Surface Characterization of Cambrian Bioworks' Carboxyl Magnetic Beads using Scanning Electron Microscopy (SEM)

Introduction

This study characterized the morphology, surface features, and particle size distribution of carboxyl (–COOH) functionalized magnetic beads used in the CamSelect NGS formulation (Sample TB84) by scanning electron microscopy (SEM). The analysis assessed particle sphericity, surface topology, and the presence or absence of aggregation, and compared image-based (SEM) particle dimensions against hydrodynamic diameter measured independently by dynamic light scattering (DLS).



Since the beads' surface area, magnetic response, and dispersion behavior are all governed by particle size and its uniformity, physical characterization by orthogonal techniques — direct (dry) phase imaging (SEM) and ensemble solution-phase measurement (DLS) — is a standard part of confirming that a bead lot meets the physicochemical profile required for consistent performance in nucleic acid purification and size-selection workflows.

Materials and Methods

Sample preparation

A representative sample (TB84) of carboxyl (-COOH) magnetic beads was prepared for SEM analysis. The beads were drop-casted onto conductive silicon substrate prior to imaging to minimize charging effects during electron beam exposure. The beads were diluted in an aqueous diluent to a ratio of 1:10.

SEM imaging

SEM imaging was performed using a Zeiss Ultra55 (FE-SEM Carl Zeiss EDS), operating at an accelerating voltage of 5 kV. Images were acquired at multiple magnifications to evaluate particle morphology and population uniformity.

Representative micrographs were captured at magnifications ranging from 10X to 250X, with particular emphasis on visualizing individual particles and particle clusters. Particle diameters were measured from SEM images using image analysis software (Zeiss inbuilt software for particle sizing), by selecting a minimum of n = 36 particles across multiple fields of view.

Particle Size Analysis

Particle diameters obtained from SEM images were used to generate a size distribution histogram. The following parameters were calculated:

- Mean particle diameter (nm)
- Standard deviation (SD)
- Coefficient of variation (CV%)
- Minimum and maximum particle diameter

Results

Morphological Characterization

SEM imaging showed a predominantly spherical bead population with a relatively uniform size distribution and smooth-to-finely-textured surfaces (Fig 1a and 1b). The particle surfaces appeared smooth to finely textured, with no evidence of particle collapse, fracture, or any other significant structural anomalies.

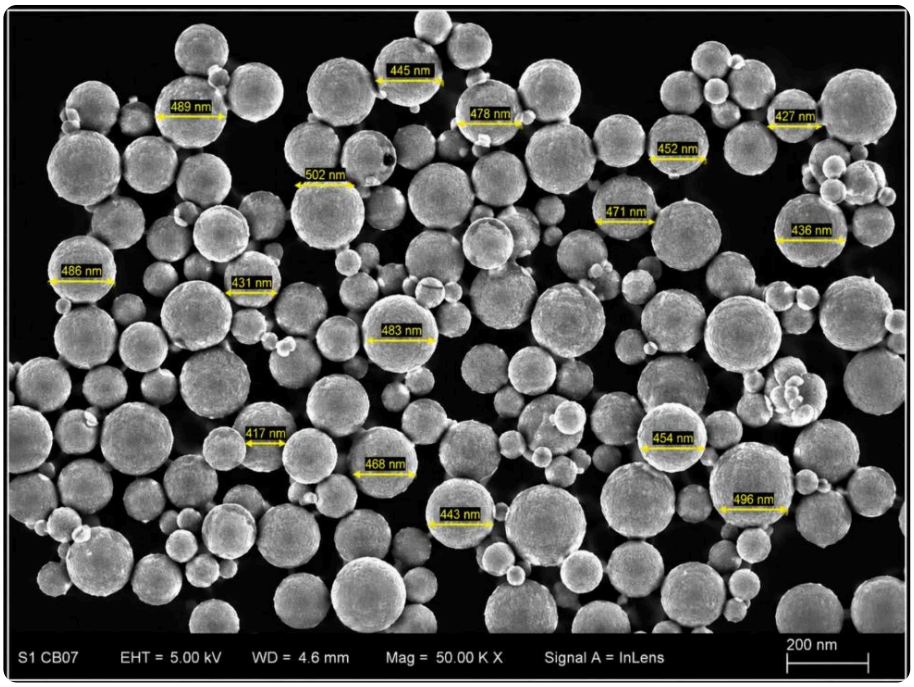

Fig 1a – Representative SEM micrograph demonstrating the morphological uniformity of CamSelect NGS beads. Predominantly spherical particles with smooth surfaces and consistent particle dimensions were observed across the field. Representative diameters are indicated for selected particles to illustrate manufacturing consistency. The morphology is consistent with a highly reproducible bead synthesis process suitable for nucleic acid purification/size selection workflows

