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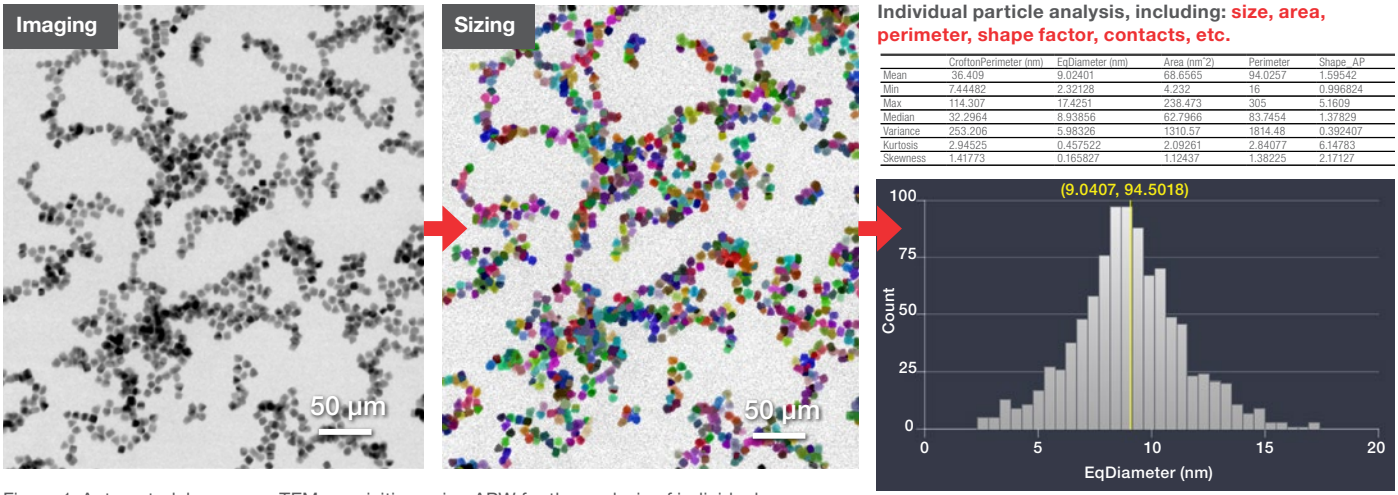
Catalyst Characterization with the Automated Particle Workflow

Statistically meaningful characterization of catalyst nanoparticles made easy with the APW on Thermo Scientific transmission electron microscopes.

Catalysis, or the facilitation and acceleration of chemical reactions through the addition of catalyst compounds, is a cornerstone of modern industry, and impacts virtually every discipline and field. Catalysts (among many other critical chemical processes) are used to:

- Purify automotive exhaust
- Synthesize ammonia from nitrogen and hydrogen
- Generate hydrogen
- Enhance photocatalytic processes
- Facilitate the anodic and cathodic reactions of fuel cells
- Enhance biocatalytic processes in food processing

Nanoparticles are a common class of catalyst due to their high surface area, providing 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 characterizing catalyst nanoparticles involves exploring and manipulating structures at the nanoscale, where dimensions range between 1 to 100 nanometers.



	CroftonPerimeter (nm)	EqDiameter (nm)	Area (nm^2)	Perimeter	Shape_AP
Mean	36.409	9.02401	68.6565	94.0257	1.59542
Min	7.44482	2.32128	4.232	16	0.996824
Max	114.307	17.4251	238.473	305	5.1609
Median	32.2964	8.93856	62.7966	83.7454	1.37829
Variance	253.206	5.98326	1310.57	1814.48	0.392407
Kurtosis	2.94525	0.457522	2.09261	2.84077	6.14783
Skewness	1.41773	0.165827	1.12437	1.38225	2.17127

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.

