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K-kit Silicon-based Micro Channel Device

K-kits are sample holders designed to facilitate TEM observation of liquid samples. This allows nanoobjects, aggregates, and agglomerates (NOAAs) in liquid samples to be characterised with vacuum compatible sealing of liquids in electron-transmitting thickness.

K-kits are micro reaction chambers for countless experiments in materials, chemical and biological research.

- Simple, quick and affordable
- Compatible to all TEM holders
- Available for TEM and SEM observations
- Good resistance to chemical solvents
- Cross-contamination free (Disposable)
- Achievable to quantitative analysis
- Reliable loading with viscous liquids
- Broad temperature range -196°C to 120°C

K-kit is an innovative wet cell which is simple, fast, reliable, powerful, and affordable for use, perfectly meeting the surging demands on liquid-EM analysis for both industry and academia.

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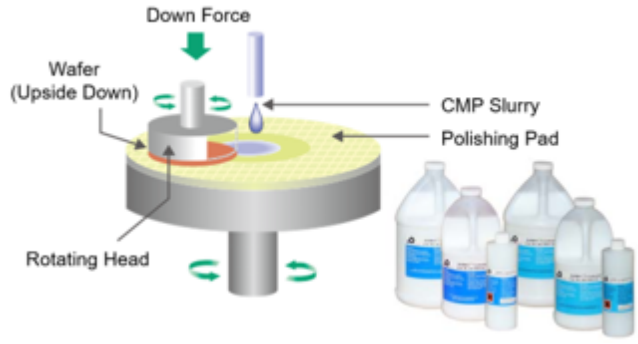
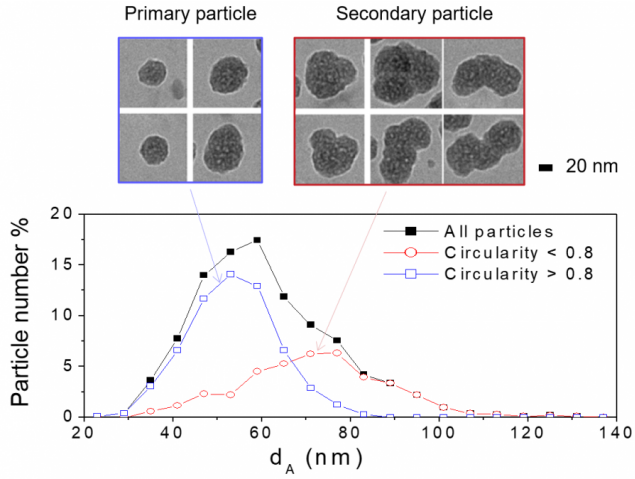
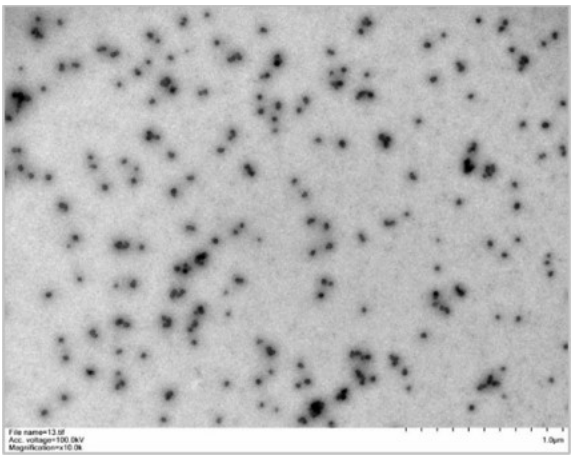
Examples of K-kit Applications

NOAAs of abrasives in CMP slurry

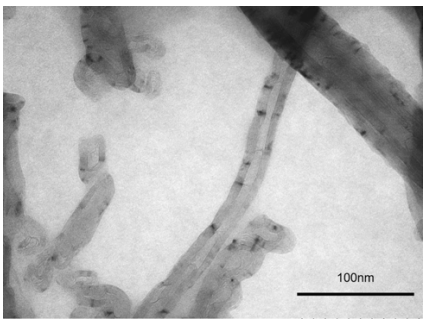




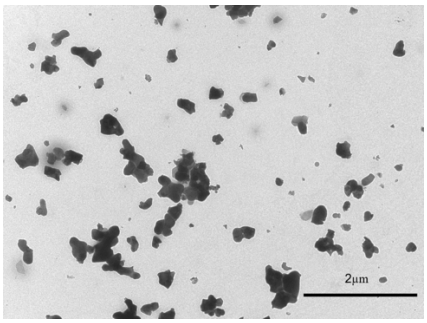


K-kit can be used for characterising primary and secondary particles in undiluted CMP slurry.

