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# Characterizations the PbS Nanoparticles Prepared by Plasma Induced Chemical Reaction

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## Abstract

The research target explores how the bursting current and sodium sulfate ($Na_2S$) concentration affect the structural and morphological properties of lead sulfide (PbS) nanoparticles. Three currents of 50, 60, and 70 A were run via a 0.5 mm-diameter lead wire. By dissolving 1, 0.75, 0.5 g of the sodium sulfate in 100 ml of water, 3 concentrations of sodium sulfate salt 10, 7.5, and 5 mg/cm$^3$ were obtained. The sulfur ions react with lead ions when the wire explodes, producing PbS nanoparticles. X-ray diffraction analysis (XRD) of the particle structure revealed a face centered cube arrangement (fcc). The nanoparticles' size and form were detected utilizing a scanning electron microscope (SEM). SEM images showed that the PbS nanoparticle is spherical and that there is a correlation between the current and the size of the nanoparticles. The average particle size was measured at 30, 24, and 36 nm at currents of 50, 60, and 70 A, respectively. The variation in lead sulfate concentration slightly impacted the morphology and dimensions of the particles. This enables us to deduce the viability of creating lead sulfate nanoparticles in an easy, cost-effective, high-purity, and environmentally friendly technique.

**Article Info.**

**Keywords:**
*PbS, Nanoparticles, Morphology, FTIR, Exploding Wire System.*

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## 1. Introduction

Nanoparticles, or particles smaller than 100 nm, and their production have catch a great deal of attention in the field of materials science in recent years [1]. These materials frequently differ from comparable coarse materials in terms of their structures and features [2-4]. Lead sulfide (PbS) is a significant semiconductor in the IV-VI family with a high mobility and a low forward gap. Despite being greater than 10 nm in size, PbS nanoparticles seem to have a strong quantum effect. At normal temperatures, lead sulfide has a Bohr excitation radius of 18 nanometers, which draws greater attention to the material [5, 6]. There are several different uses for PbS, including ion-selective sensors [7-10], renewable energy sources [11], telecommunications, laser diodes, and solar control layer adjustable infrared lasers [12, 13]. The dielectric constant and carrier mobility of PbS are both relatively high. Several ways are used to produce PbS nanoparticles, such as chemical synthesis [14-17], precipitate formation [18], and thermal decomposition [19]. Our method is in a plasma-enhanced chemical procedure to prepare PbS nanoparticles. A sulphur source, like sodyum sulphate, is solubilised in water to form the solution. A lead wire detonates upon exposure to a strong electric current. As current traverses a lead wire, plasma is generating, resulting in an increase in temperature and pressure. Lead ions are also produced, and in this environment, they mix with sulfur ions to form PbS nanoparticles. By changing the concentration of the sulfur solution, these nanoparticles' size and shape may be modified. Subsequently, we analysed the PbS nanoparticles utilising Fourier' transform infrared' spectroscopy (FTIR), X-ray diffraction (XRD), and scanning electron microscopy (SEM). This production method is easily scalable and cost effective for manufacturing quantities of PbS particles. It is important to adopt this approach due to its reliability, cost effectiveness and the requirement for one solution. Moreover, the technique, for producing the nanoparticles does not require a vacuum or use machinery [20-22].

## 2. Experimental Work

Fig. 1 shows an overview look at the explosive wire apparatus employed for the creation of PbS nanoparticles. The procedure of preparing PbS nanoparticles involves causing an explosion within a sulfur-containing solution. In this method, a 0.5 mm lead wire and a 5 mm thick lead plate (4x4 cm) were placed in a aqueous sulfur solution. The plate is connects for the positive terminal of a power source, while the wire is attached to the negative terminal. The circuit is supplied with a DC voltage of 82 V. The completion of the electrical circuit occurs upon mechanical contact between the wire and the plate, exposing the wire for a high electric current density that ultimately causes it to burst. Different current levels 50, 60, and 70 A were used. During its current passes through lead wire, plasma is generated, leading to elevated pressure and temperature, alongside the formation of lead ions that react with sulfur ions' to yield nano-sized' PbS particles. By changing the reaction conditions', such as the solution concentration and the applied current—allows one to control the size and structure of the nanoparticles. Through the process of dissolving 1, 0.75, and 0.5 g of sodium sulfate in 100 mL of distilled' water, aqueous lead sulfate concentrations of 0.020, 0.031, and 0.042 M were generated. A centrifuge device spinning at 5,000 rpm separates the generated particles from the liquid. Scanning electron microscopy, Fourier-transform infrared microscopy, and X-ray diffraction were used to study PbS nanoparticles.

