Electronic Supplementary Material (ESI) for Nanoscale.

Supplementary Material: Machine Vision-Driven Automatic Recognition of Particle Size and Morphology in SEM Images

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1. Algorithm Description

1.1 The proposed algorithm for morphology/shape recognition and core center detection

Algorithm 1: Morphology/Shape Recognition

```
Input: histogram-adjusted SEM image X
Output: set of detected core centers P={p_1,…,p_n}, binary image X_B, shape type M
1   X_B^1 ← medianBlur(binarize(X)); X_B^2 ← medianBlur(binarize(X, invert=1))
2   X_BE^1 ← X_B^1; X_BE^2 ← X_B^2
3   for i <= maxErosionCount do
4       X_BE^1 ← erode(X_BE^1, kernelSize=3); X_BE^2 ← erode(X_BE^2, kernelSize=3)
5   S^1={s^1_0,…,s^1_n} ← segmentation(X_BE^1); S^2 ← segmentation(X_BE^2)
6   initialize set of core segments, C^1 ← ∅; C^2 ← ∅
7   for s^1_i in S^1 do
8       if isBackground(s^1_i) or isBorder(s^1_i) or numAdjacency(s^1_i) > 1 then
9           Continue
10      r_s ← area(s^1_i); r_c ← area(convexHull(s^1_i))
11      if (r_s / r_c) > solidity_thres then
12          C^1 ← C^1 ∪ s^1_i
13  repeat 7 for S^2
14  if |C^1| >= |C^2| then
15      X_B ← X_B^1; S ← S^1; C ← C^1
16  else X_B ← X_B^2; S ← S^2; C ← C^2
17  initialize set of core centers, P ← ∅
18  for c_i in C do
19      P ← P ∪ centroid(c_i)
20  initialize set of shell segments, C_a ← ∅
21  for c_i in C do
22      c_a ← adjacentSegment(c_i, S)
23      if centroid(validContour(c_a)) in c_i then
24          C_a ← C_a ∪ c_a
25  if |C_a| / |C| < valid_ratio then
26      M ← core-only
27  else M ← core-shell
```

1.2 The proposed algorithm for core-shell size measurement

Algorithm 2: Core-shell Size Measurement

```
Input: histogram-adjusted SEM image X and its binary image X_B
Output: core sizes Φ, shell sizes Γ
initialize core and shell sizes, Φ ← ∅, Γ ← ∅
initialize core and shell segments, C ← ∅, S ← ∅
initialize core centers, P ← ∅
Z ← imageStatistics(X)
Λ={λ_0,…,λ_n} ← prune(segmentation(X_B), Z)
for λ_i in S do
    if not isBackground(λ_i) and not isBorder(λ_i) and numAdjacency(λ_i) == 1 then
        C ← C ∪ λ_i
C ← filterOutliers(C)
for c_i in C do
    p ← centroid(c_i)
    P ← P ∪ p
    Φ ← Φ ∪ measureSize(p, c_i)
    S ← S ∪ adjacentSegment(S, c_i)
initialize input and marker images for watershed, X_B′ ← X_B, X_M ← ones
n ← 2
for c_i, s_i in C, S do
    for (x,y) in c_i do
        X_M(x,y) ← n ++
        X_B′(x,y) ← 0
    for (x,y) in s_i do
        X_M(x,y) ← 0
X_W ← watershed(X_M, X_B′)
for p_i in P do
    Γ ← Γ ∪ measureSize(p_i, X_W)
```

Figure S1: Examples of successfully measured nanoparticles using the automatic pipeline