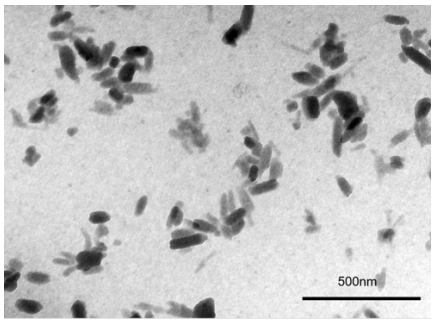
Nanomaterials and Chemicals



Carbon nanotubes (WMCNT) in water



Al_2O_3 nanoparticles in NMP solution



Pigment nanoparticles of printer ink

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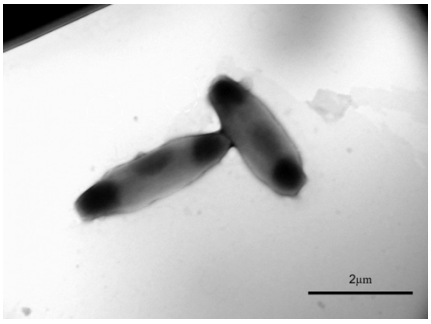
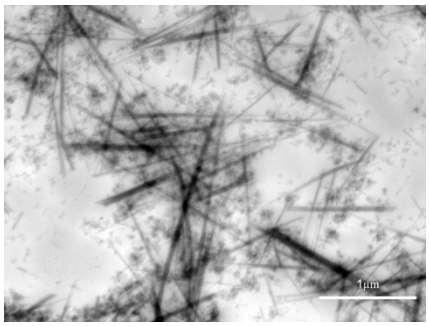
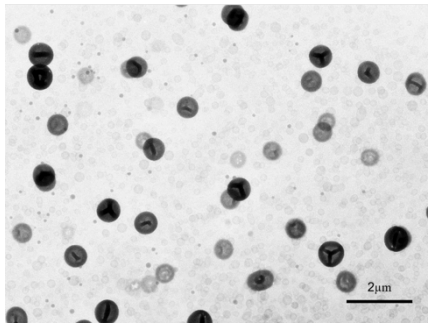
Biological Specimens and Nanopharmaceuticals



