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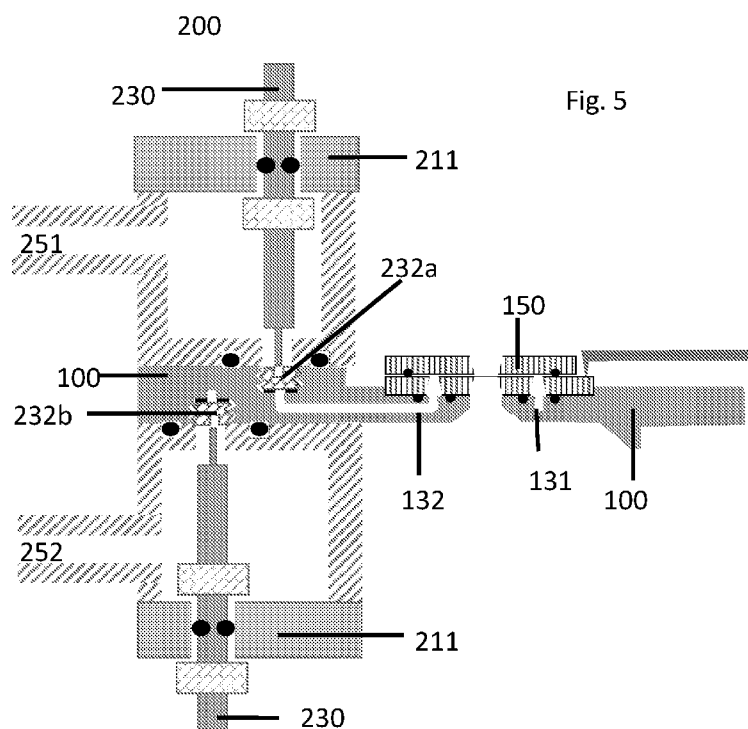


Fig. 5

(57) Abstract: The present invention is in the field of a transferrable system for use in in-situ experiments in a microscope and spectrometer, use of said transferrable system, and a microscope or spectrometer comprising said transferrable system, wherein the microscope is selected from an electron microscope, an IR-microscope, a Raman-microscope, X-ray microscope, and an optical microscope, such as a TEM, a SEM, a transmission mode SEM, and combinations thereof.

Transferrable system for use in in-situ experiments in a microscope

FIELD OF THE INVENTION

5 The present invention is in the field of a transferable system for use in in-situ experiments in a microscope and spectrometer, use of said transferrable system, and a microscope and spectrometer comprising said transferrable system.

BACKGROUND OF THE INVENTION

10 The present invention is in the field of microscopy, X-ray microscopy, specifically in the field of electron microscopy (EM), and spectroscopy. However its application is extendable in principle to any field of microscopy, such as optical microscopy, especially wherein a specimen (or sample)
15 is manipulated.

Microscopy is a technique used particularly in semiconductor and materials science fields as well as for biological samples for site-specific analysis, and optionally deposition, and ablation of materials. Also it is widely used in
20 life sciences to obtain information in the 0.1 nm to 1 μ m resolution domain. In microscopy typically a source is used to obtain an image. The source may be a source of light, electrons, and ions. Under optimal conditions a modern microscope can image a sample with a spot size typically in the order of
25 a few tenths of nanometers for a TEM, a nanometer for a FIB and Scanning (S)EM, and a few hundred nanometers for an optical microscope.

Typically a sample to be observed is provided in a holder. The holder is placed in a microscope, such as a TEM,
30 and then the holder is manipulated, such as by a goniometer. Therewith a sample can be observed under different observation angles. If a sample needs to be observed in a required environment, such as in oxygen, some microscopes, such as electron microscopes and the like, are inherently unsuited, whereas for
35 other microscopes special measures have to be taken. Prior art systems typically relate to a complex system, including gas holders, tubing, etc. to provide a gas.

Often a sample needs to be observed under various
(more than one) conditions. Such requires changing of equipment,
40 ment, possible exposure of the sample to the environment, etc.

For instance, one might want to take a sample out of one type of analysis system like an EM to another type of analysis system like an optical spectrometer, whereby it is essential that the sample remains exactly the same and thus is not modified during the transfer. Such is at the very least not practical.

Often sample need to be observed under dynamic or static conditions. Such functionality is practically not possible in prior art systems. For instance ageing of a sample is virtually impossible to monitor.

Researchers have been trying hardly to develop a system that can monitor dynamic gas-solid, and liquid-solid reaction of samples in a TEM, with a required resolution up to 0.5 Å. Such a system can be obtained by differentially pumped apertures in the TEM, dedicated environmental transmission electron microscope (ETEM), which gives very high resolution at a limited gas pressure, ≤ 50 Torr. Another approach is to develop a gas holder with two electron transparent windows isolating its gas channel to the TEM column. Gas is provided to the system through long inlet and outlet tubes which can result in safety issue if there exists a leakage. As mentioned, these systems are considered not practical for various reasons.

An example of a system having long inlet and outlet tubes is recited in EP 2,629,318 A2, of the present inventor. Therein a holder assembly for cooperating with an environmental cell and an electron microscope. The environmental cell shows a fluid inlet and outlet, the holder assembly comprising a tube for connecting an outside the microscope located fluid supply to the fluid inlet of the environmental cell.

US 2012/298883 recites flow cell devices -referred to as nanoaquariums- that are microfabricated devices featuring a sample chamber having a controllable height in the range of nanometers to micrometers. The cells are sealed (but still have openings, such as fluid connectors) so as to withstand the vacuum environment of an electron microscope without fluid loss. The cells allow for the concurrent flow of multiple sample streams and may be equipped with electrodes, heaters, and thermistors for measurement and other analysis devices. It is however very unpractical to remove these flow devices from a microscope or the like. When removing the flow cell an sealing is broken, which makes it impossible to transfer the system

from a first to a second experimental set-up. The gas volume is relatively large and is supplied by a separate entity, which makes it impossible to transfer the system from a first to a second set-up. The separate gas supply entity is also
5 difficult to remove, e.g. in case of cleaning (see e.g. claim 9 herein). The fact that cleaning is required indicates that at least from time to time purity is an issue.

