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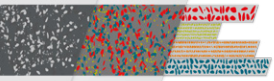

Catalyst Characterization with the Automated Particle Workflow

Easy, statistically meaningful characterization of catalyst nanoparticles on Thermo Scientific TEMs.

Introduction

Catalysis, or the facilitation and acceleration of chemical reactions through the addition of catalyst compounds, is a cornerstone of modern industry, impacting virtually every discipline and field. Nanoparticles are a common class of catalyst due to their high surface area, which provides many sites for chemical reactions to occur. This surface can also be functionalized, either with additional catalytic compounds or with stabilizing molecules that prohibit unwanted side reactions. Researchers are, therefore, constantly striving to enhance the properties of nanoparticles, thereby increasing their performance and catalytic efficiency.

The science of catalyst nanoparticle characterization involves the exploration and manipulation of structures at the nanoscale, where dimensions range from 1 to 100 nanometers.

Goal

To obtain statistically relevant information on a nanoparticle's shape, size, and chemical composition, you would typically need to characterize between 500 and several thousand nanoparticles, depending on their uniformity. Manually, you would be able to analyze less than 100 particles per day, so a complete characterization can quickly become exceedingly lengthy and tedious.

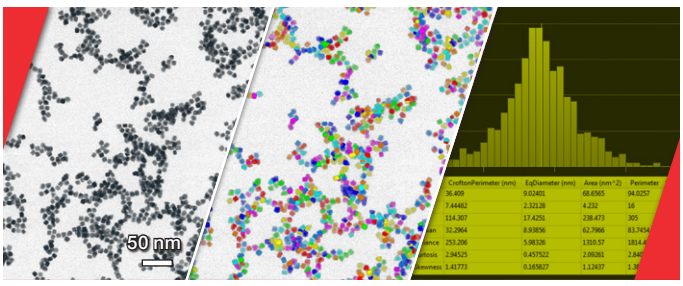

Figure 1. Automated, large-area TEM acquisition using APW for the analysis of individual nanoparticle parameters. *Sample courtesy of Prof. B. Gorman and Prof. R. Richards, Colorado School of Mines.*

Solution

Transmission electron microscopy (TEM) is well suited for nanoparticle characterization, as it can generate a wide range of high-quality data at nanometer scales. The Thermo Scientific™ Automated Particle Workflow (APW) is an image acquisition and on-the-fly data analysis workflow for Thermo Scientific TEM instruments. APW combines our unique hardware and software into a single optimized solution for nanoparticle characterization. The software and hardware included as part of APW make up a streamlined automation process that controls data acquisition and processing.

APW offers fully automated and unattended TEM and scanning TEM (STEM) imaging and energy dispersive X-ray spectroscopy (EDS) to provide you with statistically relevant information on the microstructural and chemical composition of your catalytic nanoparticles. No TEM expertise is needed to utilize APW, allowing even novice microscopists to obtain this vital information. APW also enables fast sample turnover, lowering the cost per measurement and revolutionizing product development through rapid and robust screening of new materials. Catalysis drives industry, and APW enables you to develop even more efficient catalysts with fast and easy nanoparticle analysis.

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The nanoparticle characterization workflow with APW

