient and L is the sample length. I_0 is the incident intensity. The details of mathematical description related to such NLO system has been described elsewhere.[S1]

[S1] M. Biswas, M. Amin, P. Das, E. Hoque, S. Sharafuddin, M. Younus, S. Das and Y. Haque, *J. Nonlinear Opt. Phys. Mater.*, 2015, **24**, 1550039.



Scheme S1 Schematic diagram of closed aperture single beam Z-scan technique.

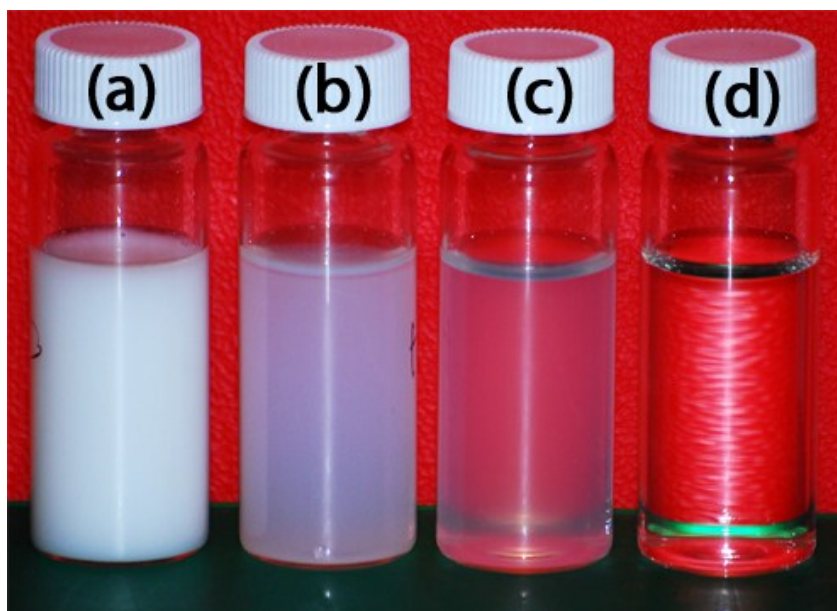


Figure S1 The concentration of chloride ions in the gel is qualitatively determined by adding a silver nitrate solution to the supernatants collected after each washing step (with water). (a, b, c) Photographs of the supernatants after addition of the silver nitrate solution ((a) supernatant after the first washing, (b) supernatant after the second washing, and (c) supernatant after the third washing). (d) Pure water with silver nitrate solution (blank sample).

Note on Figure S1: According to the experimental procedure for the synthesis of 1D-Sn(IV) hydroxide nanofluid, a brilliant white color gel was obtained after washing the gel with ethanol. The gel was kept in a centrifuge tube and shaken with 50 mL of ultrapure water. The supernatant and the gel were separated by centrifugation at 6,000 rpm and the supernatant was carefully collected. This step was repeated three times in order to reach a chloride-free system. Indeed, the 4th supernatant could not be extracted through centrifugation due to the high stability of the resulting nanofluid. The presence of chloride ions in the supernatants was qualitatively determined adding 2 mL of a silver nitrate solution (0.5 g silver nitrate was dissolved in 10 mL of 2M nitric acid solution) to each one of the three supernatants, as well as to a reference sample (pure water). In **Figure S1a-d**, the chloride ions in the supernatants reacted with the silver nitrate to form white colored silver chloride particles. The gradual increase in transparency, from **Figure S1a** to **Figure S1c**, is a direct evidence of the decreasing concentration of chloride ions.

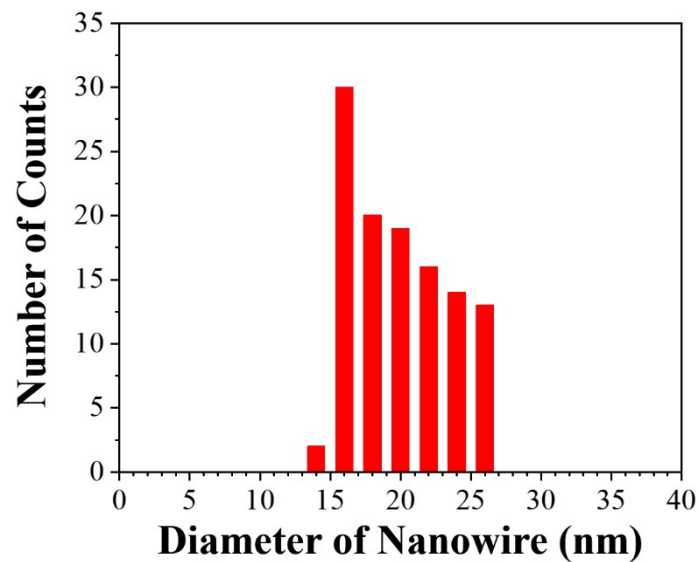


Figure S2 Histogram representing the Sn(IV) hydroxide nanowire diameters.

