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(54) Benævnelse: A method for fabricating nanoscale patterns in a surface

(57) Sammendrag:

A novel method to fabricate nanoscale pits on Au(111) surfaces in contact with aqueous solution is claimed. The method uses in situ electrochemical scanning tunnelling microscopy with independent electrochemical substrate and tip potential control and very small bias voltages. This is significantly different from other documented methods, which mostly apply high and short voltage pulses. The most important advantages of the present method are that the dimensions and positions of the pits can be controlled with high precision in aqueous environment so that nanopatterns of the pits can be designed, and that the operations are simple and require no instrumental accessories. Parameters, which control the pit formation and size, have been systematically characterised and show that the primary controlling parameter is the bias voltage. A mechanism based on local surface reconstruction induced by electronic contact between tip and substrate is in keeping with the overall patterns for pit formation. A range of potential applications is proposed.

fortsættes

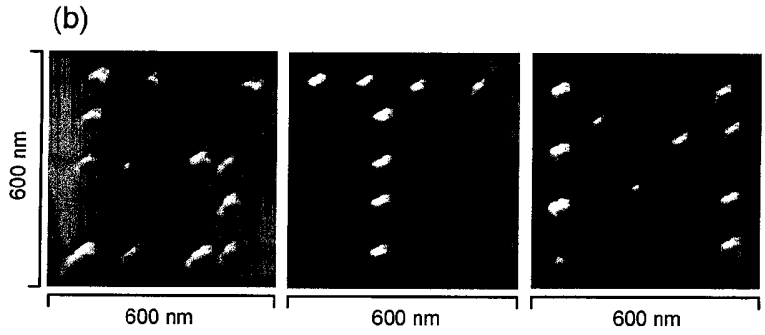


Fig. 5(b)

CLAIMS

1. A method for forming at least one nanoscale depression in a surface of a substrate, said method comprising the steps of:

- immersing at least part of the surface of the substrate into a liquid environment,

- immersing at least part of an object into the liquid environment,

- bringing the object within proximity of the surface of the substrate by applying a first set of operation parameters, said first set of operation parameters comprising bias voltage, tunnel current and working potential, and

- forming at least one nanoscale depression in the surface of the substrate by applying a second set of operation parameters, said second set of operation parameters comprising bias voltage, tunnel current and working potential, wherein the bias voltage of the second set of operation parameters is negative.

2. A method according to claim 1, wherein the liquid environment is an electrically conducting environment.

3. A method according to claim 1 or 2, wherein the object forms part of a scanning probe microscope, such as a scanning tunneling microscope.

4. A method according to claim 3, wherein the object forms part of a tunneling tip.

5. A method according to any of the preceding claims, wherein the bias voltage of the second set of operation parameters is in the range -10 mV - 0 V, preferably in the range -8 mV - 0 V, more preferably in the range -4 mV - 0 V, such as approximately -2 mV.

6. A method according to any of the preceding claims, wherein the tunnel current of the second set of operation parameters is in the range 0 - 10 nA, preferably in the

range 0 - 6 nA, more preferably in the range 0 - 4 nA, even more preferably in the range 2 - 3 nA.

7. A method according to any of the preceding claims, wherein the working potential of the second set of operation parameters is in the range -0,1 - 0,5 V vs NHE, preferably in the range 0 - 0,4 V vs NHE, more preferably in the range 0,1 - 0,3 V vs NHE.

8. A method according to any of the preceding claims, wherein the bias voltage of the first set of operation parameters is in the range 100-300 mV, and wherein the tunnel current of the first set of operation parameters is in the range 0.5-5 nA, and wherein the working potential of the first set of operation parameters is in the range 0.1-0.6 V vs NHE.

9. A method according to claim 2, wherein the electrically conducting environment comprises an aqueous acidic, basic, neutral, or salt containing electrolyte solution such as $HClO_4$.

10. A method according to claim 9, wherein the concentration of the $HClO_4$ solution is in the range 10^{-3}-10 M, preferably in the range 0,02-0,4 M, more preferably in the range 0,03-0,3 M and even more preferably in the range 0,05-0,1 M.