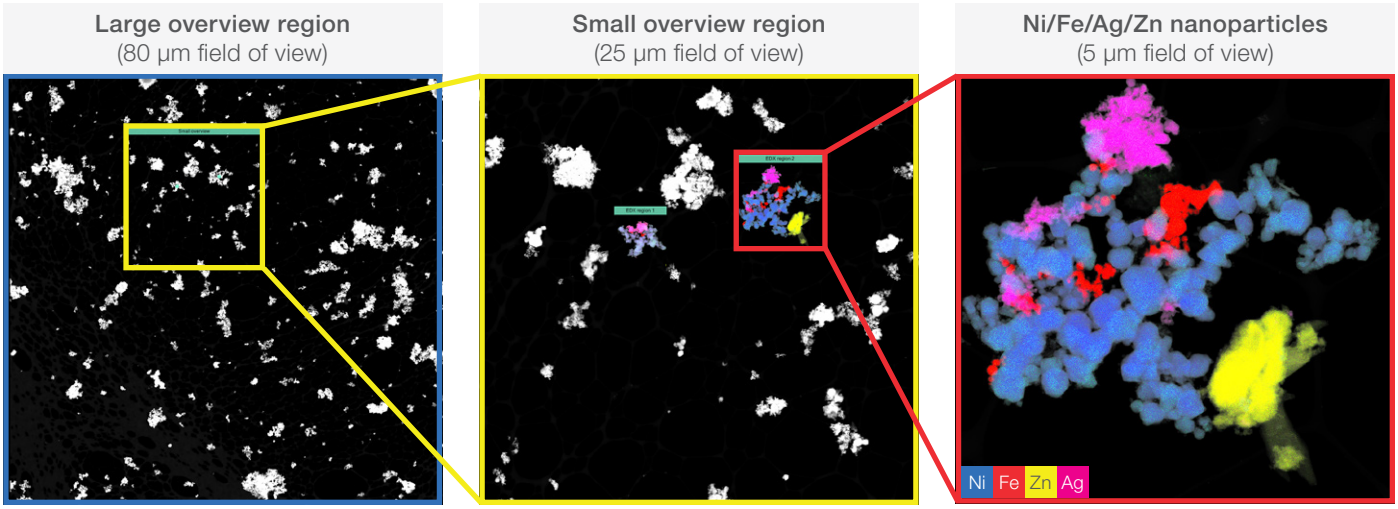
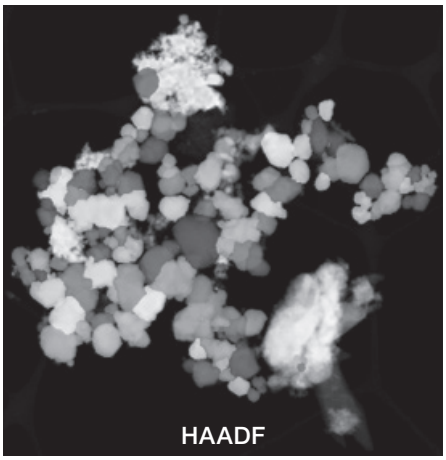
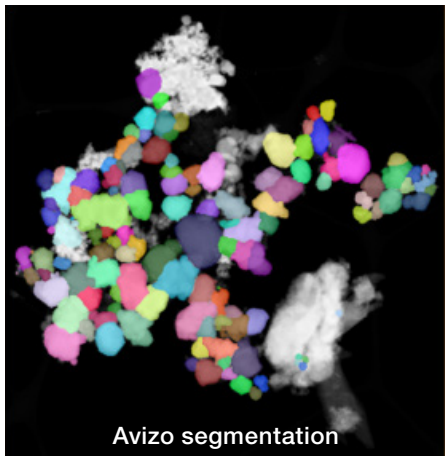
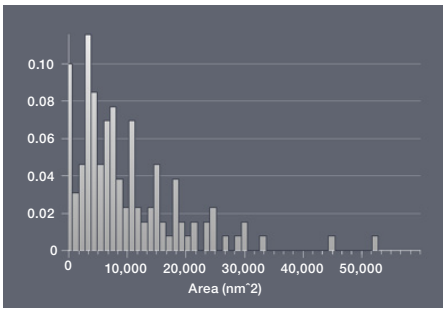
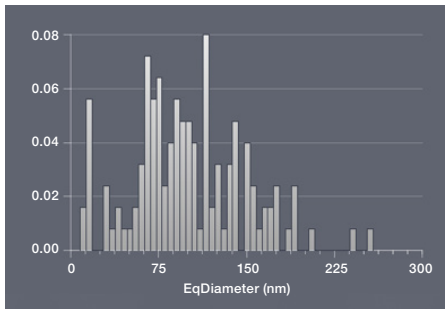


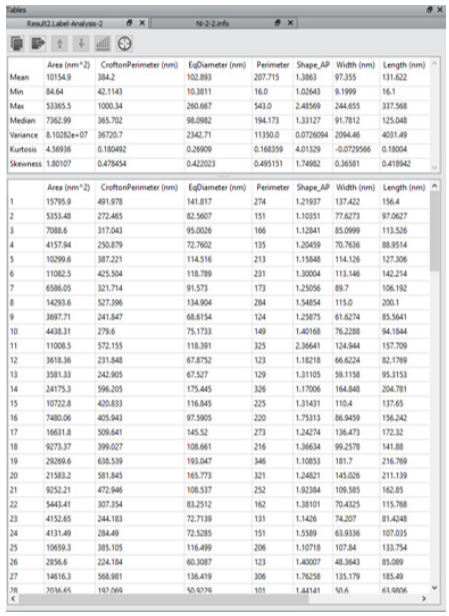
Figure 2. APW used on mixed nickel, iron, silver, and zinc catalyst nanoparticles. Different colors are assigned to represent different elements. This image was obtained in STEM mode with chemical information determined by EDS.











