

Shattering the Bulk: From Polystyrene Target to Nanoparticles via a Magnetron-based Gas Aggregation Cluster Source

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Abstract: In this contribution, for the first time, nanoparticle (NP) sputtering from a polystyrene (PS) target in radiofrequency (RF) mode using a magnetron-based gas aggregation cluster source (GAS) is reported. The influence of varying sputtering power on the characteristics of the resulting NPs was investigated, revealing notable differences in their physicochemical properties with increasing power. This study holds promises for PS-derived functional NPs in advanced optical applications.

1. Introduction

In the 1990s, Haberland et al. introduced the Gas Aggregation Cluster Source (GAS), revolutionizing magnetron sputtering by enabling nanoparticle (NP) synthesis [1]. Solid targets are sputtered with this technique to produce supersaturated vapours, which nucleate into clusters or NPs in a slightly higher-pressure aggregation chamber. The NPs are carried by argon gas to the deposition chamber for collection on high-vacuum-compatible substrates [2]. Although initially used for metallic NPs, Polonskyi et al. showed that polymer NPs can also be produced using radiofrequency (RF) sputtering [3]. This method offers advantages over conventional polymer NP synthesis including high purity, solvent-free synthesis, tuneable NP properties, deposition directionality for patterned surfaces, and more [4]. Here, magnetron sputtering of a polystyrene (PS) target is reported for the first time, with a study on how sputtering power affects the physicochemical properties of the resulting NPs.

2. Methods

A high impact polystyrene (HIPS) target (81 mm diameter and 4 mm thickness) was affixed to a planar magnetron using stainless steel threaded fasteners. NPs were sputtered in RF mode at 164 Pa within the aggregation chamber, with an argon flow rate of 40 sccm for 30 minutes. The effect of sputtering power at 40, 60, and 80 W on NP properties was studied. NP morphology was characterized by field emission scanning electron microscopy (FE-SEM), surface functionalities by X-ray photoelectron spectroscopy (XPS) and Fourier-transform infrared spectroscopy (FT-IR), and optical properties by Ultraviolet-visible (UV-VIS) spectroscopy.

3. Results and Discussion

The FE-SEM images and bar chart from Fig. 1 reveal the effect of sputtering power on NP morphology and size. At 40 W, the NPs are spherical, uniformly sized, and smooth. Increasing the power to 60 W produces larger, rougher particles, indicating the onset of structural complexity. At 80 W, the NPs transformed into cauliflower-like morphologies with aggregated irregular features. The bar chart confirms an increase in average particle diameter and greater size variation at higher powers. This trend may result from the ejection of smaller particles which then

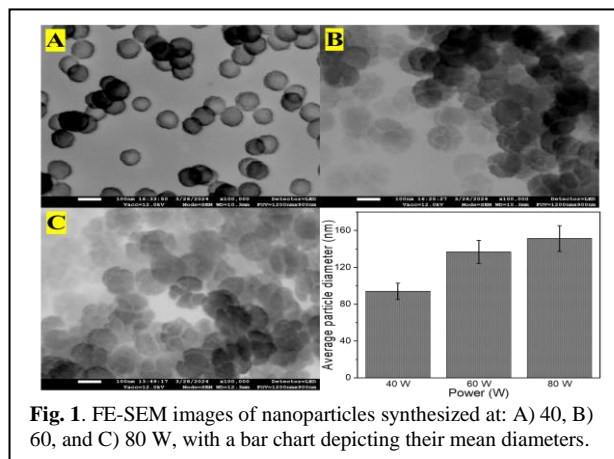


Fig. 1. FE-SEM images of nanoparticles synthesized at: A) 40, B) 60, and C) 80 W, with a bar chart depicting their mean diameters.

aggregate into larger and irregular clusters [4]. FT-IR showed partial transformation of the aromatic rings into aliphatic chains, with peak broadening attributed to the amorphous nature of plasma polymers [4]. Moreover, C=O group formation was observed in NPs at all three power settings consistent with the high resolution XPS. UV-VIS revealed the transparency of NPs obtained at 60 and 80 W in the near-infrared and visible spectrum.

4. Conclusion

This study successfully demonstrated the sputtering of PS-derived NPs in RF mode using a magnetron-based GAS. The effect of sputtering power on NP characteristics was investigated, showing that increased power leads to larger particle sizes, more complex morphologies, and the emergence of new functional groups. Moreover, NPs generated at higher power exhibited transparency in the visible and near-infrared spectrum, indicating their potential for optical applications.

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