

# Formation Mechanism and Microstructural Analysis of Silver Nanoparticles Synthesized by Chemical Route using Sodium Borohydride

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**Abstract:** Silver nanoparticles (Ag NPs) have synthesised by various methods. This research article presents Ag NPs synthesized using sodium borohydride reduction method and characterization X-ray diffraction (XRD), transmission electron microscopy (TEM). XRD data supported the crystalline nature of the Ag NPs. TEM images of Ag NPs displayed an approximate 28 nm spherical shape

**Keywords:** Silver Nanoparticles, Synthesis Route, Sodium Borohydride, XRD, TEM.

## I. INTRODUCTION

In recent years, the landscape of nanotechnology has undergone profound shifts, reshaping diverse industries and scientific. Within this transformative realm, silver nanoparticles (Ag NPs) have emerged as pivotal actors due to their distinctive physicochemical properties and wide array of potential applications. Possessing multifaceted attributes, Ag NPs exhibit properties such as antimicrobial efficacy, catalytic potential, and optical intrigue. Beyond these established functionalities, the antioxidant capabilities of Ag NPs have garnered substantial attention, with implications spanning biomedical advancements to environmental solutions.

Central to ongoing research endeavours is the exploration of various synthesis routes for Ag NPs, and their consequential influence on attributes and functionalities. Different synthesis methods lead to the creation of Ag NPs with diverse morphologies, sizes, and surface functional groups, which in turn influence their biological and catalytic behaviour.

The synthesis spectrum, chemical methods employing sodium borohydride hold their ground. Chemical reduction methodologies are well-established and offer precise control over nanoparticle attributes. Sodium borohydride, a potent reducing agent, swiftly transforms silver ions into Ag NPs. Typically yielding spherical nanoparticles, this approach allows for subsequent surface functionalization with diverse ligands, broadening their application scope in catalysis and drug delivery.

The synthesis routes wield a decisive influence on the eventual attributes of Ag NPs, encompassing size, shape, stability, and surface chemistry. Characterization of these nanoparticles is paramount for unravelling their properties and potential applications. The current study employs a suite of advanced characterization techniques, including UV-VIS spectrophotometry, X-ray diffraction (XRD), field emission-scanning electron microscopy (FE-SEM), transmission electron microscopy (TEM), and Fourier Transform Infrared Spectroscopy (FTIR) analysis. These methodologies provide insights into the structural, morphological, and chemical dimensions of Ag NPs synthesized via distinct routes.

## II. MATERIALS AND METHODS

- Silver nitrate ( $\text{AgNO}_3$ ) (Sigma-Aldrich, USA) CAS No. 7761-88-8
- Sodium borohydride ( $\text{NaBH}_4$ ) (Sigma-Aldrich, USA) CAS No. 16940-66-2
- Deionized water

### III. CHEMECALLY SYNTHESIS OF SILVER NANOPARTICLES

In the sodium borohydride-mediated approach, the robust reducing potential of sodium borohydride ( $\text{NaBH}_4$ ) was harnessed. A predetermined volume of  $\text{AgNO}_3$  solution was introduced to a reaction vessel, followed by the calculated addition of sodium borohydride under controlled conditions. The swift reduction of  $\text{Ag}^+$  ions to Ag NPs took place, heralded by the emergence of a distinct colour indicating nanoparticle formation. The reaction mixture was continuously stirred for a specified duration to ensure comprehensive reduction. Subsequent to reduction, the Ag NPs were separated through centrifugation and then thoroughly washed to eliminate any unreacted components.

### IV. RESULTS AND DISCUSSION OF SILVER NANOPARTICLES (Ag NPs)

#### X-ray Diffraction (XRD) Analysis

The elucidation of the crystalline structure of the synthesized Ag NPs was achieved through X-ray diffraction (XRD) analysis, unravelling pivotal insights into their lattice arrangement and orientation. The application of XRD data is paramount in confirming the existence of crystalline Ag NPs and delving into their structural attributes. The XRD data decisively attested to the crystalline nature of the synthesized Ag NP. The distinctive diffraction patterns observed were symbolic of the ordered atomic disposition within the nanoparticles, emblematic of crystallinity. The XRD dataset was punctuated by discrete diffraction peaks at precise angles, correlating to specific crystal planes inherent to the Ag NPs. The diffraction angles and peak intensities served as indelible markers of the crystalline configuration and dimensions of the nanoparticles. Within the XRD data, well-defined diffraction peaks were manifest at angles of  $38.09^\circ$ ,  $44.59^\circ$ , and  $64^\circ$  (Fig. 1), correspondingly aligned with the (111), (200), and (220) crystallographic planes of the face-centered cubic (FCC) crystal structure inherent to metallic silver. This congruous pattern was observed synthesized Ag NPs, unaffected by the diversity in synthesis pathways. The identification of diffraction peaks corresponding to the (111), (200), and (220) planes of the FCC crystal structure lent credence to the birth of Ag NPs with a meticulously arranged crystalline layout. This face centered cubic framework is emblematic of metallic silver and acted as a resolute testament to the triumphant synthesis of Ag NPs marked by their distinct crystalline attributes. The XRD data bore direct relevance to the dimensions and interspacing of crystal planes within the Ag NPs. The positions of diffraction peaks and their corresponding angles resonated harmoniously with particular particle size distributions, bequeathing vital insights into the uniformity and crystalline composition of the synthesized Ag NPs.