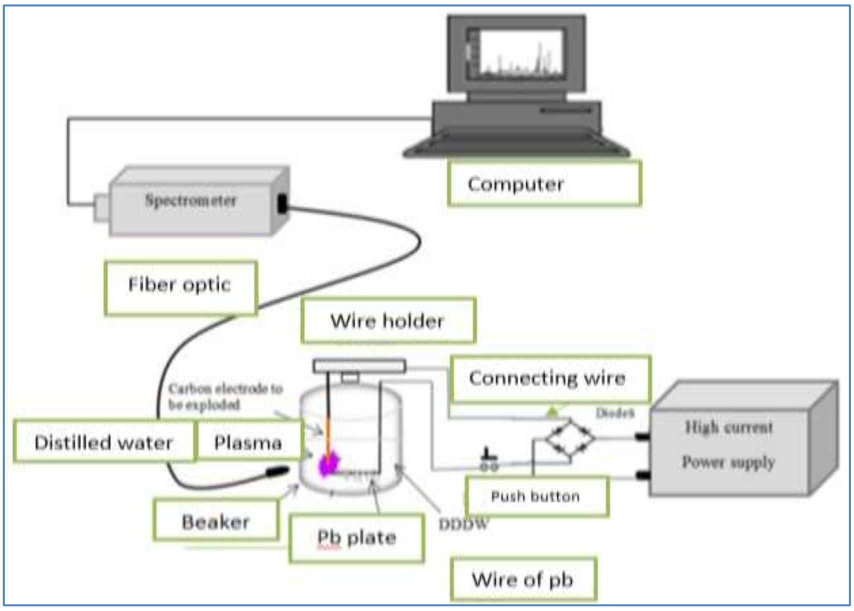


***Figure 1: Schematic of the explosive wire apparatus employed for the preparing of PbS nanoparticles.***

## 3. Result and Discussion

### 3.1. XRD Analysis

The PbS nanoparticles' X-ray diffraction' patterns are shown in Figure 2. Peaks in the XRD patterns for the PbS nanoparticles were quite similar to those in the typical face-centered cubic PbS structure. The diffraction peaks correspond to the PbS crystalline planes (111), (200), (220), (311), (222), (400), (331), (420), and (422). No distinctive peaks form other phases were observed, indicating that the synthesis resulted a pure PbS a compound. The findings are very consistent with the data's established reference values (JC-PDS No. 96-900-8840). The average particle' size for a 70-ampere current was determined using Scherrer's equation, Eqn 1. The mean size of the particles had been 32.7 nm at a concentration of 10 $mg/cm^3$, 20.5 nm at 7.5 $g/cm^3$, and 15 nm at 5 $mg/cm^3$. This indicates that as the concentration increases, so does the average particle size. At higher concentrations, particles have a greater possibility of colliding and sticking to each other, forming larger particles [23].

$$D = \frac{k\,\lambda}{\beta\,\cos\theta} \tag{1}$$

where: λ equals 0.15406 nm, the wavelength of the X-ray source, D denotes the crystallite size in nm; K is the Scherrer constant, valued at 0.9; β signifies the Full Width at Half Maximum (FWHM) in radians; and θ represents the Bragg angle in radians [24].