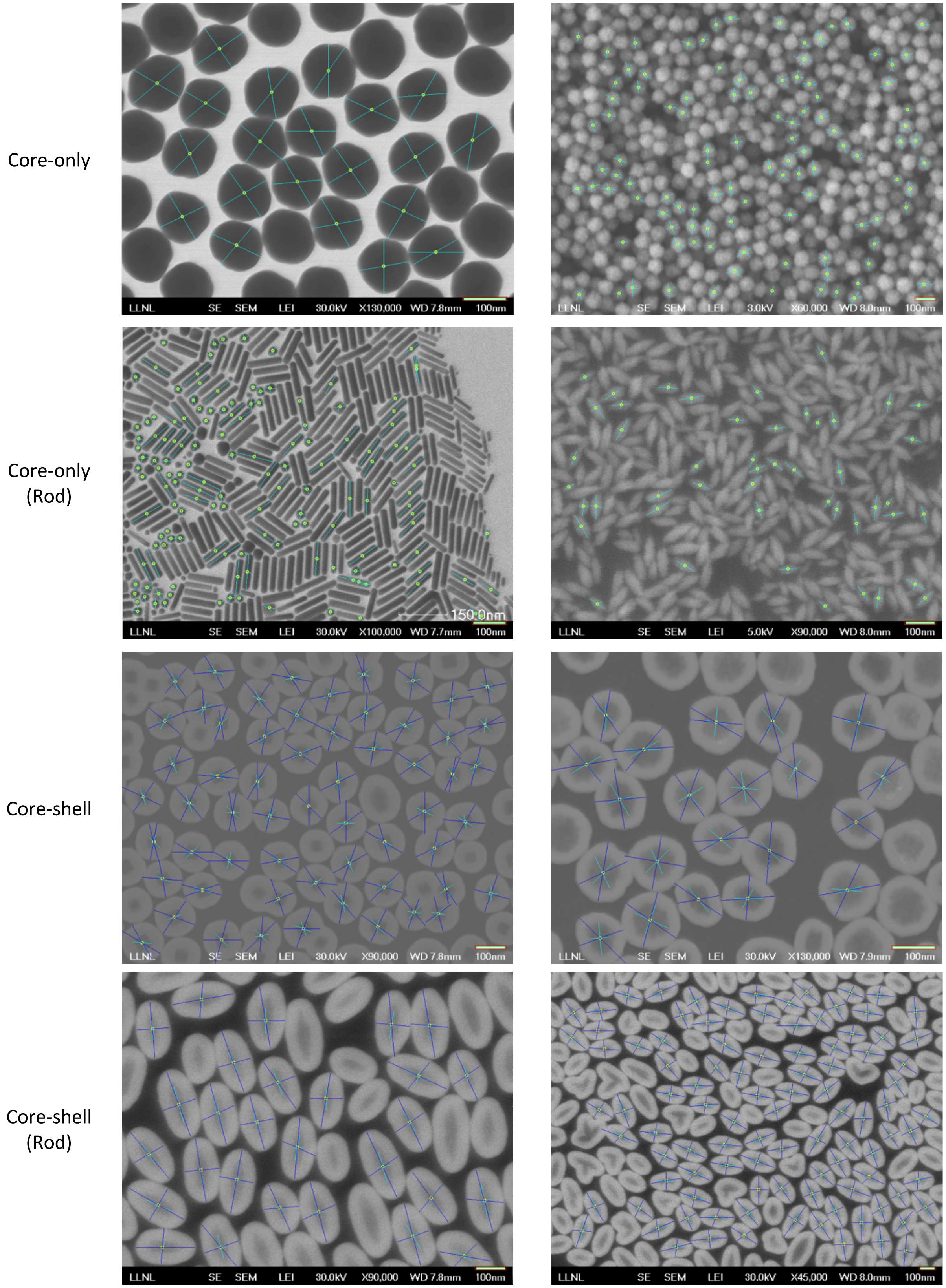
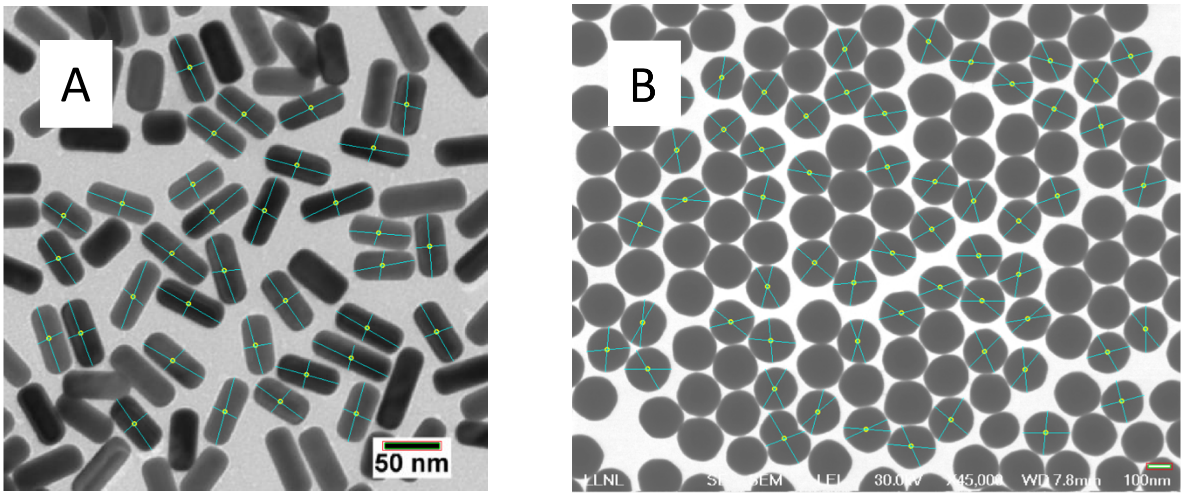
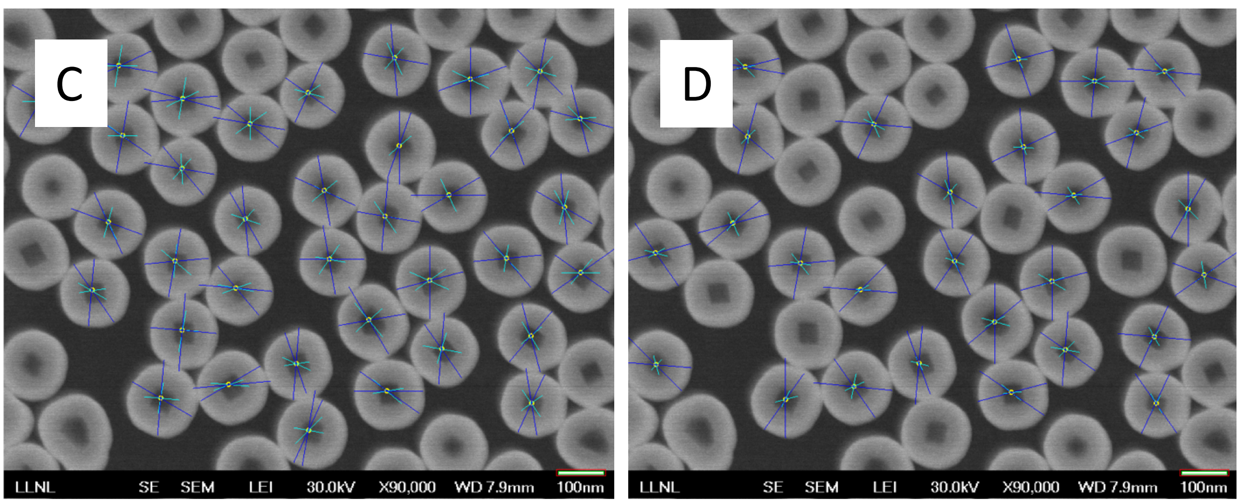