None of the two documents mentioned above relate to a system that can be transferred from a first set-up to a second
10 set-up.

The present invention therefore relates to a transferrable system for use in (combination with) microscopy and spectroscopy, and a microscope or spectrometer comprising said transferrable system, which solve one or more of the above
15 problems and drawbacks of the prior art, providing reliable results, without jeopardizing functionality and advantages.

SUMMARY OF THE INVENTION

The present invention relates to a transferrable system according to claim 1, use of the transferrable system according to claim 10, and a microscope according to claim 11.
20 For convenience of the reader a table with reference numerals is incorporated below.

With the present removable transferrable system it is now possible to make use of various shapes of samples, functionality, to perform experiments at temperatures up to about
25 800 °C, in a safe way, in a user friendly way, with improved control and reliability, etc. The present transferrable system can be moved from a first system (or set-up), such as a SEM, to another system (or set-up), such as an ageing tool. Likewise gas loading can be done at a location, and thereafter
30 sealing the present transferrable system by at least one and typically at least two removable seals, and then moving the transferrable system to an analytical tool, to an ex-situ ageing set-up etc. Put differently, the present system can be
35 used in a first experimental setting, having capabilities to study a first set of parameters, such as in an InfraRed microscope, and then be transferred to a second experimental setting, without changing the experimental conditions, in particular a gas or liquid environment, to study a second set of parameters, or likewise to confirm the first set of parameters,
40

or part thereof, such as in an electron microscope. The first and second experimental settings may be in a same location or room, or not, and could even be combined in one experimental set-up comprising the first and experimental setting such as in one housing; the latter is atypical. It is considered essential in this exchange from one system to another system is that the specimen (sample) is shielded, e.g. from the ambient atmosphere. Thereto a removable sealing, typically a vacuum tight sealing, is provided, as is e.g. exemplified in the figures. In addition use can be made of a removable gas system provided in the tip, including one or more internal gas tubes for passive supply of gas.

With the present transferrable system easy and very controlled transfer from and to a gas loading or liquid loading system is now possible. Heating of a sample, also during transfer, is an option. The transferrable system may be considered as a stand-alone system and it does not require complicated gas-flow systems, such as in flowing-gas holders. The sample itself is may be positioned in a reaction chamber, which reaction chamber is then sealed, e.g. by o-rings.

An advantage is that much less gas/liquid compared to prior art systems is used, and thus less danger is brought to e.g. a TEM and operators thereof. A control over gas pressure can be realised by add-on features, such as micro pump. A precise measurement of pressure is possible with a micro pressure meter, which may be included in the removable transferrable system. The may be clamped to the holder well and very easily.

The transferrable system may comprise a reactor, such as a micro reactor or a nanoreactor, and may have inherent functionality to function as a reactor. Electrical connections from the holder and/or from the transferrable system to the reactor can be made easily. Therewith the reactor can be operated with ease.

From a practical point of view the present transferrable system can be cleaned and/or baked out, in order for it to be ready for further experimentation, without much effort.

As the transferrable system is removable it can be hooked into/onto an aging set-up. In the set-up the sample can be subjected to aging e.g. at industrial conditions such as 1.000 kPa (10 bar). The pressure can be very high by realising

a pressure of a reaction gas inside the (nano)reactor and a pressure of an inert gas of the same pressure outside of the (nano)reactor.

5 The present transferrable system can contain compartments, e.g. to store optional reaction products. It can also contain a sieve, such as a molecular sieve. It may also contain an absorbent, e.g. to absorb water.

10 Further components may be present in the (nano)reactor or the rest of the transferrable system, such as a pump to pump a gas around. Certain reaction products may be captured for instance by absorption.

15 Ageing experiments have become an important issue. The transferrable system can be positioned into a set-up in which gas can be led controllably through the present transferrable system, c.q. nanoreactor, at a constant (flow) rate over a long period of time (months) and whereby every now and then the sample changes may be quickly checked by TEM. Such an (aging) experiment could take from a few days to months.

20 The present transferrable system is suited for advanced material science research, e.g. at harsh conditions, and control of advanced manufacturing, such as semiconductor manufacturing. The present transferrable system is also suited for loading in a glovebox and the like.

25 The present transferrable system, as indicated above, is very well suited for use in in-situ experiments, including aging. Thereto the transferrable system comprises a space for receiving a sample to be observed in in-situ experiments. The space typically comprises a window, through which the sample may be inspected. The window may be a quartz or glass window, e.g. for use in optical microscopy, a SiN window, for use in
30 electron microscopy, etc. The window is preferably as thin as possible, to reduce interference thereof, and thick enough to withstand pressure. It also provides adequate sealing properties, e.g. in view of gas/liquid used.

35 For performing in-situ experiments at least one gas and/or liquid is provided. The gas or liquid is stored in a container, until it may be released. It can be released at once, gradually, intermittent, etc., as required. The present container typically has a volume of 10^{-3} -500 mm³, such as 10^{-2} -
40 100 mm³. The present transferrable system may be somewhat larg-

er in size if more than one gas/liquid is provided, the present containers may be somewhat smaller, or both.

For transferring the gas/liquid from the container to the space at least one fluid passage way is provided. The passage way has suitable dimensions, such as a width and height of 5-500 μm .

The gas/liquid remains in the transferrable system, as such, and/or as a reaction product. In other words, leakage of gas/liquid is minimized or absent.

As mentioned above, it is a big advantage that the present transferrable system is removable. As such it can be mounted on a microscope, it can be stored as such, it can be mounted on an aging set-up, etc. Thereto on set of contacts may be present, or a variety of contacts, providing mounting of the transferrable system on various devices.

In view of costs the present transferrable system is clearly much cheaper and less complicated than e.g. a (complete) holder offering similar possibilities.

In a second aspect the present invention relates to use of the present transferrable system, and in a third aspect to a microscope comprising said transferrable system.

Thereby the present invention provides a solution to one or more of the above mentioned problems and drawbacks.

Advantages of the present description are detailed throughout the description.

DETAILED DESCRIPTION OF THE INVENTION

The present invention relates in a first aspect to a transferrable system according to claim 1.

