HiSST: 3rd International Conference on High-Speed Vehicle Science Technology
14 -19 April 2024, Busan, Korea

Optical, magnetic, and structural stability analysis of PbS nanoparticles using a shock tube

P. Sivaprakash[1], Surendhar Sakthivel[1], Ki-Won Kim[1], Ikhyun Kim[2]*

Abstract

Developing materials with high stability in such an atmosphere is crucial for meeting the actual needs of practical applications because the majority of functional materials lose their crystallographic sustainability at high temperatures and pressures under shock-loaded conditions. A series of shock pulses with Mach values 2.2 of 100, 200, and 300 have been applied to the PbS nanomaterials with an interval of 5 sec per shock pulse. To investigate the crystallographic, electronic, and magnetic phase stabilities, powder X-ray diffractometers (XRD), diffused reflectance spectroscopy (DRS), and vibrating-sample magnetometers (VSM) are used. The material exhibits a rock salt structure (NaCl-type structure), and the XRD indicates that it is monoclinic with the space group C121 (5). Further, the shift was observed as a result of the lattice's contraction and expansion when the material was subjected to shock loading, which indicated the material's stable structure in XRD.

Keywords: *PbS nanoparticles, Stability analysis, Shock tube*

1. Introduction

Recent studies have shown that semiconducting sulfide nanoparticles, in particular, are structurally stable at room temperature and pressure, but that their properties become highly pretentious under non-ambient conditions. In specific, it is crucial for both academic study and practical uses of crystalline materials to have a firm grasp of their polymorphic character, whether in bulk or nanoform. To learn about the polymorphic qualities of the proposed sample, the static pressure and temperature-driven phase transition techniques are commonly used. Interestingly, there has been much research conducted for PbS at ambient pressure and temperature but the investigations on extreme conditions are very rare.

Shock waves differ from other common types of waves like pressure waves and sound waves in how they behave and interact with materials. Regardless of the distinctive nature of shock waves, the study of their effects when they come into contact with various materials has seen a significant surge in recent years, which has led to the development of a variety of new applications such as biology, engineering, aerodynamics, medical.

In this study, the isothermal magnetization has been measured for ambient and shock wave samples, superparamagnetic behavior changed to diamagnetic at higher shock conditions (300 shock pulses) due to the unraveling of the alignment of magnetic moments within the material under shock wave flow conditions. Based on the data obtained, we believe that the title PbS nanomaterials is a good choice for high-pressure, high-temperature, and aerospace applications due to its superior shock resistance characteristics.

[1] *Department of Mechanical Engineering, Keimyung University, Daegu 42601, Republic of Korea*
[2] *Department of Mechanical Engineering, Keimyung University, Daegu 42601, Republic of Korea, kimih@kmu.ac.kr*

2. Experimental details

The nanomaterials of PbS have been purchased commercially from Sigma Aldrich with a purity of 99.99 %. Shock waves are produced in the current experiment by a table-top, pressure-driven, semi-automatic shock tube. By utilizing the appropriate diaphragms, this shock tube can produce shock waves with Mach values ranging from 1 to 5. It is divided into three parts: a driver portion, a driven section, and a diaphragm. Common terminology designates the driven part as the lower-pressure segment and the driver section as the higher-pressure section.

3. Results and discussion

The samples have been subjected to a series of shock pulses with Mach values 2.2 of 100, 200, and 300 at intervals of 5 seconds. Powder X-ray diffractometers (XRD), diffused reflectance spectroscopy (DRS), and vibrating-sample magnetometers (VSM) are employed to examine crystallographic, electronic, and magnetic phase stabilities.

