White-light controlled ferromagnetic and ferroelectric properties in multiferroic single-crystalline $BiFeO_3$ nanoflowers at room temperature

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Supplementary Information

XRD and EDX measurement

Microstructure of $BiFeO_3$ nanoflowers was characterized at room temperature by X-ray diffraction (XRD, Shimadzu XRD-7000 X-ray diffractometer) with Cu Kα radiation, as shown in Figure 1(a). We put $BiFeO_3$ nanoflowers powder with mass about 2 g on a glass plate, and characterized the sample by XRD for 2θ range from 15° to 80°, where the scan speed is 1.5° per minute.

The EDX and SEM data of $BiFeO_3$ nanoflowers were characterized using scanning electron microscopy at room temperature (SEM, JSM-6510). Firstly, we dissolved $BiFeO_3$ nanoflowers in alcohol, then, it was dispersed on a piece of aluminum. After alcohol was volatized, EDX and SEM characterization were carried out.

TEM and HRTEM measurement

TEM and HRTEM images and SAED patterns were recorded digitally with a SIS charge-coupled device (CCD) camera and TEM analysis software on a JEOL 2010 electron microscope operating at 200 kV at room temperature. Firstly, we dissolved the $BiFeO_3$ nanoflowers in alcohol, then, it be dispersed in a copper grid. After dried for 4 hours at 60 °C, the sample was put in the

TEM high vacuum cavity for TEM characterization. In order to demonstrate the $BiFeO_3$ nanoflowers are single crystalline, we selected several $BiFeO_3$ nanoflowers to do HRTEM images and selected area electron diffraction (SAED). The results show that the $BiFeO_3$ nanoflowers are single crystalline.

Magnetic measurement

Magnetic properties were characterized by a vibrating sample magnetometer (VSM) from ADE Corporation in USA. For the saturation magnetization measurement, the sample with mass 0.1 g packed in small glass box was measured. For the white-light-controlled ferromagnetism and the temperature-dependent magnetization measurement, the sample with much less mass was uniformly dispersed on adhesive plastic tape for measurement. In order to evenly illuminate these $BiFeO_3$ nanoflowers, the sample with much less mass was used for measurement. The magnetisms of the small glass box and the plastic tape were firstly measured and then subtracted from the measured magnetism of the sample. The light power density was controlled by changing the distance between the sample and the lamp. The light power density was measured by irradiatometer. In order to exclude the thermal effect of the lamp on the sample, the distance between the sample and the lamp was always more than 30 cm. In addition, we used a local temperature sensor to test the effect of heating during illumination again, and we found there was a temperature increase of about 4^oC after our sample was illuminated by white light with power density 65 mW/cm^2 for 1 hour. The magnetization of the $BiFeO_3$ nanoflowers with at applied magnetic field 0.1 T decreases just about 0.28% when its temperature increases from room temperature 16^oC to 20^oC (not show here).

Therefore, we can eliminate the influence of white-light heating on magnetic properties of $BiFeO_3$ nanoflowers.

Ferroelectric measurements

The measurements of ferroelectric hysteresis loops (P−E) were performed by a Precision Premier Workstation ferroelectric test system (Radiant Technology, USA) at room temperature. First, we dissolved $BiFeO_3$ nanoflowers in alcohol, and then, it was dispersed on an insulated silicon substrate with SiO_2 layer. After dried for 4 hours at 60 ^oC, the silicon substrate with $BiFeO_3$ nanoflowers was covered mask plate, and placed into a vacuum deposition system. Then, many Ag electrodes were deposited on the surface of silicon substrate. In order to measure the ideal data, we tested one by one electrode during the ferroelectric measurements to exclude the poor electrode contact. An ordinary filament lamp was used as light source in this experiment. And in order to exclude the thermal effect of the lamp on the sample, the distance between the sample and the lamp is always more than 30 cm. Because the cross-sectional areas of these $BiFeO_3$ nanoflowers are unknown, the unit of the measured ferroelectric polarization P is μC.