In an example the present transferrable system comprises a means for moving gas or liquid, such as a pump, a chip, a piezo element, a piston, a pressure differentiator (for creating a difference in pressure), and a high pressure chamber. The example provides an alternative to static experiments, where conditions remain (largely) the same, by moving gas/liquid around. Therewith the present transferrable system can be operated in a dynamic fashion. The means for moving the gas/liquid are typically so small that they can be integrated in the (design of) the transferrable system. Therewith all of the functionality of the transferrable system can be moved together with the transferrable system.

In an example the present transferrable system comprises at least one of a sensor, such as a pressure sensor, a temperature sensor, a heat provider, a specimen (micro)heat provider, wherein the specimen (micro)heat provider comprises an first electrically controlled heat device, having a maximum heat capacity of 0.01 mW-1 W, such as 0.1 mW-0.5 W, a connector, such as a valve, a gas/liquid inlet, and a gas/liquid outlet, a gas/liquid chamber, a sealing, a cover, a regulator, such as a heat regulator, software, and logics, a controller, a MEMS, a means for accessing the container, a contact, preferably 2-6 contacts, a compartment, chemically-physically active elements, such as a sieve, an absorbent, a capturing agent, a catalyst, and a gel, and a cooler. The sealing provides adequate sealing for the gas/liquid. The sensors and meters are for measuring parameters. The measurements obtained can be used to control the conditions in the transferrable system. The inlets, outlets and valves can be used to direct the gas/liquids to a location and to provide or remove the gas/liquid, respectively. It is noted that the inlets and outlets of the present system relate to, with respect to the present system, internal connectors, contrary to prior art inlets and outlets which are connected to an outside world, such as (fluid supply parts of) a microscope, an external gas supply, etc. For heating a sample or a reactor one or more heat providers are provided in the example.

Software and controllers, on board, external, or in combination, can be used to control variables. The at least one container is filled with a liquid/gas, typically at a different location compared to a location where in-situ experiments take place. In order to fill the present container special measures may be taken (see examples), and the gas/liquid is confined in the container by a closing means/accessing means, such as a screw for fixing various parts of the container, and an air tight valve for controlling access. The air tight valve may be comprised of a screw and an O-ring or O-segment; the screw may close a valve opening by pressing the O-ring (or -segment), and may allow fluid passage when pressure is partly or fully relieved. Further also various contacts are provided, typically electrical contacts, e.g. for providing heat, for manipulating elements in the transferrable

system, such as opening/closing a valve, for manipulating a position of the sample/transferrable system, in order to observe the sample under a different angle (or angles). The MEMS device(s) may also contain logics, e.g. for optimizing performance, operability and reducing a number of (electrical) connections.

One of the big problems with in-situ electron microscopy and X-ray microscopy experiments with a gas is deposition of C-like species on the surface of a sample to be investigated, due to cracking of hydrocarbon molecules to carbon-type species by an electron beam or an X-ray beam. Further, water can play a catalytic role in this cracking. Both the hydrocarbons and the water are present as contamination in the (nano)reactor as well as the gas system in the transferrable system. It is very difficult in prior art systems to get rid of these contaminants. For instance, heating of a chip to about 500 °C is required, in combination with heating a sample to 250 °C (if possible at all). Use of a glove box or the like is found to be insufficient in this respect as well. It has been found that if the transferrable system is cooled to a temperature well below 0 °C, such as -50 °C, surface diffusion and release from the surface of the unwanted hydrocarbon and water molecules can be greatly reduced. The present MEMS heater allows for very local heating, a high temperature in the sample area can be realized, while the transferrable system and the main body of the nanoreactor are at such a low temperature that they will not release any unwanted hydrocarbon and water molecules and even capture these if a gas is flown through them. In a similar manner, somewhere in the transferrable system one can realize capturing "agents" such as a zeolites, and noble metals, such as Pd, or one can actively crack the hydrocarbons by a combination of local temperature and cracking catalysts, which can be realized in a second or third nanoreactor optionally included in the transferrable system.

In an example the present transferrable system comprises a means of manipulating the sample, such as a multi-contact device. Therewith the sample can be observed at a different location/angle. The present transferrable system may also be capable of providing double tilt, a first tilt provided by the goniometer and the second tilt provided by the

(specimen) cradle.

In an example the present transferrable system comprises one or more connections, such as to a microscope holder, such as electrical connections, fixing means, such as for
5 fixing electrical connectors, for fixing sealants of the nanoreactor, such as screws and for operating valves, and for fixing elements of the nanoreactor, such as a viewing window, and manipulation means. By having connections the transferrable system can be fixed in place, such as to a microscope. An example
10 is a slit type connection. A click type connection is for some systems considered not particularly suited in view of a risk of damage of parts of the system. Further the transferrable system is preferably fixed, such as to (a holder of) the microscope, in order to secure its relative position. The
15 transferrable system may also comprise manipulating means. Therewith the transferrable system and sample can be observed under different conditions and angles.

In an example of the present transferrable system the microscope is selected from an electron microscope, an IR-
20 microscope, a Raman-microscope, X-ray microscope, and an optical microscope, such as a TEM, a SEM, a transmission mode SEM, and combinations thereof. The spectrometer may be selected from a (FT)IR spectrometer, a UV(-vis) spectrometer, and a Raman spectrometer. The present transferrable system is ex-
25 changeable to various sorts of microscopes. Therewith a spectrum of different observation techniques is available.

In an example of the present transferrable system the means for sealing the reactor can withstand a 100 kPa pressure difference, preferably 500 kPa. The present space and contain-
30 er and window are preferably sealed tightly, in order to withstand pressures (an outside pressure in a SEM is typically absent). Such allows for at least some variation of pressure inside the present transferrable system, and thus to perform in-situ experiments under (partly) pressurized conditions.

35 In an example the present transferrable system is in combination with a holder. Typically such a holder is present in for instance an electron microscope, such as a SEM, and a TEM.

In an example the holder, and likewise the microscope
40 and spectrometer may comprise a cooler for providing cooling

to a sample and/or to the transferrable system.

In a second aspect the present invention relates to a use of the present transferrable system according to claim 10. Herewith a large range of experiments may be performed with the present transferrable system.