Figure S2: Examples of somewhat poorly measured nanoparticles using the automatic pipeline, together with improved sizes using the semi-automatic pipeline, respectively.

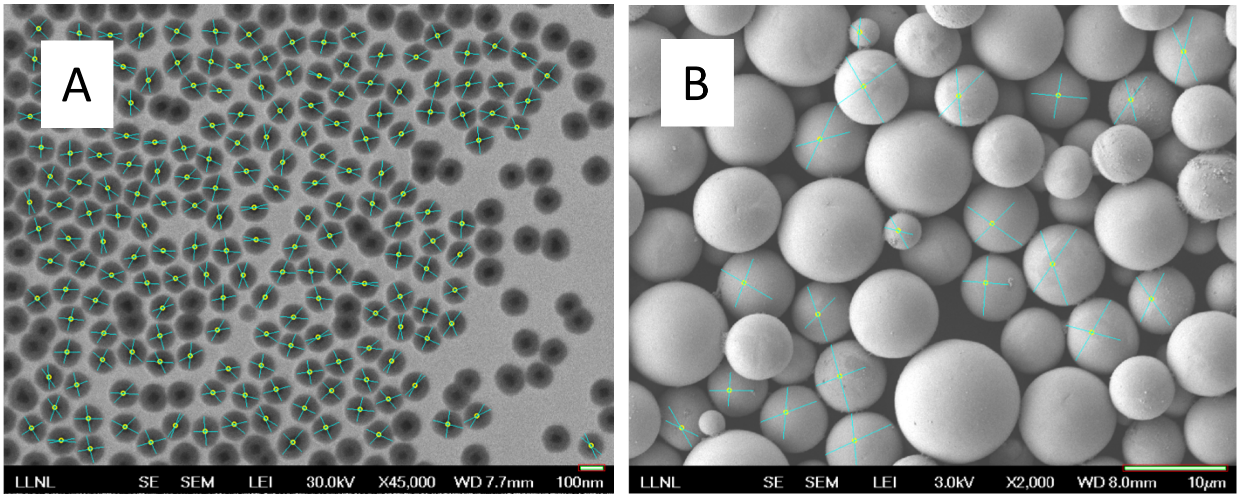


A, B: failure cases of scale bar text information retrieval. The provided manual scale selection function enabled to measure sizes correctly.



C: Poorly measured core sizes due to incorrect segmentation. *D*: Improved core measurement using manually chosen parameters

Figure S3: Examples of incorrectly measured nanoparticles



A: Incorrect morphology classification due to vague core boundary. *B*: Incorrectly measured sizes due to occlusion