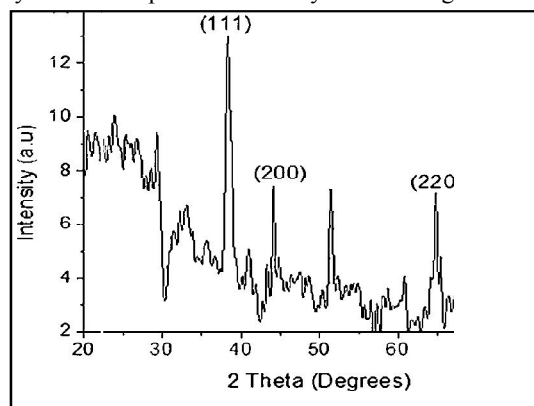


Fig. 1 XRD diffraction spectra of Ag NPs.

#### Transmission Electron Microscopy (TEM) Analysis

The curtain rose on the stage of transmission electron microscopy (TEM) analysis, casting a spotlight on the size, distribution, and intricate details of the synthesized Ag NPs. This technique, akin to a virtuoso performance, allowed for an intimate exploration of the nanoparticle characteristics. Through TEM, the nanoparticles revealed themselves in their truest form, baring their size, shape, and potential congregation. TEM analysis unfurled its canvas to paint a portrait of the synthesized Ag NPs, capturing their size and distribution with precision. The imagery bestowed by TEM served as a

magnifying glass, revealing the unique attributes embedded within the nanoparticles brought to life through diverse synthesis routes. Fig. 2 emerged on the scene, a visual symphony conducted by TEM micrographs and particle size distribution histograms. This exhibition shed light on the nuances of the synthesized Ag NPs, offering a front-row seat to their size and spatial distribution. Like brushstrokes on a canvas, the TEM micrographs imparted distinct morphological traits to the synthesized Ag NPs. The images showcased the sculptural form and architectural marvels hidden within the nanoparticles, a window into their structural soul. In Fig. 2 spotlighted chemically synthesized Ag NPs, a petite ensemble with a diameter of about 7 nm, a testimony to the chemical route's unique finesse in nanoparticle crafting. As the TEM and dynamic light scattering (DLS) measurements entered the spotlight for comparison, the performance was harmonious with past records. DLS, often orchestrating larger sizes compared to TEM, introduced its cadence, dancing to the rhythm of hydrodynamic determinations, aggregation proclivities, solvents, and surfactants.

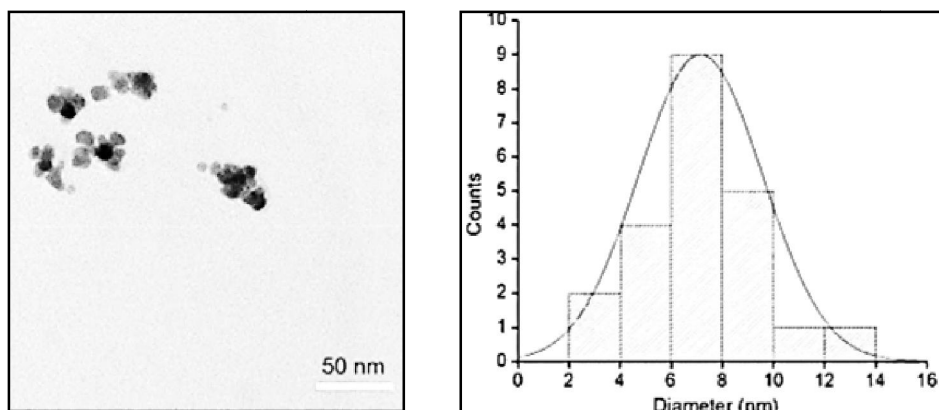


Fig. 2 Transmission electron micrographs and size distribution histograms of Ag NPs

A characterization of the synthesized Ag NPs validated the success of the chemical synthesis route. XRD patterns confirmed the crystalline nature of the Ag NPs, with diffraction peaks corresponding to FCC crystallographic planes. TEM analysis provided insights into the morphological attributes and size distribution.

## V. CONCLUSION

In this study, synthesis and characterization of silver nanoparticles (Ag NPs) through chemical route has been successfully demonstrated. X-ray diffraction (XRD) analysis confirmed the crystalline nature of Ag NPs, exhibiting sharp peaks corresponding to face-centered cubic (FCC) crystallographic planes. Transmission electron microscopy (TEM) revealed the morphology and size distribution of Ag NPs synthesized through diverse methods. Energy-dispersive X-ray spectroscopy (EDX) analysis validated the presence of silver and additional elements in Ag NPs, highlighting the influence of synthesis routes and capping agents. Chemical synthesis highlighted chemical reduction precision in controlling particle size. The synthesis and characterization outcomes provide a solid foundation for further exploration and applications of Ag NPs in various fields. The ability to control Ag NPs properties through this route opens avenues for targeted applications in nanomedicine, catalysis, and environmental remediation. Continued research could delve into optimization, toxicity studies, and advanced applications, contributing to the ongoing advancements in nanotechnology.

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