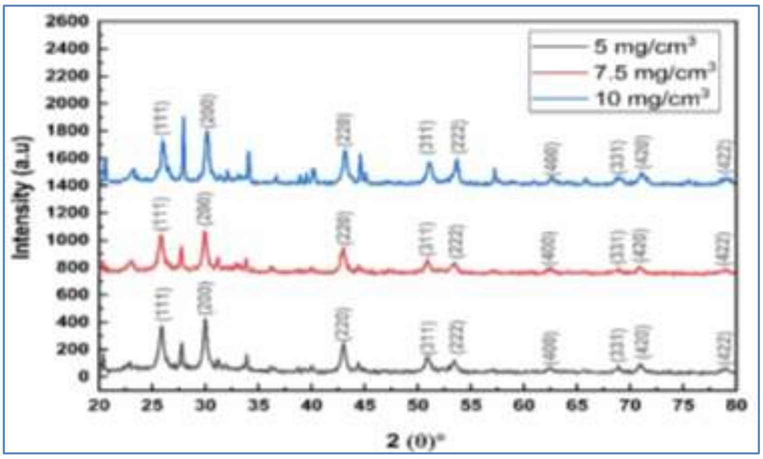
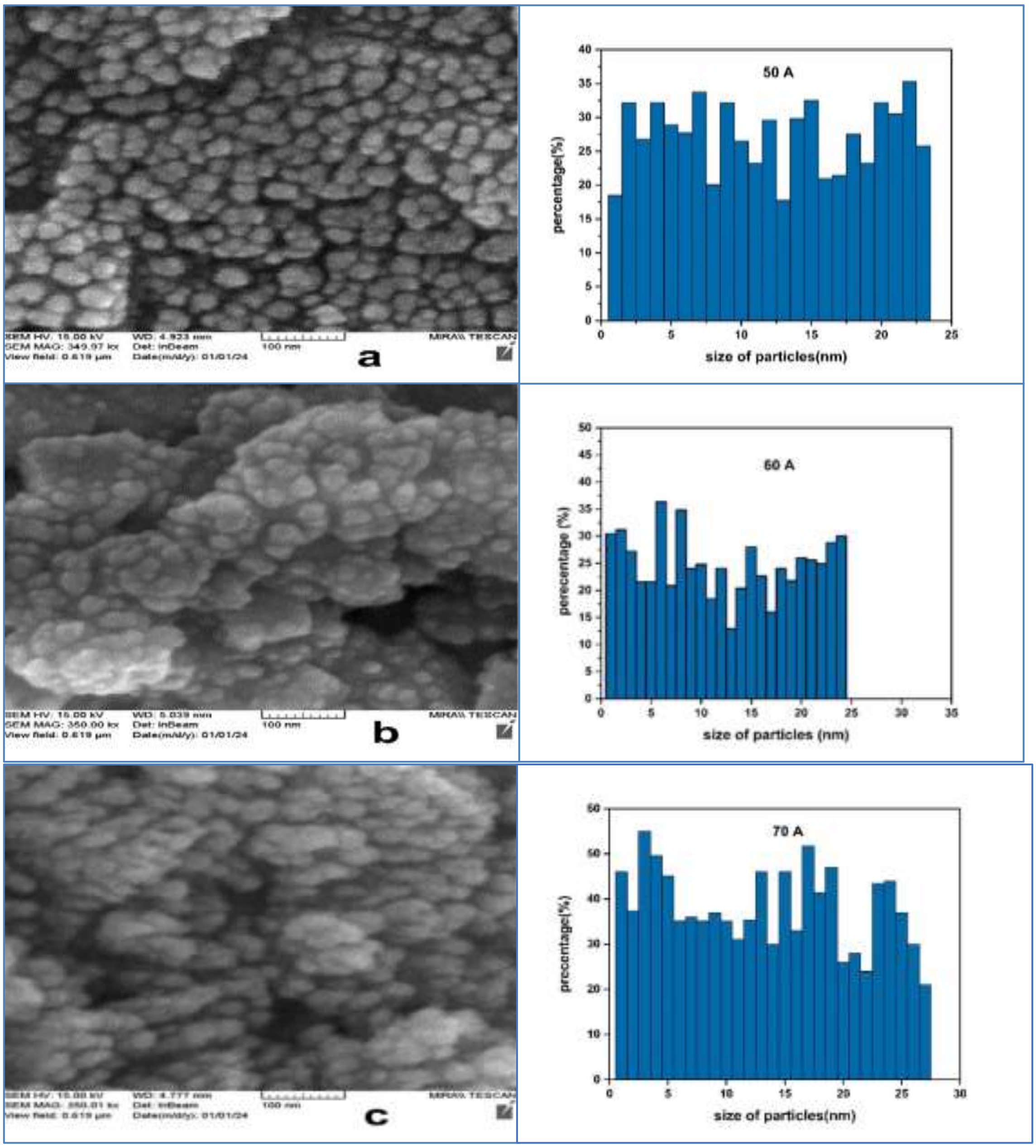