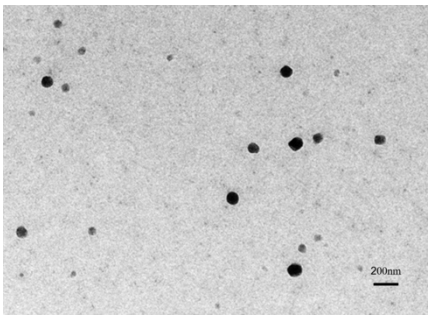
The nucleoid of E.coli



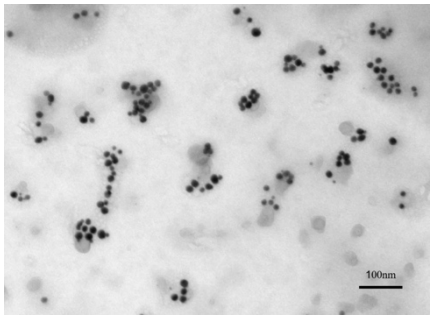
Collagen bundles in liquid



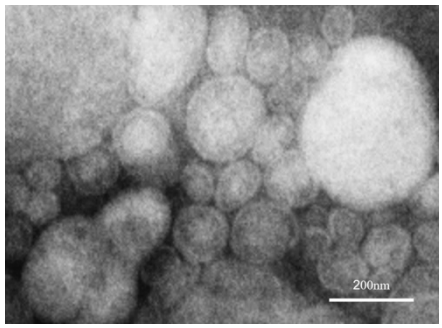
Extracellular vesicles of platelets



Abraxane® drugs (paclitaxel) in saline

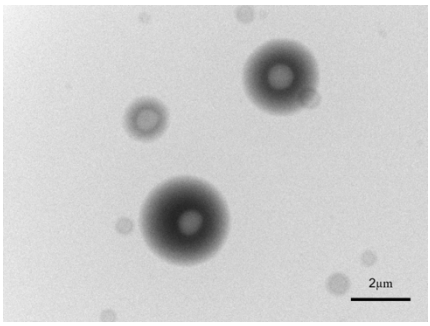


AuroVist® gold nanoparticles in PBS

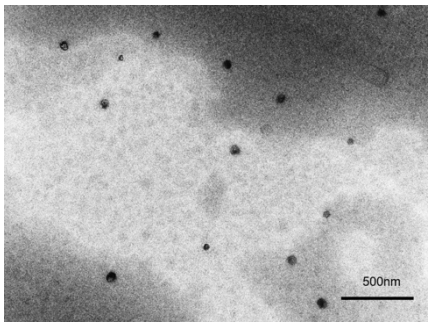


Liposomes with negative staining

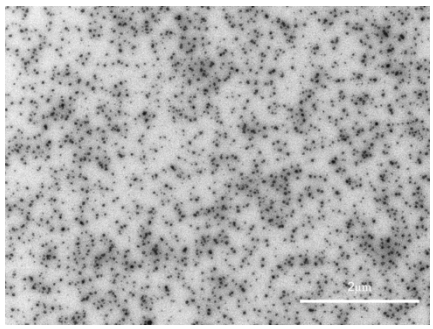
Foods and Cosmetics



Snail mucins in essence



Calcium particles in milk


Nano-additives in beer

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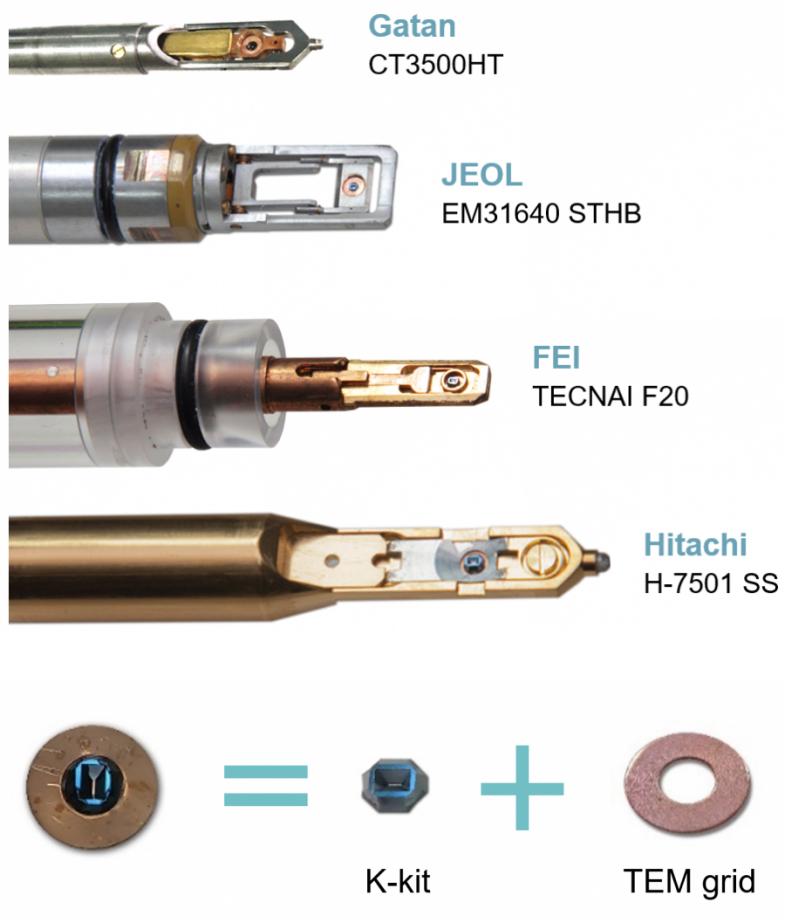
Compatible with all kinds of TEM holders



K-kit is carried with a 3mm TEM grid so that it is compatible with all kinds of TEM holders.

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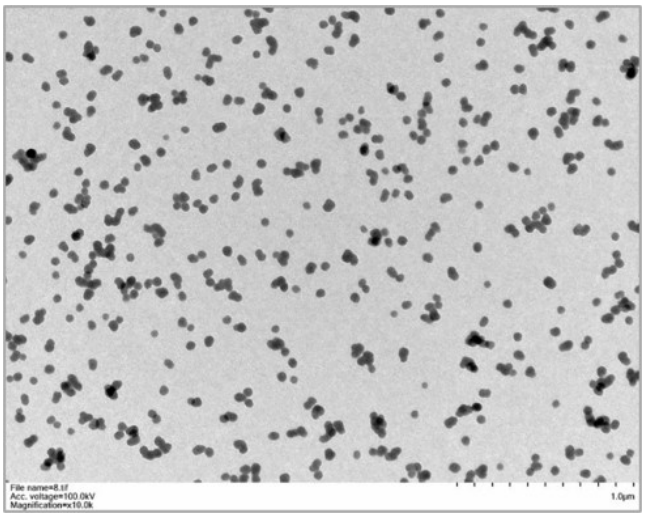
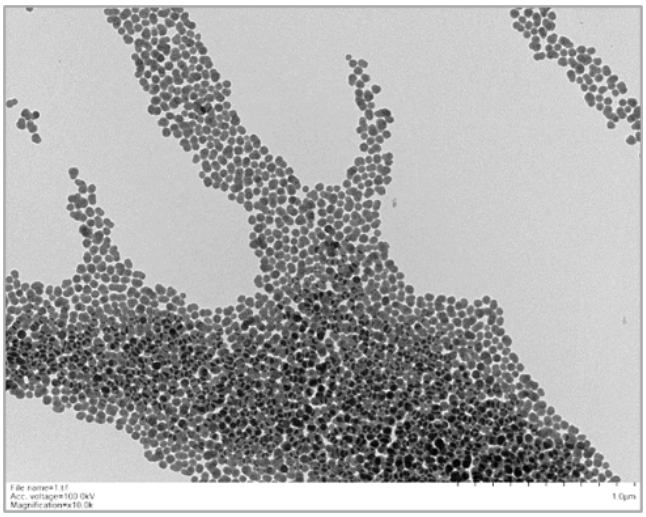
K-kit vs TEM grid



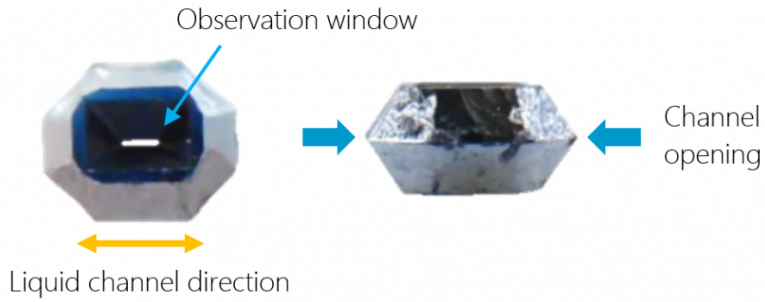
TEM image of liquid state CMP slurry with K-Kit, enabling individual particles to be clearly identified.



TEM image of dried CMP slurry on Cu grid, unable to be analyzed individual particles due to agglomeration.

Physicochemical Parameters	K-kit	Cu Grid
Composition	Good	Good
Size	Good	Good
Shape	Good	Good
Size distribution	Good	Case dependent
Aggregation and agglomeration in liquid	Good	Not available
Particle concentration	Good	Not available
Liquid TEM observation	Good	Not available

Material and Competitiveness



K-kits are Si-based microchannel devices with silicon nitride windows that allow TEM observation. The seemingly irregular shape is a result of KOH anisotropic wet etching, which is also responsible for forming the rectangular observation window in the middle of the device. The liquid channel is parallel to the window, with openings at both ends.