	Area (nm^2)	CroftonPerimeter (nm)	EqDiameter (nm)	Perimeter	Shape_AP	Width (nm)	Length (nm)
Mean	10154.9	384.2	102.893	207.715	1.3863	97.355	131.622
Min	84.64	42.1143	10.3811	16.0	1.02643	9.1999	16.1
Max	53365.5	1000.34	260.667	543.0	2.48569	244.655	337.568
Median	7362.99	365.702	98.0982	194.173	1.33127	91.7812	125.048
Variance	8.10282e+07	36720.7	2342.71	11350.0	0.0726094	2094.46	4031.49
Kurtosis	4.56936	0.180492	0.26909	0.168359	4.01329	-0.0729566	0.18004
Skewness	1.80107	0.478454	0.422023	0.495151	1.74982	0.36581	0.418942

	Area (nm^2)	CroftonPerimeter (nm)	EqDiameter (nm)	Perimeter	Shape_AP	Width (nm)	Length (nm)
1	15795.9	491.978	141.817	274	1.21937	137.422	156.4
2	5353.48	272.465	82.5607	151	1.10351	77.6273	97.0627
3	7088.6	317.043	95.0026	166	1.12841	85.0999	113.526
4	4157.94	250.879	72.7602	135	1.20459	70.7636	88.9514
5	10299.6	387.221	114.516	213	1.15848	114.126	127.306
6	11082.5	425.504	118.789	231	1.30004	113.146	142.214
7	6586.05	321.714	91.573	173	1.25056	89.7	106.192
8	14293.6	527.396	134.904	284	1.54854	115.0	200.1
9	3697.71	241.847	68.6154	124	1.25875	61.6274	85.5641
10	4438.31	279.6	75.1733	149	1.40168	76.2288	94.1844
11	11008.5	572.155	118.391	325	2.36641	124.944	157.709
12	3618.36	231.848	67.8752	123	1.18218	66.6224	82.1769
13	3581.33	242.905	67.527	129	1.31105	59.1158	95.3153
14	24175.3	596.205	175.445	326	1.17006	164.848	204.781
15	10722.8	420.833	116.845	225	1.31431	110.4	137.65
16	7480.06	405.943	97.5905	220	1.75313	86.9459	156.242
17	16631.8	509.641	145.52	273	1.24274	136.473	172.32
18	9273.37	399.027	108.661	216	1.36634	99.2578	141.88
19	29269.6	638.539	193.047	346	1.10853	181.7	216.769
20	21583.2	581.845	165.773	321	1.24821	145.026	211.139
21	9252.21	472.946	108.537	252	1.92384	109.585	162.85
22	5443.41	307.354	83.2512	162	1.38101	70.4325	115.768
23	4152.65	244.183	72.7139	131	1.1426	74.207	81.4248
24	4131.49	284.49	72.5285	151	1.5589	63.9336	107.035
25	10659.3	385.105	116.499	206	1.10718	107.84	133.754
26	2856.6	224.184	60.3087	123	1.40007	48.3643	85.089
27	14616.3	568.981	136.419	306	1.76258	135.179	185.49

Figure 3. Thermo Scientific Avizo Software statistical analysis of the nickel nanoparticles shown in Figure 1. Here, the different colors represent different sizes (based on segmentation). The size distribution, diameter, surface area, and other parameters of individual nanoparticles are shown in the diagrams.