In a third aspect the present invention relates to a microscope and a spectrometer according to claim 11. Such a microscope, in combination with the present transferrable system, provides an easy to use and flexible set up for a large variety of experiments.

The one or more of the above examples and embodiments may be combined, falling within the scope of the invention.

EXAMPLES

The invention is further detailed by the accompanying figures, which are exemplary and explanatory of nature and are not limiting the scope of the invention. To the person skilled in the art it may be clear that many variants, being obvious or not, may be conceivable falling within the scope of protection, defined by the present claims.

FIGURES

The invention although described in detailed explanatory context may be best understood in conjunction with the accompanying figures.

Figure 1 (a) Image of the static gas holder and its large view in the transferrable system part.

(b) A sketch of holder transferrable system in cross section view. O-ring positions are indicated with arrows.

Figure 2 (a) PdOx nanoparticles in O₂ with pressure of 64.5 kPa (0.645 bar) at 500 °C.

(b) FFT of image (a), the white circle is 1 Å. The triangle indicates a diffraction spot with a d-spacing of 0.88 Å.

Figure 3 Pd nanoparticles in H₂ with a pressure of 52 kPa

(0.52 bar) at 200 °C. (b) FFT of image (a), the white circle is 1 Å. The triangle indicates a diffraction spot with a d-spacing of 0.85 Å.

Figure 4 shows a gas loading system.

Figure 5 shows a gas loading system.

Figure 6 shows a side view of a transferrable system.

Figure 7a shows a side view of a transferrable system in combination with a receiving holder in a non-connected status, whereas figure 7b a connected status. Figure 7c shows a top view of figure 7b.

5 Figure 8 shows a side view of a transferrable system in combination with a receiving holder.

Figure 9 shows a side view of a transferrable system in combination with a receiving holder in a TEM.

DETAILED DESCRIPTION OF THE FIGURES

10 List of elements:

- 100: Transferrable system
- 131: Fluid passageway from nanoreactor to outlet (partly visible)
- 132: Fluid passageway from nanoreactor to inlet
- 15 133: Fluid passageway from nanoreactor to extra MEMS
- 134: Fluid passageway from extra MEMS to inlet (and outlet) (gas line) partly visible
- 150: Nanoreactor
- 160: Pump
- 20 170: Extra MEMS device
- 180: Fixing means electrical contacts (block)
- 190: Electrical connector (contact); optionally more connectors
- 200: Gas fill equipment
- 25 210: Transparent Flange
- 211: Viewing window (optional)
- 220: Stops to prevent that screwdriver is blown out/in
- 230: Screwdriver, screw not in transferrable system
- 232a,b: Screw valve
- 30 236: Screw for closure
- 240: To vacuum gas supply and vacuum
- 251: Inlet
- 252: Outlet
- 280: Transferrable system support
- 35 300: Transferrable system receiver
- 321: (Electrical) contacts for control (e.g. pressure meter)
- 322: (Electrical) contacts for control of (nano)reactor
- 323: (Electrical) contact pads
- 410: TEM Holder
- 40 420: Vacuum Chamber

430: Electron beam
460: Sapphire window
480: Laser
481: Laser pulse
5 482: Reflected laser pulse (to e.g. Raman spectrometer)

In an example of the present invention a TEM experiment is given beyond the ~ 2 kPa (20 mbar) pressure regime that is achieved by ETEM. In the present nanoreactor concept, a gas is enclosed along the beam direction by two very thin
10 membranes of for instance SiN. With this approach pressures up to 450 kPa (4.5 bar) are obtainable. An obvious question in this approach is what kind of resolution can be obtained, given that the resolution limit is now no longer set by the electron microscopes, provided these are equipped with aberration
15 correctors.

Inventors present a new type of gas holder, which in an example relates to a static gas holder, which has also two windows but no dynamic gas supply system (figure 1). Instead, the holder has a separable tip, which contains an airtight
20 chamber that can store gas with volume of 1.5 to 10 cubic millimeter. Gas is loaded in or pumped out through a valve in the tip (see figure 1). Similar to the dynamic nanoreactor, it consists of two silicon chips, which have a low stress 400 nm thick SiN membrane of for instance 400 μm x 400 μm . One of the
25 two membranes contains a Pt heater spiral and both of the membranes contain with 5-20 small thin SiN membranes "windows" with thickness of 10-20 nm. The windows of the top and bottom chip have to be aligned to be overlapping, such that a sample on top of one of the windows can be investigated by transmission electron microscopy. In this system, the temperature can
30 be changed within a second over for instance 100°C with low specimen drift. Since the gas volume is very small, no harm to the gun part of the TEM when there is a sudden release of all gas inside the nanoreactor and the tip. An obstacle for high-
35 resolution imaging can be the contamination in the system, which can originate from sample, chips, gases, O-rings etc. We demonstrate that when contamination is minimized, the resolution of the system can reach the resolution limitation of the microscope at gas pressures of e.g. oxygen of at least 60 kPa
40 (0.6 bar) (figure 2 and figure 3).

In figure 4 a gas loading system is shown. In view of optionally poisonous/toxic gas (or liquid) the present system if filled in an enclosed environment. Thereto the system (100) is placed on a transferrable system support 280. The present system can be "opened" and "closed" by removing or introducing a screw 236 with a screw driver 230.

Figure 5 shows a gas loading system, comparable to figure 4, that can also be used as an aging set-up, because gas can be led through the nanoreactor over a long period of time, while if required the heater of the nanoreactor can maintain an elevated temperature. Note that the gas line 131 and valve 232b are connected by a gas line that is not in the field of view. Various fluid passageways 131, 132, a reactor 150, screws 232, screw driver, and an inlet and outlet are shown.

Figure 6 shows a side view of a transferrable system. Note that the gas line 132 and 134 are connected by a gas line that is not in the field of view. Further electrical connections 190 may be present. Typically these connections are fixed by fixing means 180. The system may further comprise one or more pumps 160, and a MEMS device 170.