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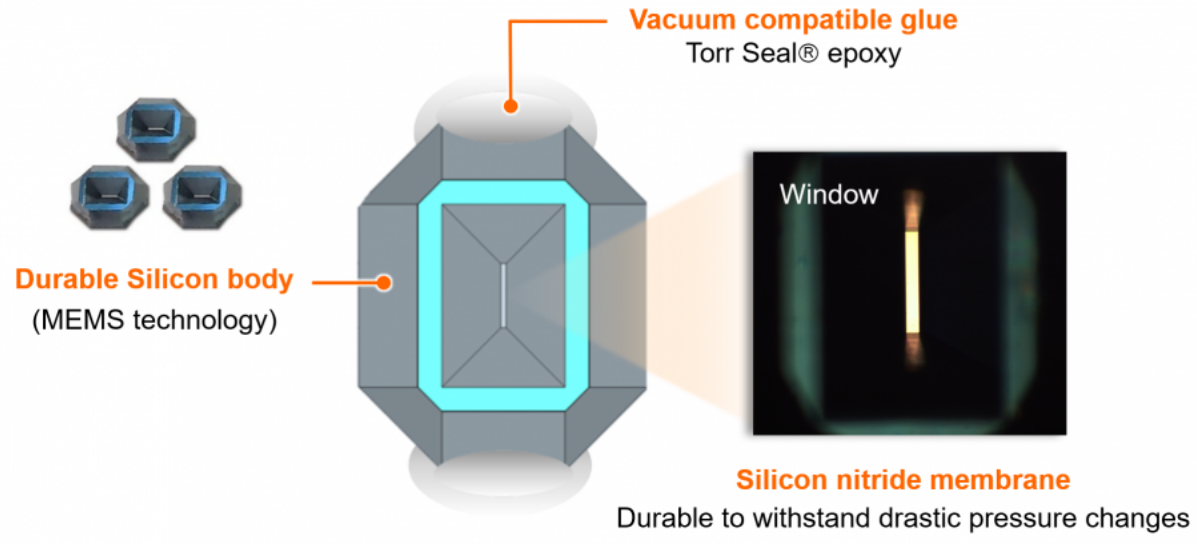
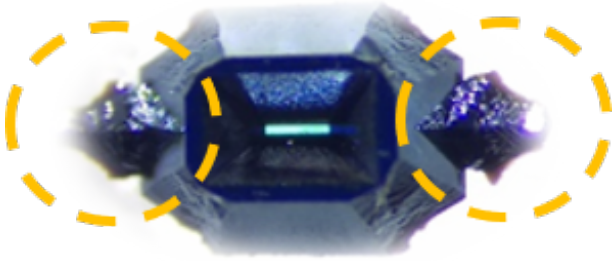
Broad temperature range for K-Kit -196°C to 120°C

Applicable with heating & cryo TEM holders.



Channel tips

There are channel tips at both ends, to protect the surface condition and cleanness of the channel in K-kit.



Reliable liquid loading

By capillary action, liquid can be loaded into a K-kit reliably, even the viscosity of up to 3000 mPa-s.

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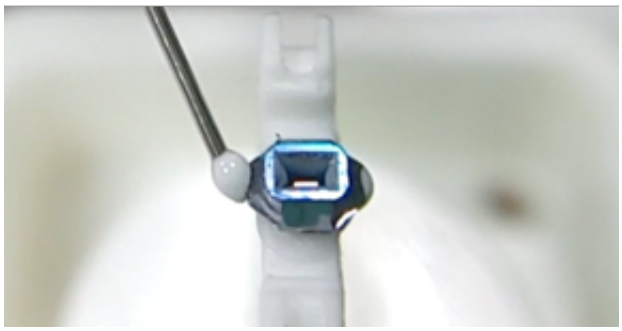
Good resistance to solvents

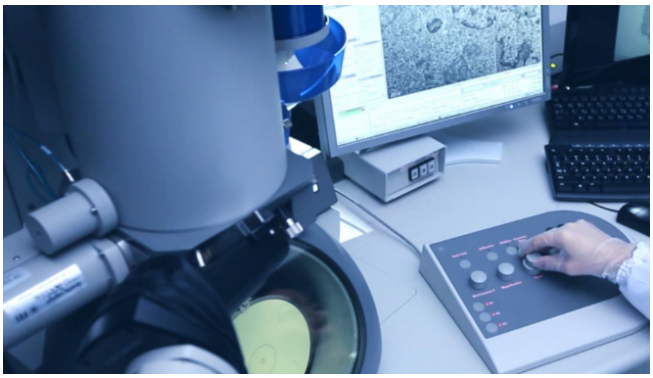
After soaking the K-kit sealing glues (Torr Seal) in those chemicals individually for 24 hours, the FTIR analysis results looked perfect.



Water	PEG400	DMSO	Ethanol	0.1N HCl	0.1N KOH
Compatible	Compatible	Compatible	Compatible	Compatible	Compatible
Toluene	**NMP**	**ACN (CH_3CN)**	**Chloroform ($CHCl_3$)**	**1% NH_4OH**	**0.1N HNO_3**
Compatible	Compatible	Compatible	Compatible	Compatible	Compatible
Hexane	**IPA**	**Methanol**	**DCM**	**THF**	**Acetone**
Compatible	Compatible	Compatible	Use with care (FTIR detected)	Use with care (FTIR detected)	Use with care (FTIR detected)

High image quality in TEM

SiN Film Thickness	Sample Preparation of K-kit (to observe Au nanoparticles)	
	Wet Mode	Dry Mode
100nm	< 10nm	< 5nm
30nm	< 5nm	< 2nm