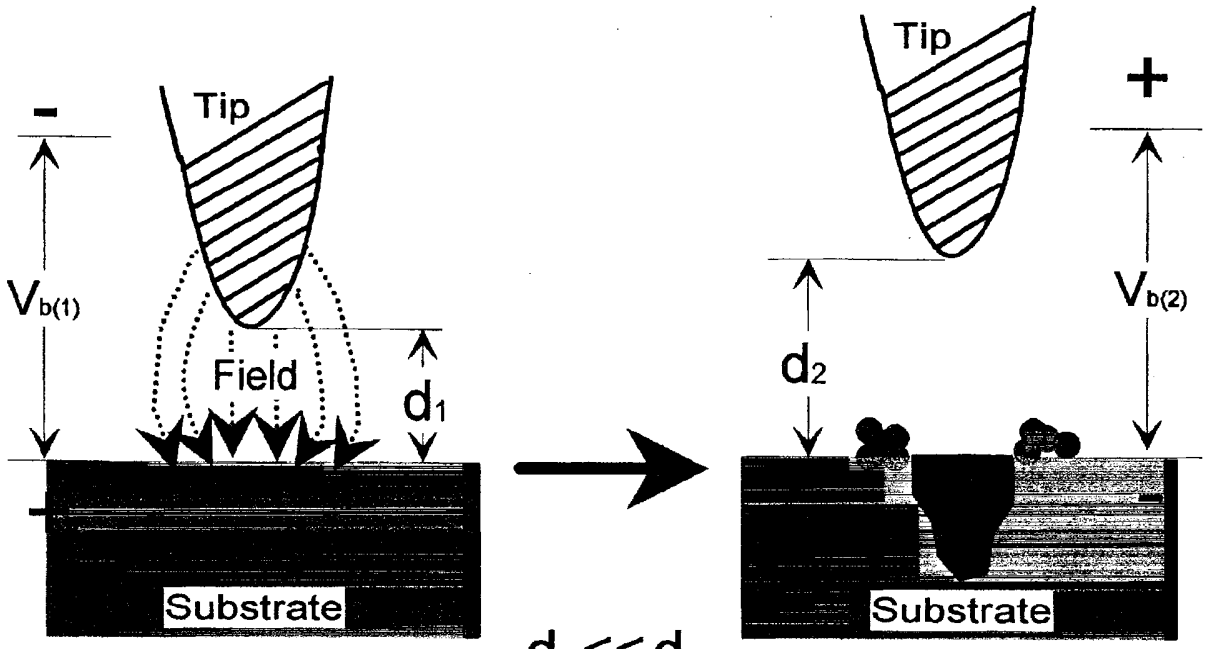
11. A method according to any of the preceding claims, wherein part of the surface of the substrate holds an electrically conducting material, such as a metal, so that the at least one depression is formed in said electrically conducting material.

12. A method according to any of the preceding claims, wherein part of the surface of the substrate holds a gold film, or constitutes bulk gold.

13. A method according to claim 1, wherein the liquid environment comprises chloride, sulphate, or other adsorbing inorganic or organic anions or molecules.

14. A method according to any of the preceding claims, wherein part of the surface of the substrate holds a semiconductor material, such as silicon.

15. A method according to claim 1, wherein the object forms part of a tip of a commercially available scanning probe microscope, such as a scanning tunneling microscope.