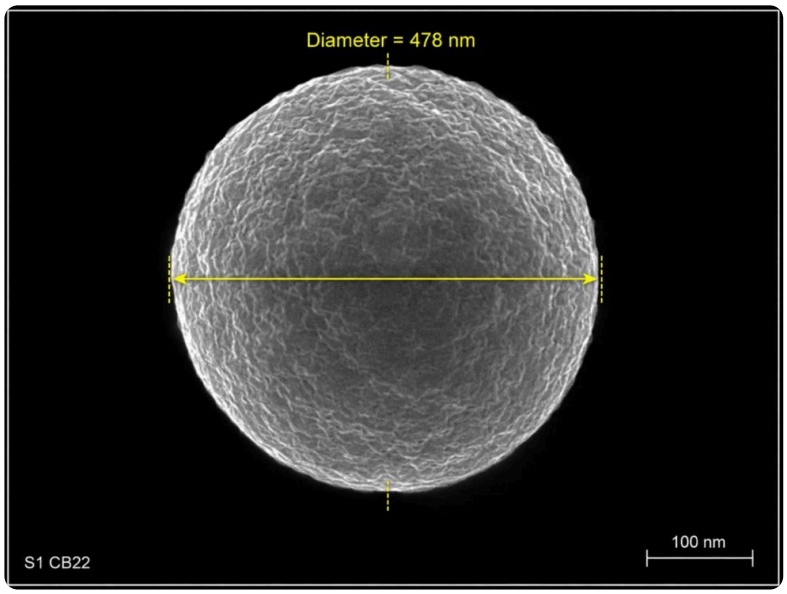

Fig 1b – Representative single-particle SEM image. High magnification visualization of an individual CamSelect NGS magnetic bead highlighting its spherical geometry and intact surface morphology. Direct image-based (Feret) diameter measurement demonstrates agreement with the nominal particle size and supports the dimensional consistency observed across the bead population.

Particle Size Distribution

Image-based particle measurements demonstrated a mean particle diameter of 450 ± 62 nm, with the range being 400-700nm. The resulting size distribution exhibited a unimodal Gaussian profile with no evidence of multimodal populations (Fig 2).

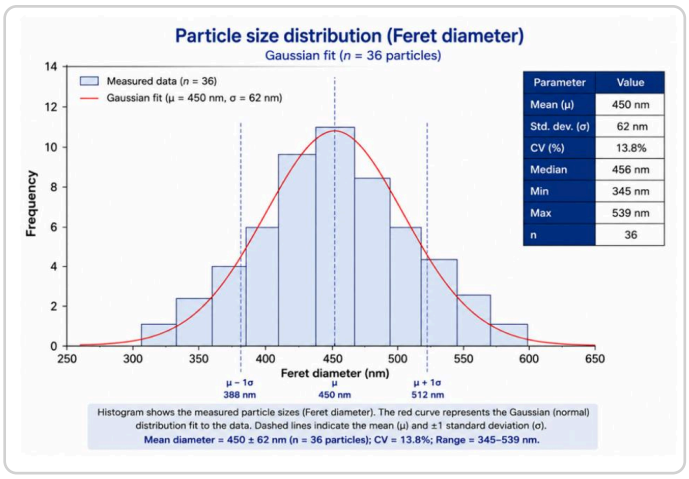

Fig 2

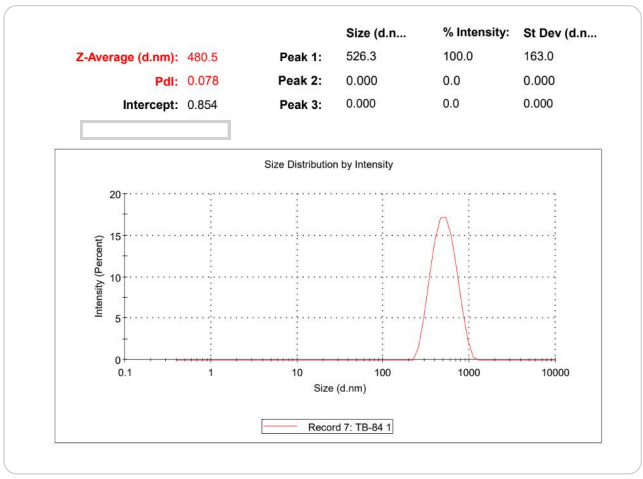

Fig 3

Fig 2. Particle size distribution of CamSelect NGS magnetic beads determined by SEM: Particle diameters were quantified from SEM micrographs using ImageJ software and reported as Feret diameter (nm), defined as the maximum distance across each segmented particle. The histogram shows the measured particle size distribution for n = 36 particles, with an overlaid Gaussian fit shown in red. Dashed vertical lines indicate the mean diameter and ±1 standard deviation. The SEM-derived physical particle size (dry) was found to be comparable with hydrodynamic diameter (aqueous) measurements obtained by DLS, which reported a particle size of 526.3 nm (Fig 3)

Conclusion

SEM analysis confirmed the production of a predominantly spherical and morphologically uniform bead population between 400-700nm. The statistical analysis demonstrated a tight distribution of sizes, indicating a controlled and reproducible manufacturing process. These findings together with DLS and zeta potential characterization, support the physicochemical consistency of the magnetic nanoparticles and correlate to:

- **Reproducible magnetic separation kinetics** - beads of consistent size respond uniformly to an applied magnetic field, so separation/pellet-formation time is predictable across wells.
- **Predictable surface area and binding capacity** - surface area scales with particle size, so a tight size distribution keeps nucleic-acid binding capacity per unit bead mass consistent.
- **Automation compatibility** - uniform, well-dispersed beads settle more predictably and are less prone to clumping in solution, which matters directly for liquid-handling workflows
- **Batch-to-batch reproducibility** - a tight, well-characterized size distribution is a standard input into lot-release and QC criteria.

Ordering Information

Product name	Format	SKU	Pack Size
Cambrian CamSelect NGS (for OEM)	Magnetic beads	CBWD010.450	450 ml

CB-MKT-B-024/v1.1

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