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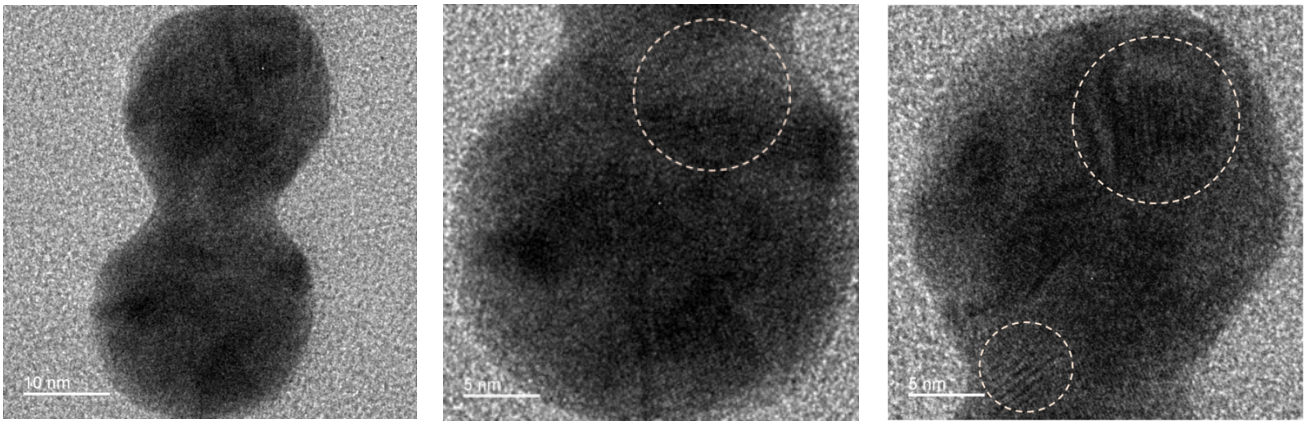
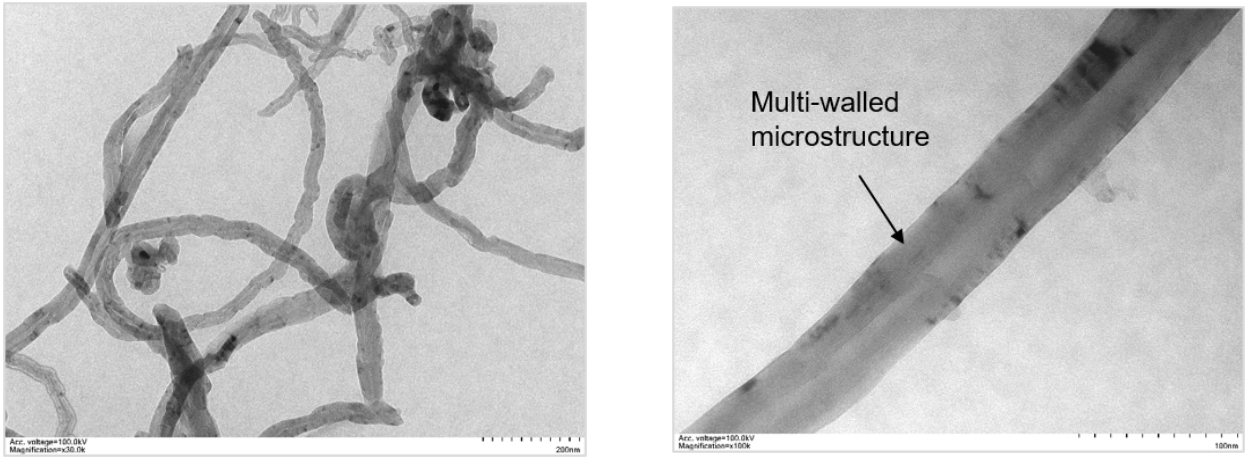


As shown in the TEM images of gold nanoparticles that formed from reduction process of $AuCl_4$ solution, the lattice lines of gold particles could be clearly observed by using Gap 0.2um/ SiN30nm K-kit. (By FEI Talos TEM @ 200KV)



TEM images of multi-walled carbon nanotubes (WMCNT) that were fully dispersed in water. By using Gap 2um/ SiN30nm K-kit, the structures of MWCNTs could be observed clearly. (By Hitachi HT7700 TEM @100KV; WMCNTs: OD 30-80 nm, Length <10 μm, 10wt%)