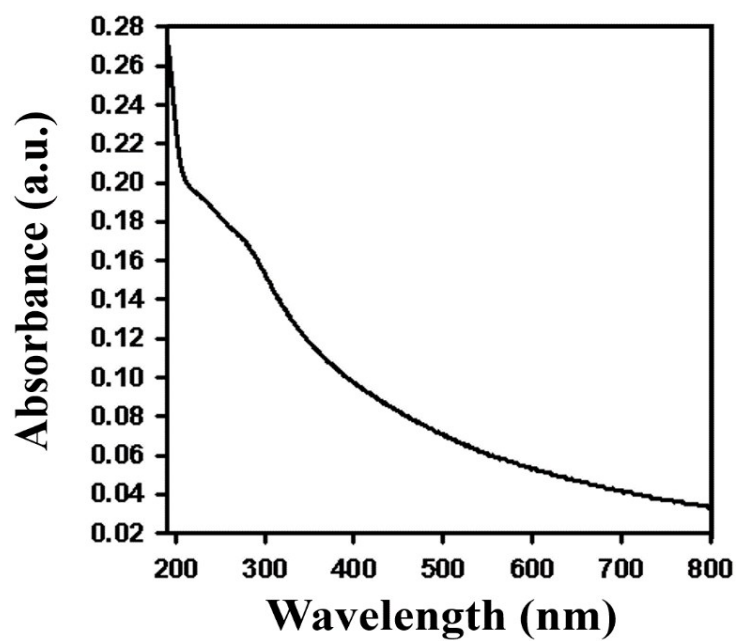


Figure S3 UV-Vis spectrum of the TMHO.