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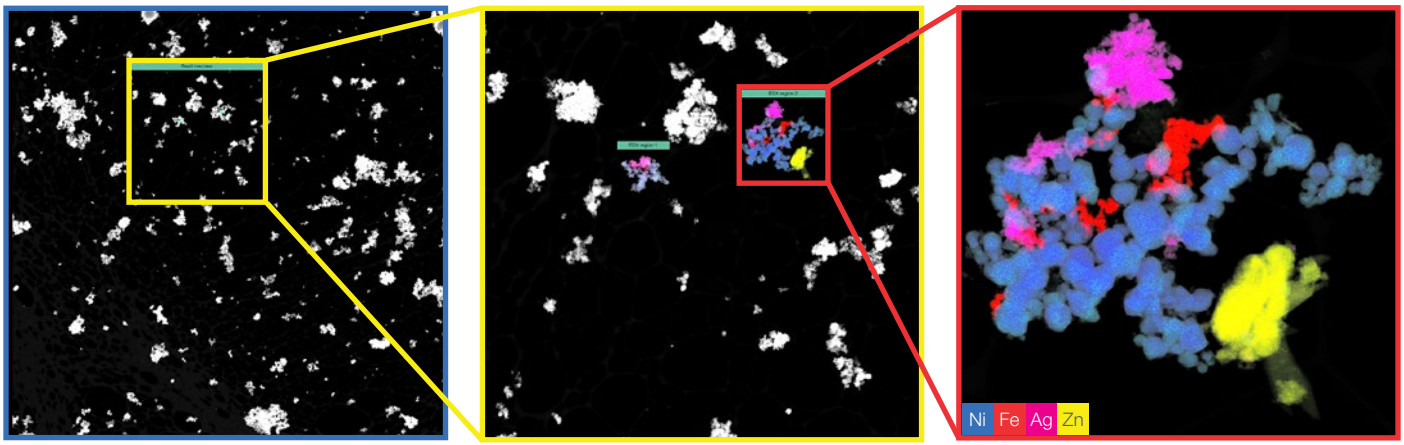
To obtain statistically relevant information on a nanoparticle's shape, size, and chemical composition, one would typically have to characterize between 500 and several thousand nanoparticles, depending on their uniformity. Manually, a scientist would be able to analyze less than 100 particles per day, so a complete characterization can quickly become exceedingly lengthy and tedious. Ideally, you would be able to automate this routine process to generate precise, high-resolution data quickly and reliably.

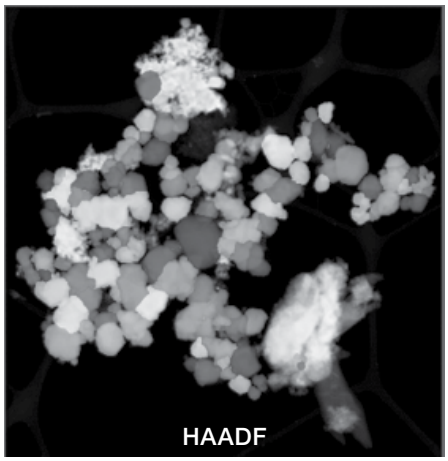


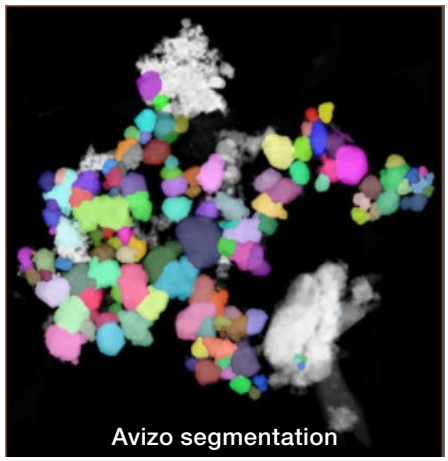
Large overview region (80 µm field of view)

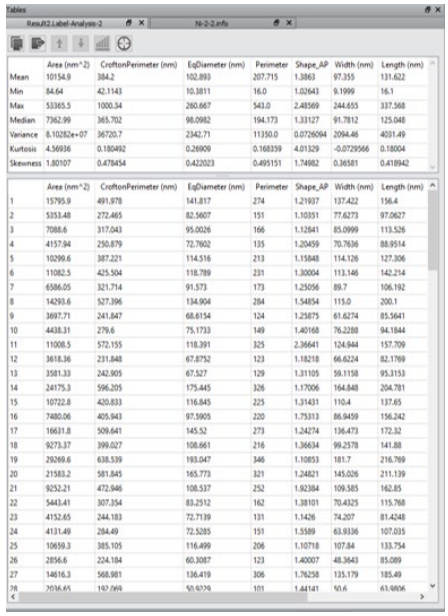
Small overview region (25 µm field of view)

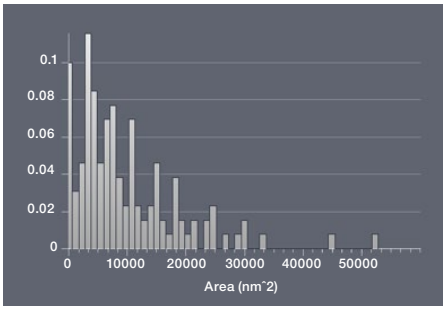
Ni/Fe/Ag/Zn nanoparticles

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.









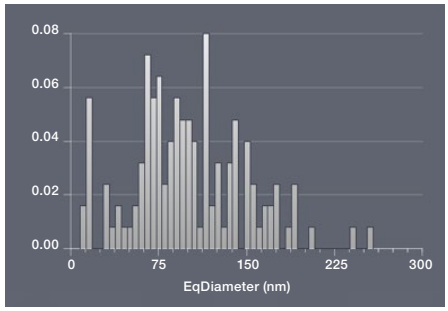


Figure 3: Avizo statistical analysis of the nickel nanoparticles shown in Figure 1. Here, the different colors represent different sizes (based on segmentation). The size distribution, diameter, surface area, and other parameters of individual nanoparticles are shown in the diagrams.