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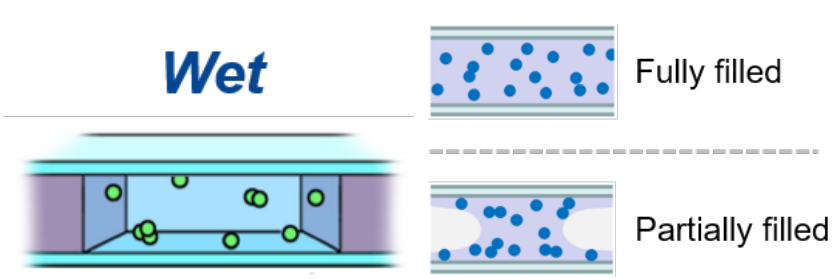
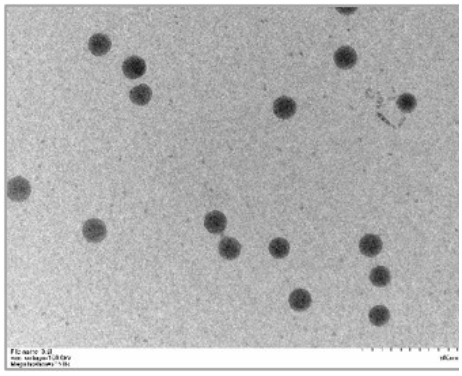
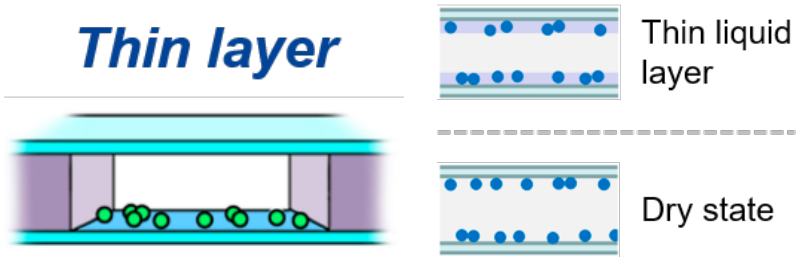
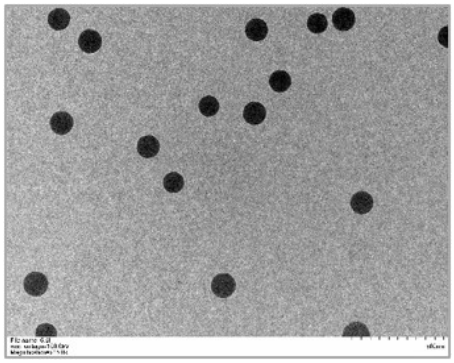
Wet and Dry mode in Sample Preparation





The loaded liquid sample is sealed and imaged using TEM in the native liquid environment. (Acceptable image quality with liquid inside the K-kit)





A patented liquid drying protocol preserves the original morphology and physical state of nanomaterials with improved imaging resolution. (Very good image quality, due to the channel being dried out)

There're two modes of sample preparation Wet and Thin Layer (also called as Dry Mode) available for K-kit. Generally, by using K-kits with larger gap heights (like 2um ones), it will be easily to result in the inner conditions in either fully dried or with a thin liquid layer (with the thickness around 100nm) preserved on the inner walls. Basically, it can be with relatively slight reaction with TEM electron beam if less amount of liquid remained in the channel. Being able to reduce the liquid bubbling effect by the dry mode, it's also a unique feature of K-kit that better than the other products in the market.

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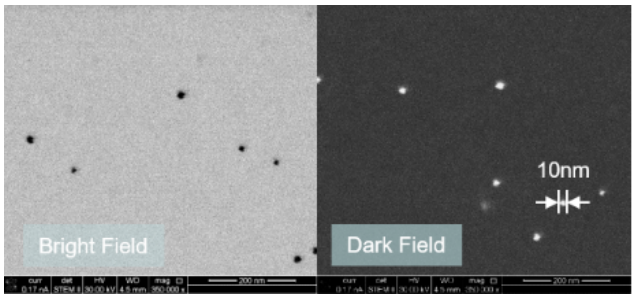
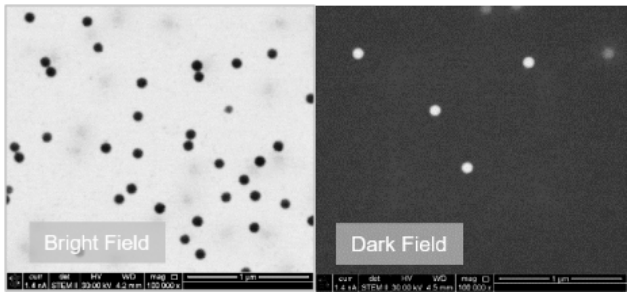
SEM Observation

K-kit also can be imaged by SEM, no matter what it prepared in wet or dry mode. Per our test results, the particles (Au) in K-kit with sizes less than 10nm could be well imaged by using SEM/ STEM.