Figure 7a shows a side view of a transferrable system in combination with a receiving holder in a non-connected status, whereas figure 7b a connected status. Air tight connectors may be provided, such as valves comprising a screw and a flexible element. Figure 7c shows a top view of figure 7b. The holder and system can be slit together, and likewise separated. Further various (electrical) contacts for control may be present, such as for control of the reactor, for control of various additional elements, such as a pressure meter, etc. Also contact pads 323 for the contacts may be present.

Figure 8 shows a side view of a transferrable system in combination with a receiving holder. The present system 100 is placed in a TEM holder 410. A laser 480 may be provided for generating a laser pulse 481. The laser pulse passes through a sapphire window to the present system. A reflected laser pulse 482 may be further analysed, such as by a Raman spectrometer. The present system is located in a vacuum chamber (of the TEM).

Figure 9 shows a side view of a transferrable system

in combination with a receiving holder in a TEM (see also fig. 8). Therein an electron beam 430 is shown (schematically).

CLAIMS

1. Transferrable system for use in in-situ experiments comprising:

- (a) a space for receiving a sample;
- (b) at least one window for inspecting the sample;
- 5 (c) at least one container for gas or liquid;
- (d) at least one fluid passage way connecting the space for receiving the sample and the container for gas or liquid,
- (e) wherein the transferrable system is removable,
- (f) wherein the gas/liquid can be confined in the transferrable system,
- 10 (g) an inlet for introducing gas/liquid, and
- (h) wherein confinement is secured by at least one removable sealing in the inlet.

2. Transferrable system according to claim 1, further comprising a means for moving gas or liquid.

3. Transferrable system according to any of the preceding claims, further comprising at least one of a sensor, a heat provider, a cooler, a regulator, a connector, and a chamber.

20 4. Transferrable system according to any of the preceding claims, further comprising a means of manipulating the sample.

5. Transferrable system according to any of the preceding claims, further comprising at least one connection, fixing means, and manipulation means.

6. Transferrable system according to any of the preceding claims comprising at least one of a cover, a controller, a means for accessing the container, a compartment, and a chemically-physically active component.

30 7. Transferrable system according to any of the preceding claims, wherein the means for sealing the reactor can withstand a 100 kPa pressure difference.

8. Transferrable system according to any of the preceding claims, further comprising a valve, the valve comprising a flexible element and a screw.

9. Transferrable system according to any of the preceding claims, in combination with a holder.

10. Use of a transferrable system according to any of

the preceding claims, for use in experiments, for securing a sample over a time period of at least one week, for spectroscopy, for ageing experiments, and combinations thereof.

11. Microscope or spectrometer, and combinations
5 thereof, comprising a transferrable system according to any of claims 1-9.

12. Microscope according to claim 11, comprising an electron microscope, and an integrated optical microscope.

AMENDED CLAIMS**received by the International Bureau on 03 September 2015 (03.09.2015)**

1. Transferrable system (100) for use in static and dynamic in-situ experiments comprising:

5 (a) a micro reactor or nanoreactor (150), the reactor comprising

(ai) a space for receiving a sample; and

(a ii) at least one window for inspecting the sample;

10 (c) at least one container for storing gas or liquid, the container having a volume of 10^{-3} -500 mm³;

(d) at least one fluid passage way (132,133,134) connecting the space for receiving the sample in the reactor and the container for gas or liquid,

15 (g) an inlet (132) for introducing gas/liquid,

(h) at least one removable sealing (232) in the inlet for securing confinement, for introducing gas/liquid, and for opening and closing the transferrable system,

(f) wherein the gas/liquid can be confined in the transferrable system,

20 (e) wherein the transferrable system is removable, and wherein the system is transferrable from a first experimental setting to a second experimental setting, such as an electron microscope with the confined gas or liquid.

25 2. Transferrable system according to claim 1, further comprising a means (160) for moving gas or liquid.

3. Transferrable system according to any of the preceding claims, further comprising at least one of a sensor, a heat provider, a cooler, a regulator, a connector, and a chamber.

30 4. Transferrable system according to any of the preceding claims, further comprising a means of manipulating the sample.

35 5. Transferrable system according to any of the preceding claims, further comprising at least one connection (190, 321,322), fixing means, and manipulation means.

40 6. Transferrable system according to any of the preceding claims comprising at least one of a cover, a controller, a means for accessing the container, a compartment, and a chemically-physically active component.

7. Transferrable system according to any of the preceding claims, wherein the means for sealing the reactor can withstand a 100 kPa pressure difference.

5 8. Transferrable system according to any of the preceding claims, further comprising a valve (232), the valve comprising a flexible element and a screw.

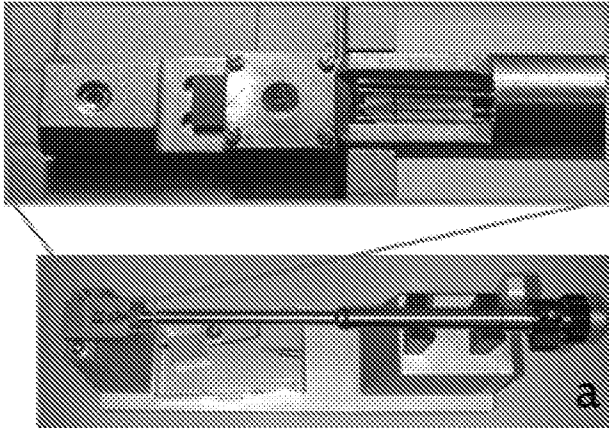
9. Transferrable system (100) according to any of the preceding claims, in combination with a holder (300).

10 10. Use of a transferrable system according to any of the preceding claims, for use in experiments, for securing a sample over a time period of at least one week, for spectroscopy, for ageing experiments, and combinations thereof.