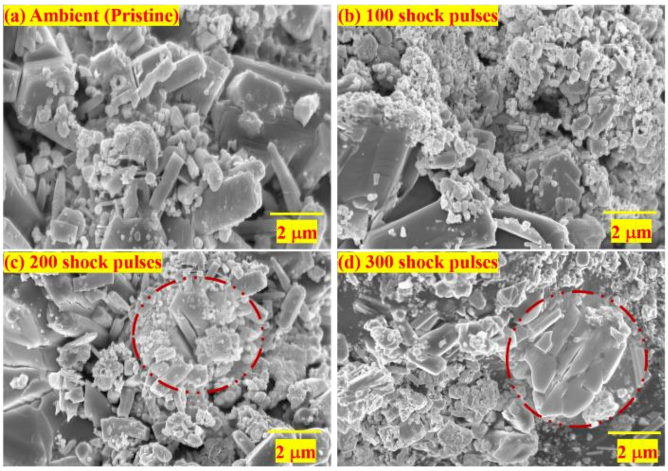

Fig 1. FESEM images of ambient and shocked PbS NPs

Under shock wave loaded conditions of 100, 200, and 300 shock pulses, grain size (D) and volume (V) decrease, and these changes provide indisputable proof that lattice disorder occurs. In contrast to the ambient PbS NPs, which have a stable monoclinic structure, the shocked PbS NPs exhibit lattice deformations and disorders. Due to increased transient pressure in shocked conditions, it may lose its native crystal geometry and produce a deformed crystallographic phase.

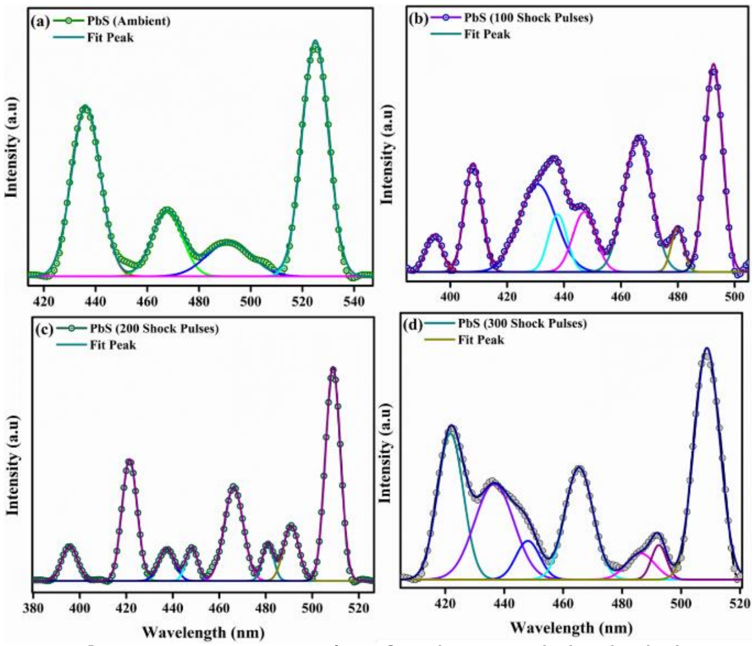

Fig 2. PL spectra results of ambient and shocked PbS NPs

4. Conclusion

We have carefully examined the structural, optical, morphological, and magnetic characteristics of the commercially available PbS NPs under shock loads of up to 300 and a Mach number of 2.2. The material has a monoclinic structure, which the powder XRD confirms. It is extremely stable under shock-loaded conditions, and we have seen a shift in angle from higher to lower owing to lattice expansion and contraction. In both the case of UV-DRS and PL measurements, a similar pattern has been noted.

Acknowledgment

This work was supported by a National Research Foundation of Korea (NRF) grant funded by the Korean Government (MSIT) (No.2022R1C1C1006414).

References

1. A. Sivakumar et al., Structural Phase Stability Analysis on Shock Wave Recovered Single- and Polycrystalline Samples of NiSO4.6H2O, JOM (2023), https://doi.org/10.1007/s11837-023-06023-x.
2. K. Giribabu, R. Suresh, R. Manigandan, L. Vijayalakshmi, A. Stephen, V. Narayanan, Hydrothermal synthesis of lead sulphide nanoparticles and their electrochemical sensing property, Adv. Mater. Res., 584 (2012) 276–279.
3. A. Sivakumar, A. Rita, S. Sahaya Jude Dhas, and S. A. Martin Britto Dhas, "Tuning of surface plasmon resonance of silver nano particles by shock waves for plasmonic device applications," Opt. Laser Technol., vol. 128, p. 106235, Aug. 2020, doi: 10.1016/j.optlastec.2020.106235.
4. M.S. Bakshi, P. Thakur, S. Sachar, G. Kaur, T.S. Banipal, F. Possmayer, N.O. Petersen, Aqueous phase surfactant selective shape-controlled synthesis of lead sulfide nanocrystals, J. Phys. Chem. C., 111 (2007) 18087–18098.