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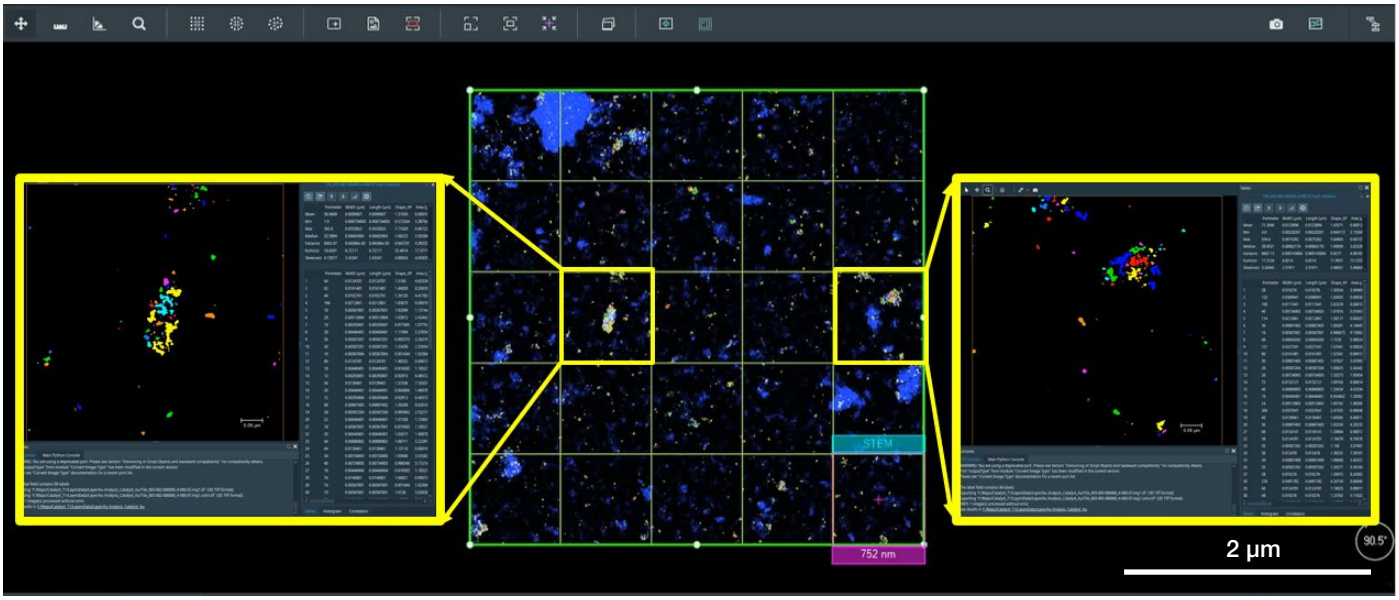
The Automated Particle Workflow (APW)

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 that 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 expert 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 the APW package enables you to develop even more efficient catalysts with fast and easy nanoparticle analysis.



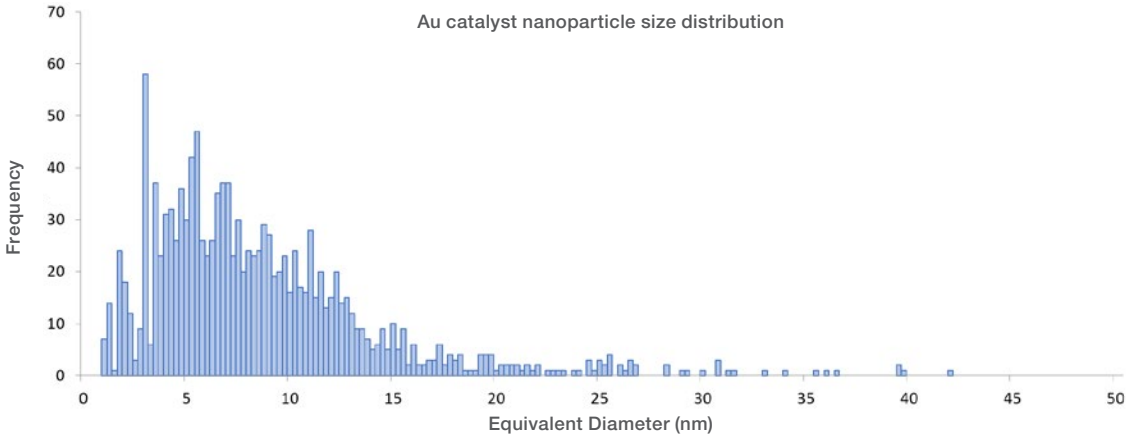


Figure 4: Top - APW used on gold catalyst nanoparticles with aluminum oxide (Al_2O_3) carriers. Bottom - gold nanoparticle size distribtuion diagram.

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