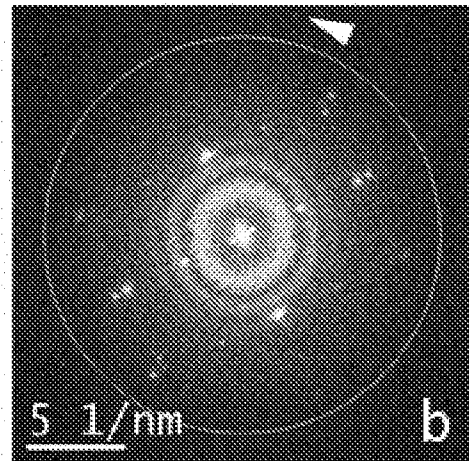
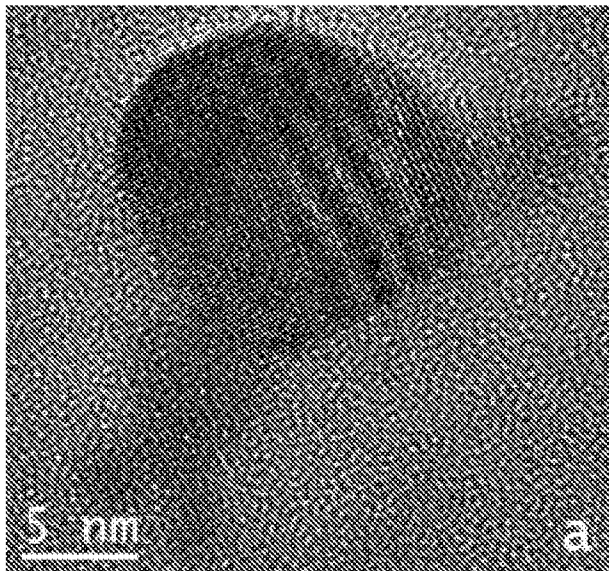
15 11. Microscope or spectrometer, and combinations thereof, comprising a transferrable system according to any of claims 1-9.

12. Microscope according to claim 11, comprising an electron microscope, and an integrated optical microscope.

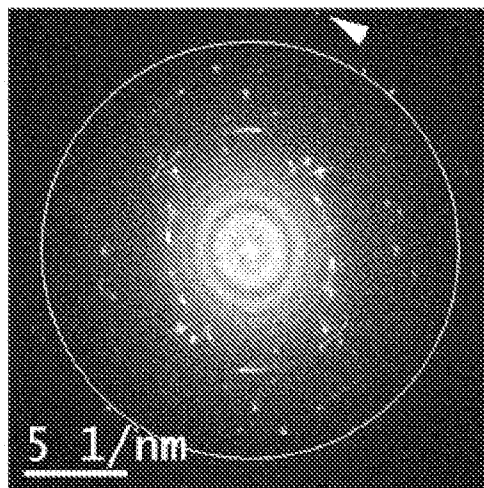
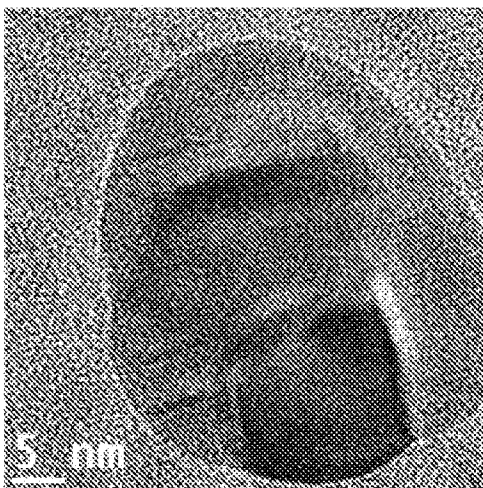
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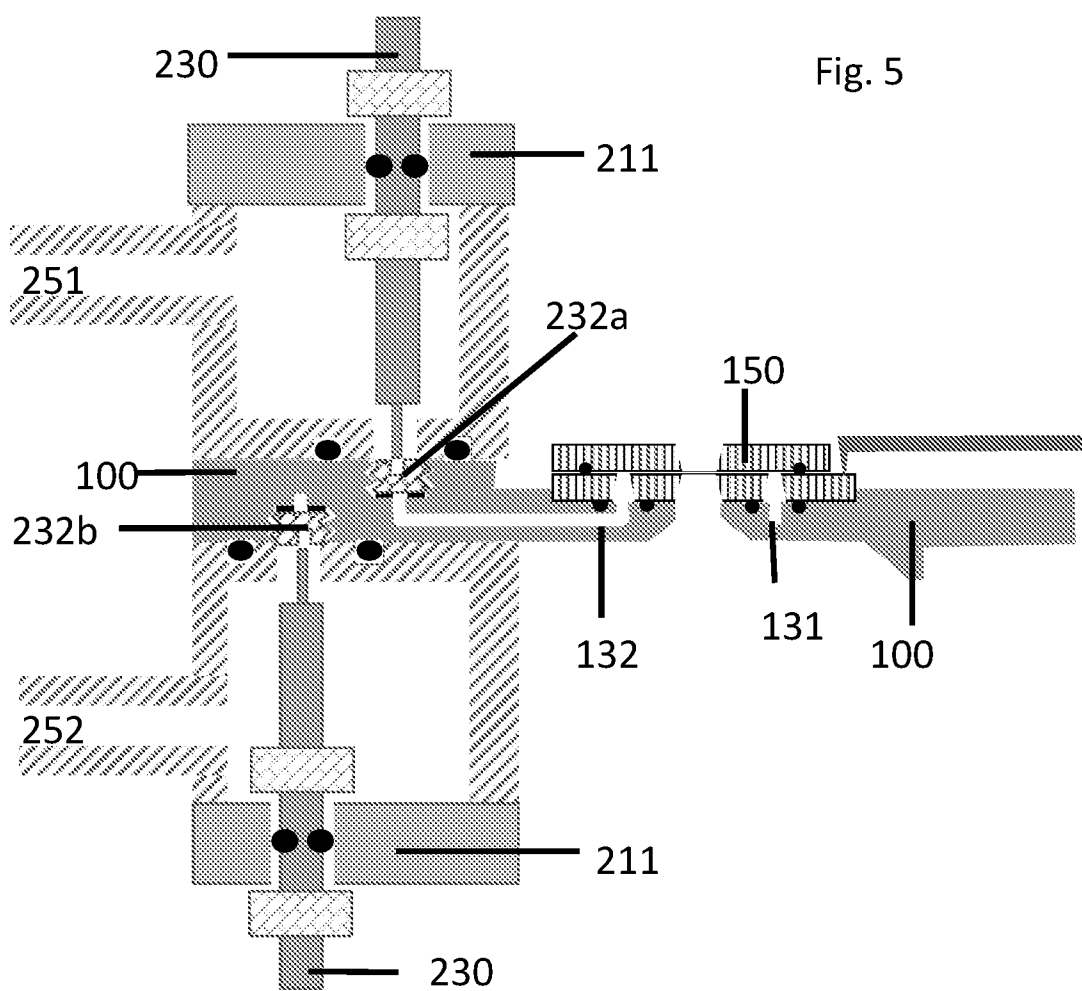
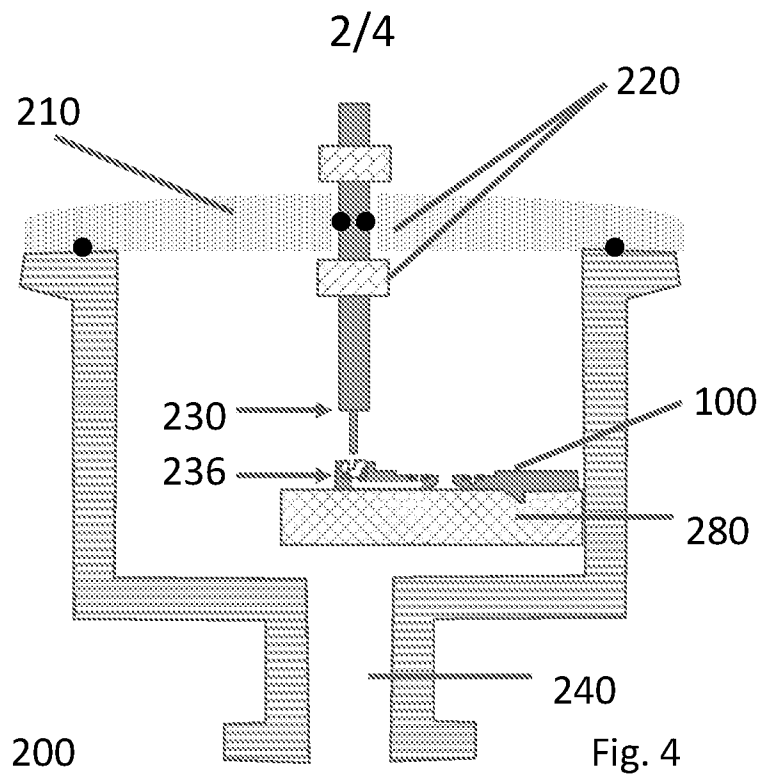
Figs. 1a and 1b