***Figure 2: At a current of 70 A, XRD diffraction patterns of PbS were observed at three different concentrations of aqueous sodium sulfate: 0.5, 0.75, and 0.1 $mg/cm^3$.***

## 3. 2. Scanning Electron Microscope Images

Fig. 3 shows the scanning electron microscope (SEM) images with the statistical distribution of the PbS nanoparticles prepared by three currents 50, 60, and 70A where the concentration of aqueous sodium sulfide salt was 10 $mg/cm^3$. From the SEM images and the statistical distribution of the prepared lead sulfide particles, it was evident that the particles exhibited a narrow statistical distribution, and were nearly spherical in shape with minimal aggregation. The electrical current influenced both the average particle size and their statistical distribution. The average particle sizes were 30, 24, and 36 nm for currents of 50, 60, and 70 A, respectively. Generally, the best statistical distribution was observed at a current of 50 A, where most of the particles within the distribution range were approximately the same size. A narrow statistical distribution indicates that the particles are nearly uniform in size. Based on the shape of the particles and their statistical distribution, it is possible to prepare lead sulfide nanoparticles with a narrow range of particle sizes by controlling the current at a fixed wire diameter. The most important applications of PbS nanoparticles are found in the range of 10-18 nm. At ambient temperature, the Bohr excitation radius measures 18 nm, so PbS is receiving significant attention from scientists [2, 3].



***Figurer 3: Scanning electron microscope images with statistical distribution of the PbS nanoparticles prepared by three currents of (a) 50 A, (b) 60 A, and (c) 70 A where a concentration of aqueous sodium sulfide salt 10 mg/cm$^3$.***

## 3.3. Fourier-Transform Infrared (FT-IR) Analysis

Fig. 4 shows the FTIR spectrum for PbS nanoparticles. The spectrum shows a broad band between 3200 and 3500 cm$^{-1}$ due to the intermolecular hydrogen bonding in the water molecules. The stretching frequency of 3423.41 cm$^{-1}$ contributes to the O-H bond; water is the cause of the appearance of this group. The peaks seen at 621.04 and 453.24 cm$^{-1}$ are the distinctive peaks that indicate the presence of PbS. The peak at 453.24 cm$^{-1}$ is assigned to Pb-S stretching vibrations. The peak at 1647.10 cm$^{-1}$ corresponds to CO adsorbed on the PbS nanoparticles surface. All peaks in the FTIR spectrum confirmed that the prepared particles were pure PbS particles. The Pb-S bond is essentially a covalent, and therefore, the FT-IR spectrum of PbS does not show strong peaks of high intensity that belong to the stretching or bending vibrational mode. In PbS, the typically active vibrational mode in IR spectroscopy is the stretching mode of the Pb-S bond. The stretching frequency of the Pb-S bond in PbS generally resides in the infrared spectrum, namely within a wavelength range of 300-500 $cm^{-1}$ [25].