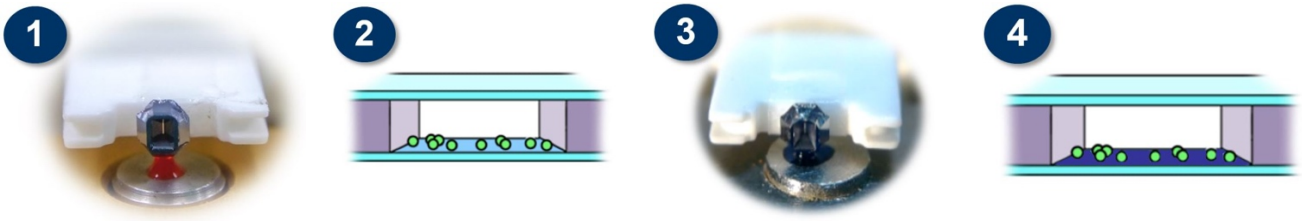


Gold nanoparticles in K-kit



100nm NIST Polystyrene beads in K-kit

Multiple Loadings



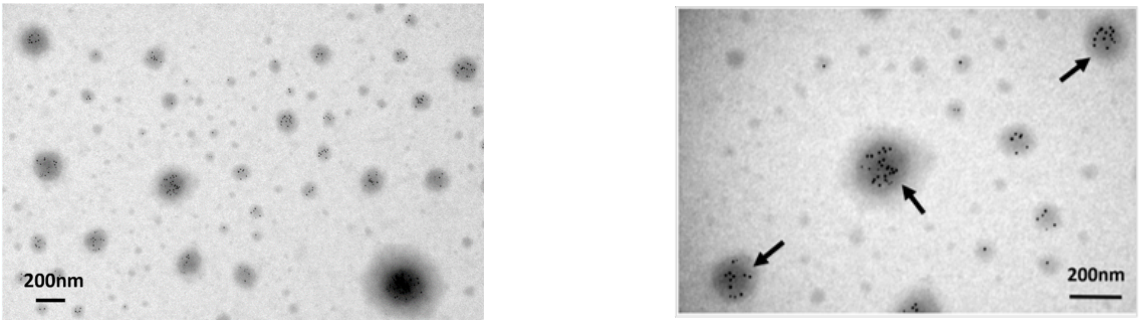
First K-kit loading with liquid A

Prepared in dry mode for liquid A

Second loading with liquid B

Prepared in dry or wet mode with liquid B

The presence of specific platelet granules could be labelled and observed by using a K-kit with multiple loadings. After some necessary pre-treatments and washings, the platelet sample in K-kit was incubated with the primary antibody (mouse monoclonal anti-P-selectin antibody) and next was reacted with a secondary antibody (6-nm gold-conjugated goat anti-mouse IgG antibody) for 2h at 37°C, and then the K-kit was sealed and examined in TEM. (Appl. Sci. 2020, 10, 4946)



Immunoelectron micrographs of isolated platelet granules in a K-kit.

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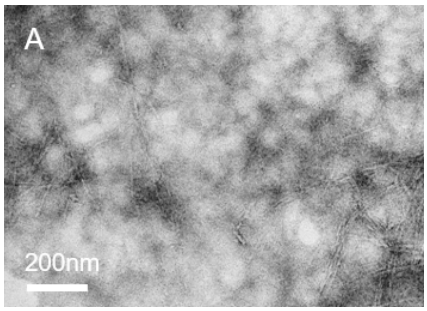
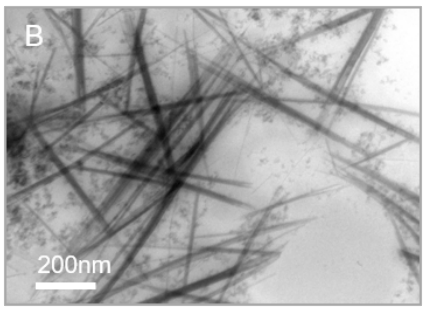
Negative Staining

Some biological granules such as liposomes or exosomes usually suffer low-contrast issue in their EM images; negative staining with heavy elements (metals) can enhance the contrast for those samples. Regarding the negative staining protocol for K-kit, we suggest using Uranyl Acetate (UA). Please refer to the steps as below:

1. Dilute the UA agent (such as UA-Zero) first by adding exact DI water, to make it the volume ratio of 2% UA in the liquid
2. Mix the diluted UA and the sample solution, by the volume ratio of 1:1
3. Liquid loading with K-kit and TEM observation

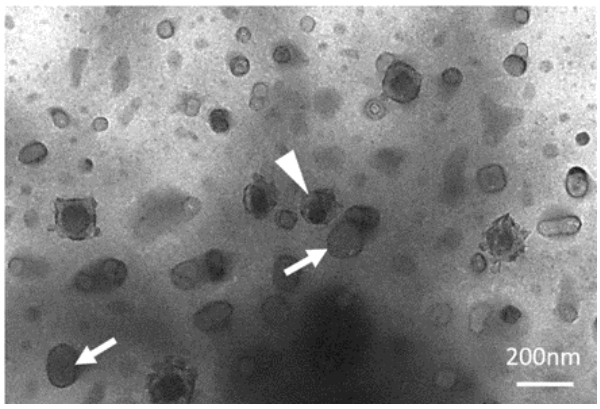


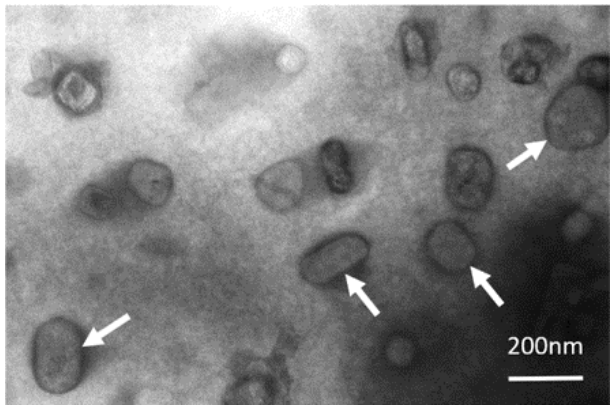
On Cu grid (In dry state)



In K-kit (With liquid)

Negative staining TEM images of collagen on Cu grid and in K-kit. As shown in Fig. B, the collagen nanofibers could be clearly observed by using a wet-mode K-kit.





Negative staining TEM images of isolated platelet granules in K-kit. (Appl. Sci. 2020, 10, 4946)