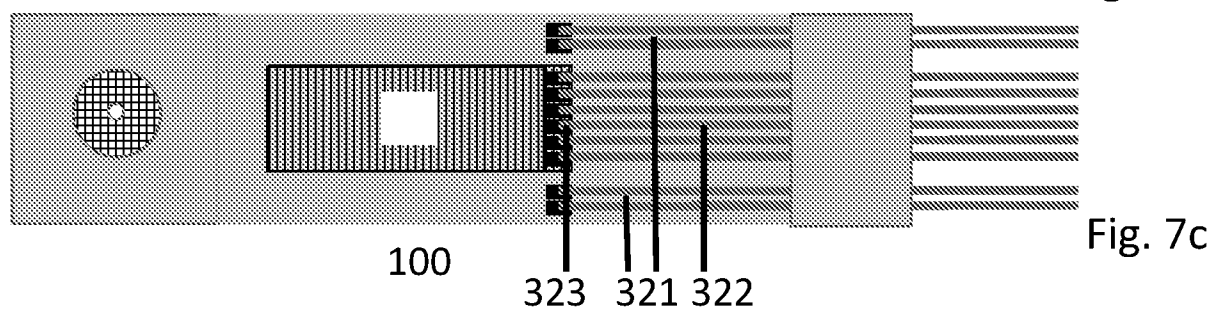
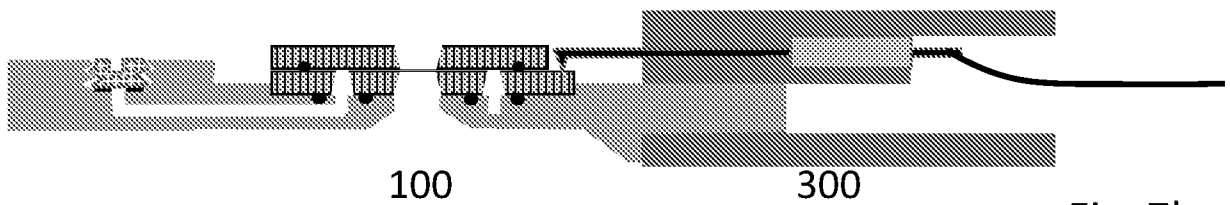
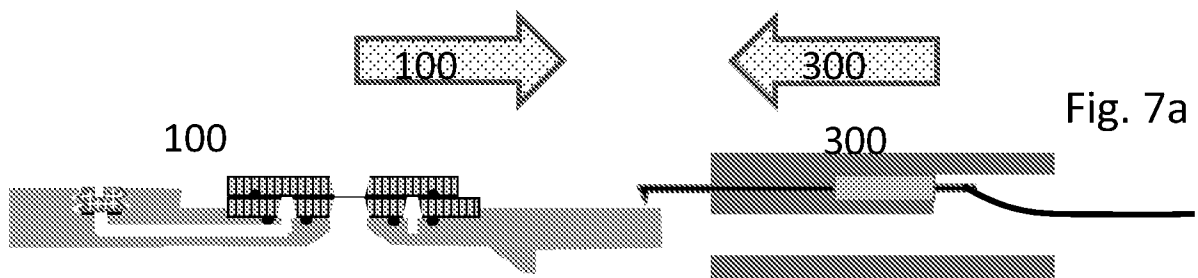
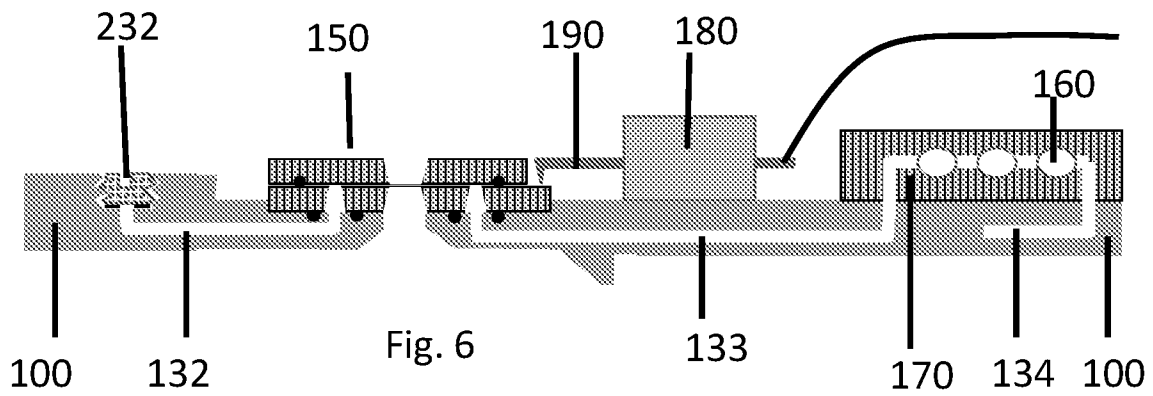
Figs. 2a and 2b