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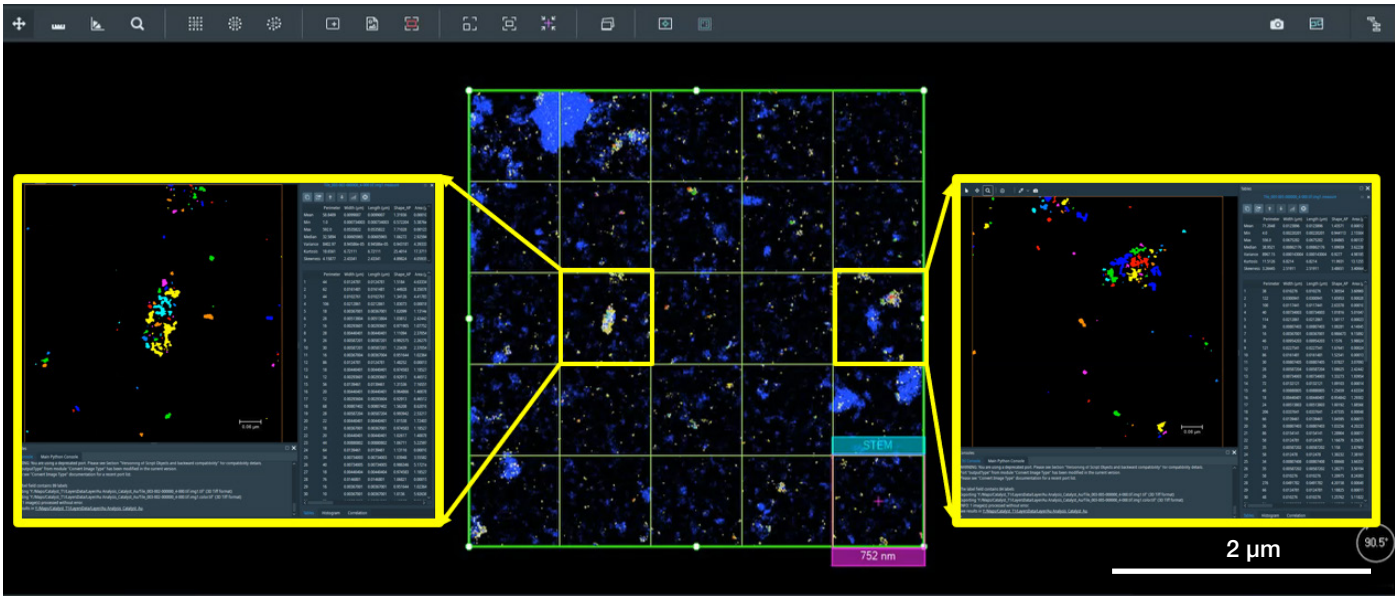

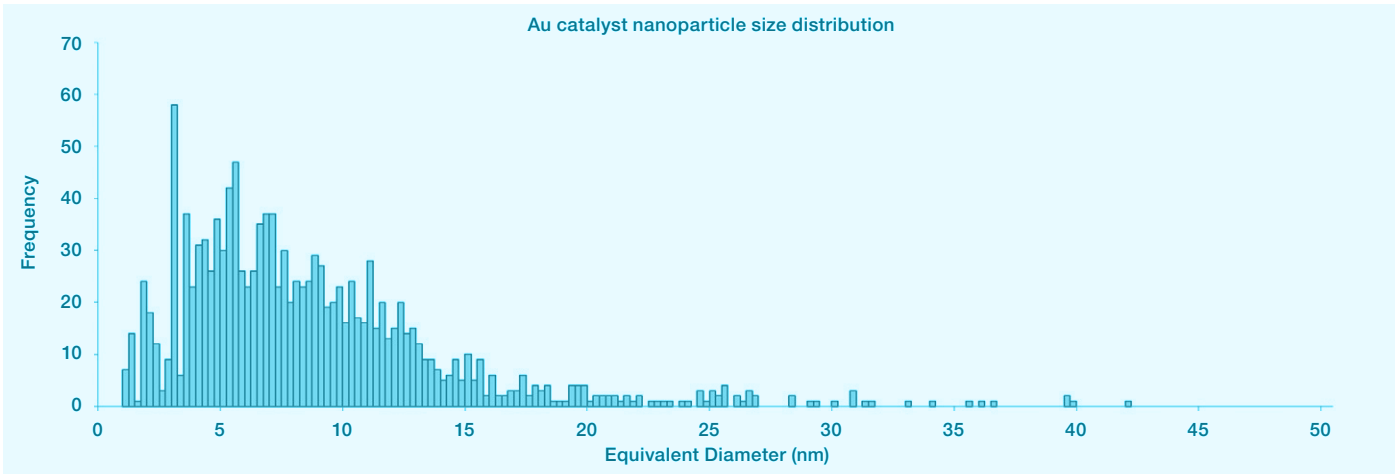

Figure 4. Top: APW used on gold catalyst nanoparticles with aluminum oxide (Al_2O_3) carriers. Bottom: Gold nanoparticle size distribution diagram.

Automated Particle Workflow in action

Duration 2:49

Find out more at **thermofisher.com/APW**

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