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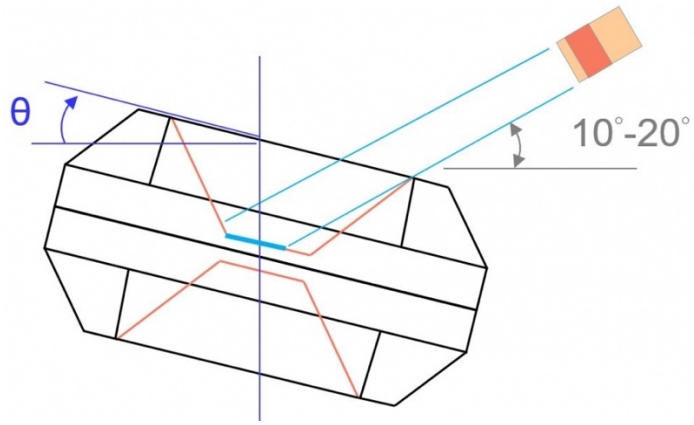
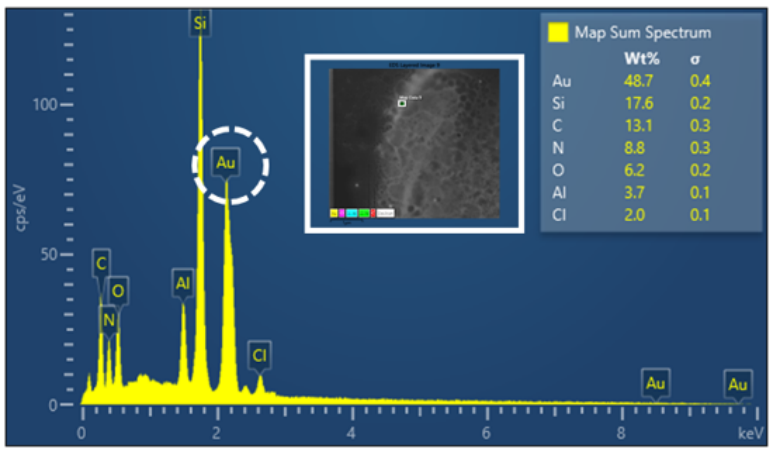
EDX Analysis

In a TEM, an EDX detector is usually located at an angle of around 10 - 20º with regard to the sample; X-ray signals excited from the observation window of a K-kit will be easily blocked by that deep cavity. If so, by pointing the window long side of the K-kit toward the EDX detector along with tilting the TEM holder at some angles over 15º, which can make the EDX analysis achievable on it.





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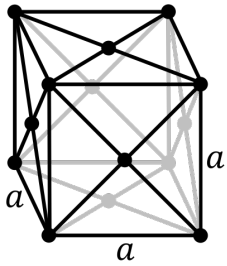
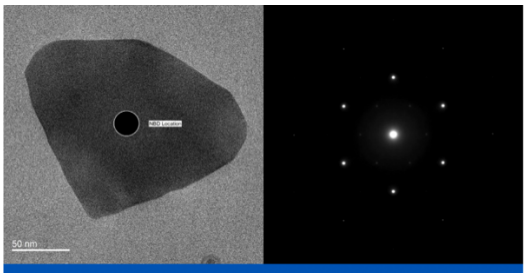
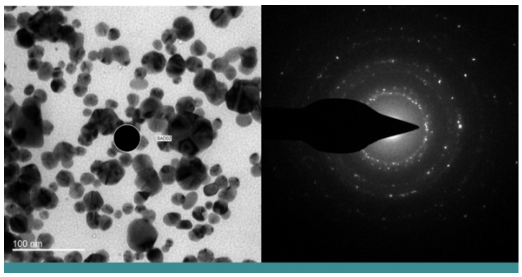
Diffraction Pattern Analysis

TEM diffraction patterns of nanoparticles in liquid can be analysed by using K-kit.





NBD (Nano-beam diffraction)

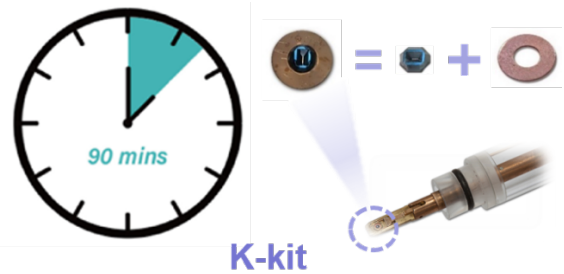


SAD (Selective area diffraction)

In this example above, Au nanoparticles were formed from reduction process with AuCl4 solution and analysed with FEI Tecnai TEM @200KV.

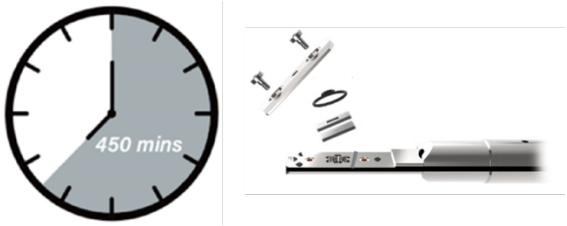
K-kit vs in-situ TEM holder

K-kit can be the fastest and most convenient option in the market for liquid-TEM observation.



K-kit

Around 90min required for 10 samples
Liquid loading and gluing for 10 K-kits (~70min) + vacuum pumping (~20min)



Liquid-TEM holder

450min at least for 10 samples
One by one; it needs the steps including surface treatment, assembly, leakage detection, and post-clean etc. for one sample. (> 45min for each)

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Product	K-kit	In-situ TEM holder
Cell size	1.7mm x 1.4mm (fit in with 3mm diameter grids)	> 2.4mm x 2.4mm
Custom holder	No need	Required
Price	< US$200	~ US $100,000
Competitiveness	♦ Simple, quick and affordable ♦ Compatible with all TEM holders ♦ Available for SEM observation ♦ Good resistance to chemical solvents ♦ Cross-contamination free ♦ Achievable to quantative analysis ♦ Reliable loading with viscous liquids ♦ Broad temperature range -196°C to 120°C	Available for flowing and electromechanical studies
Weakness	♦ Only for static liquid analysis ♦ Electrodeless design	♦ Expensive ♦ Further pre-clean and assembly processes required ♦ Risk of liquid leakage in TEM ♦ Dedicated for specific TEMs
User base	Industry and academia	Only for academia