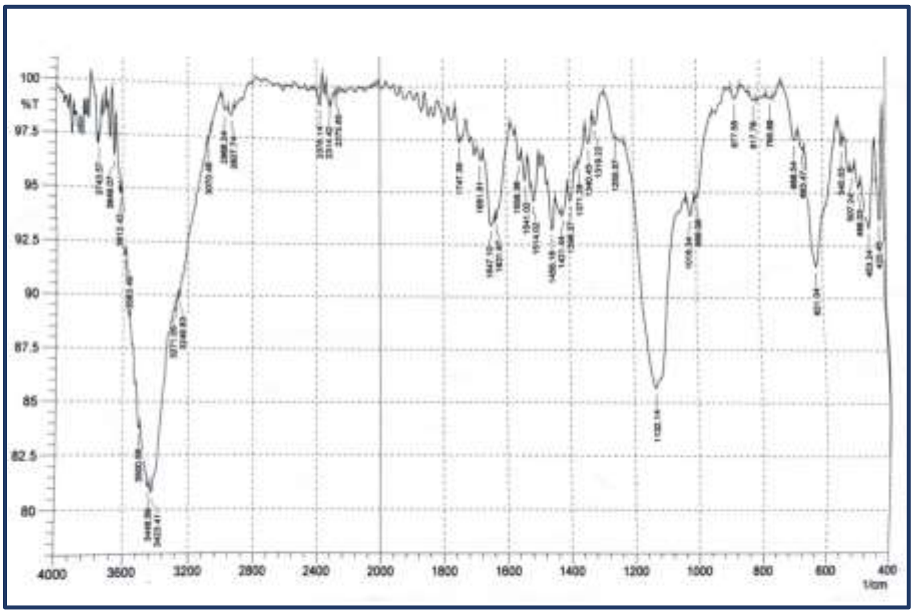


***Figure 4: FTIR spectrum of PbS nanoparticles.***

## 4. Conclusions

This work successfully prepared PbS nanoparticles using the explosive wire method. The exploding process was carried out inside an aqueous solution of sodium sulfate salt. The current and concentration of sodium sulfide salt were used to adjust the nanoparticle size. The statistical distribution of the prepared nanoparticles was narrow, ranging between 3-27 nm for the three currents used. FTIR analysis of the PbS nanocrystals showed the presence of several functional groups, which proved the presence of PbS particles. The explosive wire approach used to create the PbS nanoparticles is simple, inexpensive, prolific, and eco-friendly, as shown in the study.

## Conflict of interest

Authors declare that they have no conflict of interest.

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# توصيف جزيئات PbS النانوية المحضرة عن طريق التفاعل الكيميائي الناتج عن البلازما

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## الخلاصة

هدف البحث هو استكشاف تأثير تيار الانفجار وتركيز كبريتات الصوديوم على الخصائص الهيكلية وعلم التشكل لجسيمات PbS النانوية. تم استخدام نظام الأسلاك المتفجرة أثناء التجربة حيث تم تمرير تيارات مختلفة (50، 60، 70) امبير عبر سلك رصاص يبلغ قطره 0.5 ملم. ثلاثة تراكيز من ملح كبريتات الصوديوم (5، 7.5، 10) ملجم/سم3 حيث يتم تحضيرها بإذابة 1.75،5. جرام من كبريتات الصوديوم في 100 مل من الماء لإنتاج أيونات الكبريت التي تتفاعل مع أيونات الرصاص عند انفجار السلك وينتج عن ذلك تشكيل الجسيمات النانوية PbS. تم تحليل بنية الجسيمات من خلال حيود الأشعة السينية مما يوضح ترتيب المكعب المتمركز حول الوجه (fcc). تم تحديد حجم وشكل الجسيمات النانوية باستخدام المجهر الإلكتروني الماسح (SEM). كشفت صور SEM عن وجود علاقة بين التيار وحجم وشكل الجسيمات النانوية الكروية، وتم قياس متوسط حجم الجسيمات ليكون 30 و24 و36 نانومتر عند التيار 50 و60 و70 أمبير على التوالي. كان للاختلاف في تركيز كبريتات الرصاص تأثير طفيف على شكل وأبعاد الجسيمات. وبناءً على ذلك، يمكننا استنتاج جدوى إنتاج جزيئات كبريتات الرصاص النانوية باستخدام طريقة بسيطة وفعالة من حيث التكلفة وعالية النقاء ومستدامة بيئياً.

**الكلمات المفتاحيه:** جسيمات PbS النانوية، علم التشكل المورفولوجيا، مطيافية الأشعة التحت الحمراء، سلك متفجر.