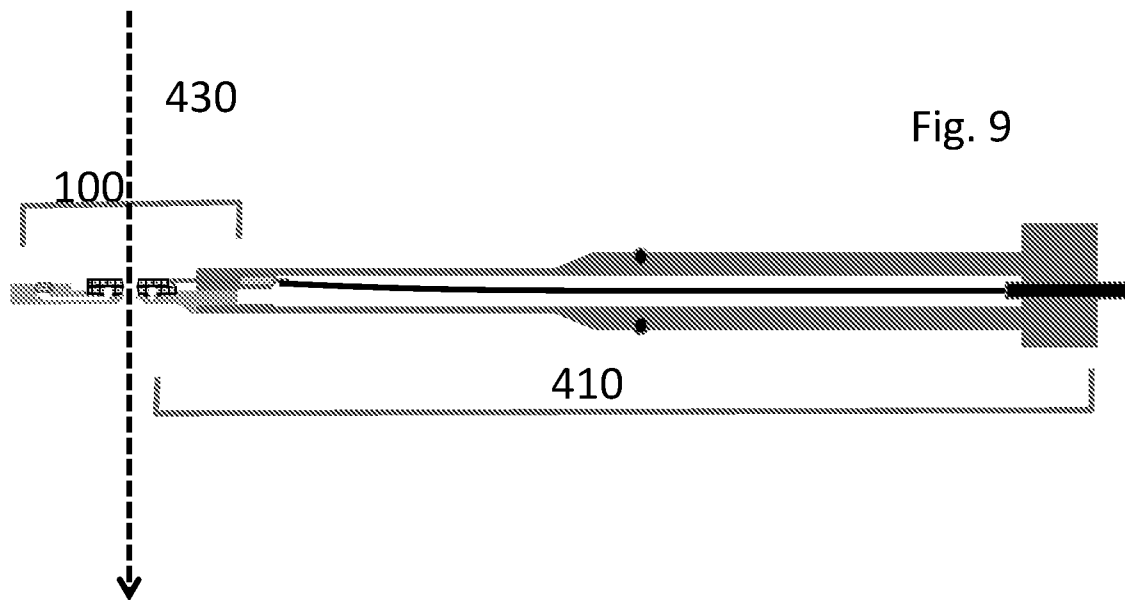
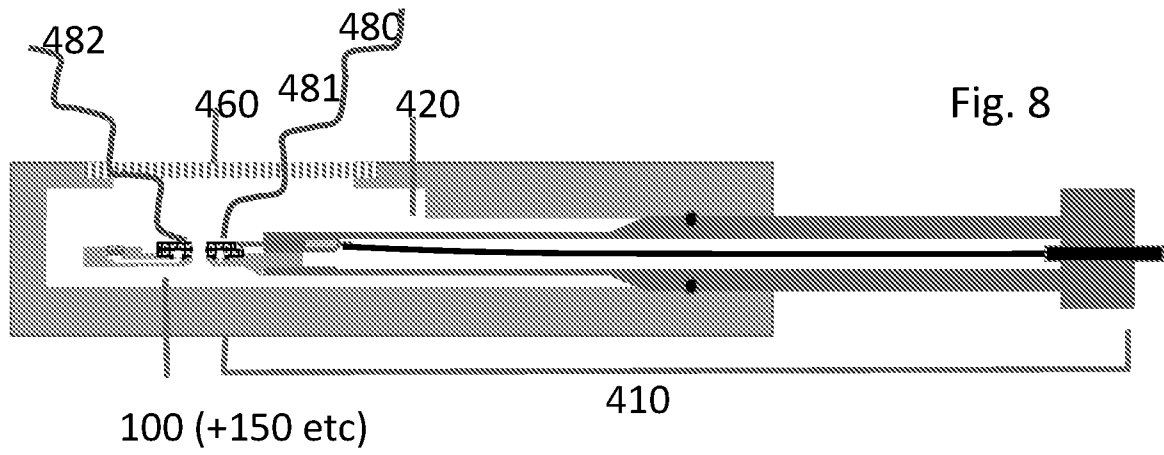
Figs. 3a, and 3b



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INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2015/050177

A. CLASSIFICATION OF SUBJECT MATTER

INV. H01J37/20

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2 629 318 A2 (FEI CO [US]; DELFT UNIVERSITY OF TECHNOLOGY [NL]) 21 August 2013 (2013-08-21) paragraphs [0008], [0039]; figure 1 -----	1,6,8-12
X	US 5 326 971 A (THEODORE N DAVID [US] ET AL) 5 July 1994 (1994-07-05)	1,3,5-12
Y	paragraph [0008] -----	2
Y	US 2012/298883 A1 (GROGAN JOSEPH M [US] ET AL) 29 November 2012 (2012-11-29) paragraphs [0024], [0028], [0057]; figure 1 -----	2

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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Date of the actual completion of the international search

19 June 2015

Date of mailing of the international search report

03/07/2015

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/NL2015/050177

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