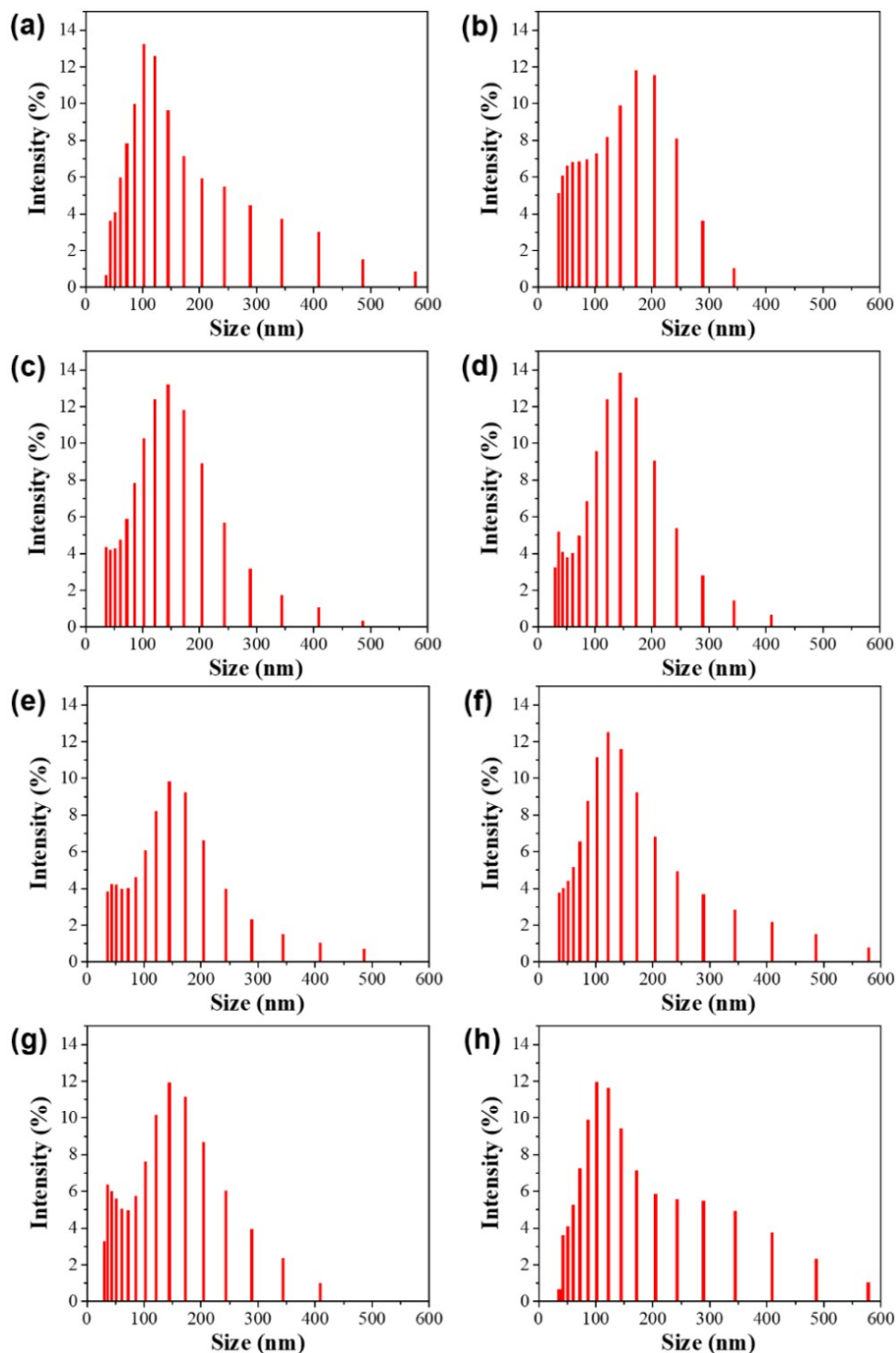


Figure S4 Effect of the applied pHs on the average size of 1D-Sn(IV) hydroxide nanowires in the nanofluid ((a) without any additives, (b) pH=4, (c) pH=5, (d) pH=6, (e) pH=7, (f) pH=8, (g) pH=9, and (h) pH=10).

Note on Figure S4: The pHs (4-10) were controlled by the addition of buffer solutions made previously by mixing of an appropriate volume of 1.0 M nitric acid solution to 1.0 M sodium hydroxide solution. Briefly, 1 mL of the nanofluid was kept in a 50 mL test tube and then 10 mL of the buffer solution was added. The mixture was shaken well and then the corresponding pH was measured.

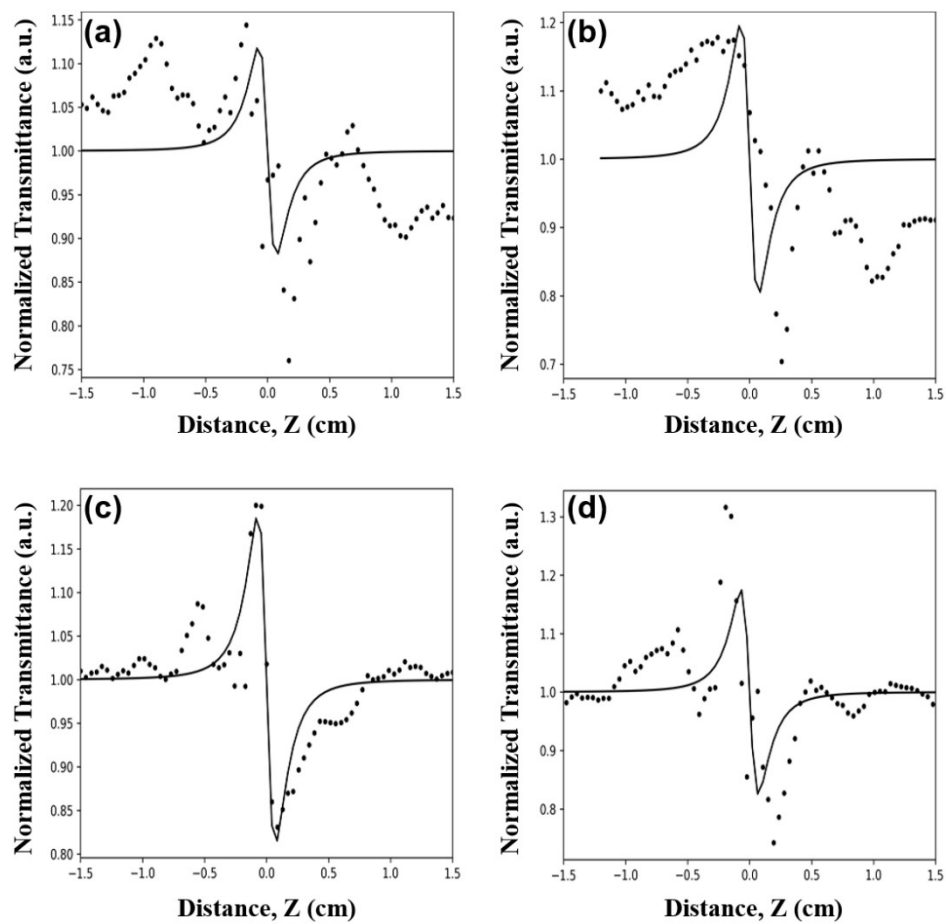


Figure S5 Closed aperture Z-scan transmittance trace of Sn(IV) oxide nanoparticles for (a) 50 μW (b) 500 μW , (c) 1000 μW and (d) 5000 μW incident power at 514 nm laser beam.