(a) Formation of pits (b) Imaging of pits

Fig. 1

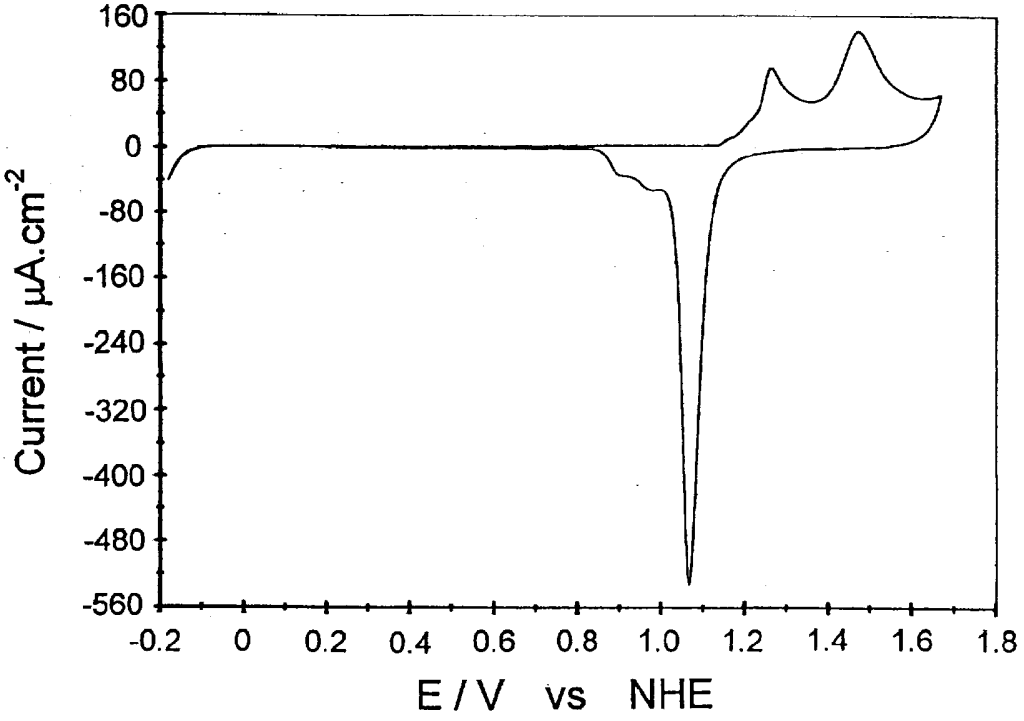

160
80
0
-80
-160
-240
-320
-400
-480
-560
Current / µA.cm-2
-0.2
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
E / V vs NHE

Fig. 2

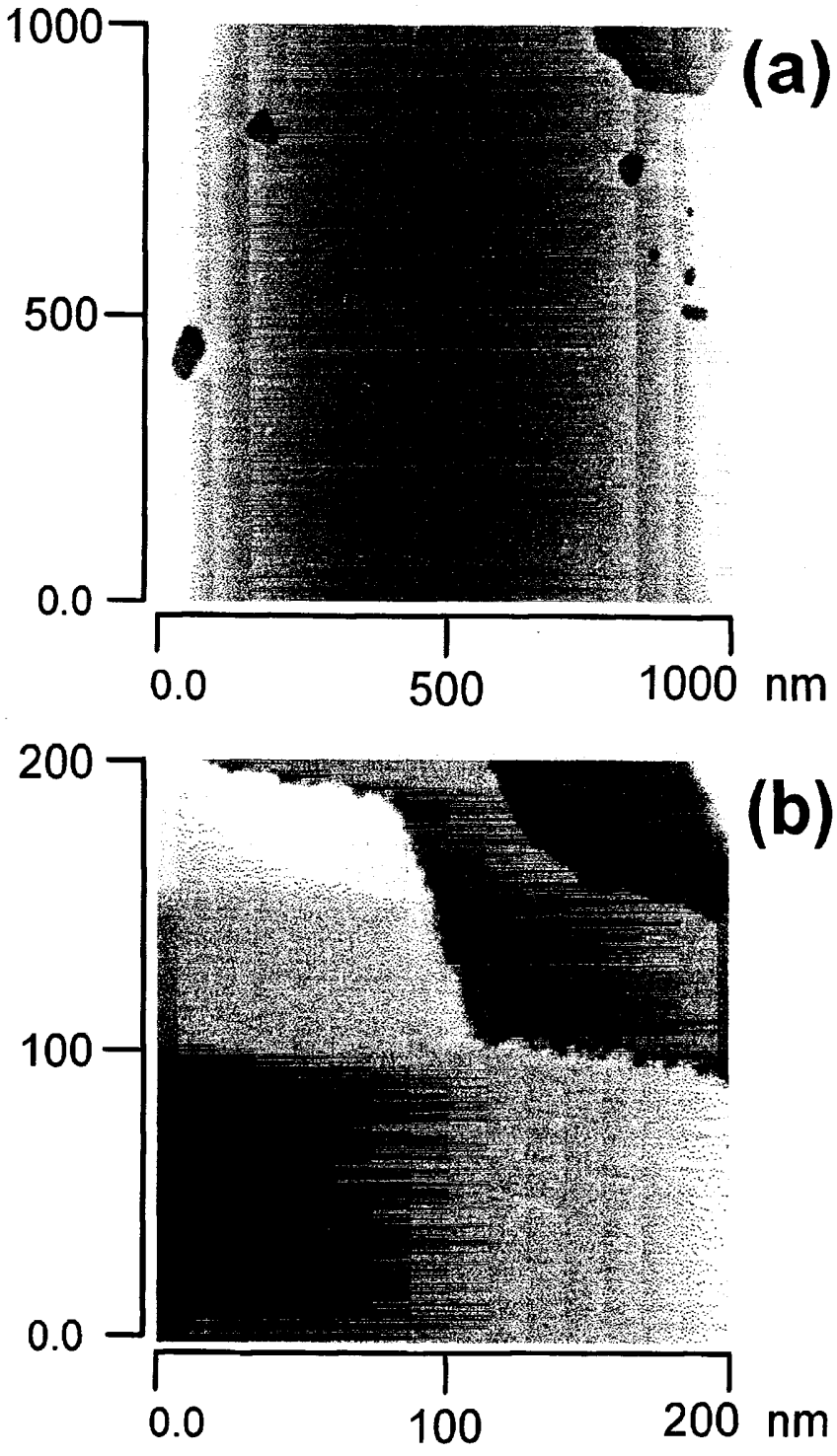


Fig. 3

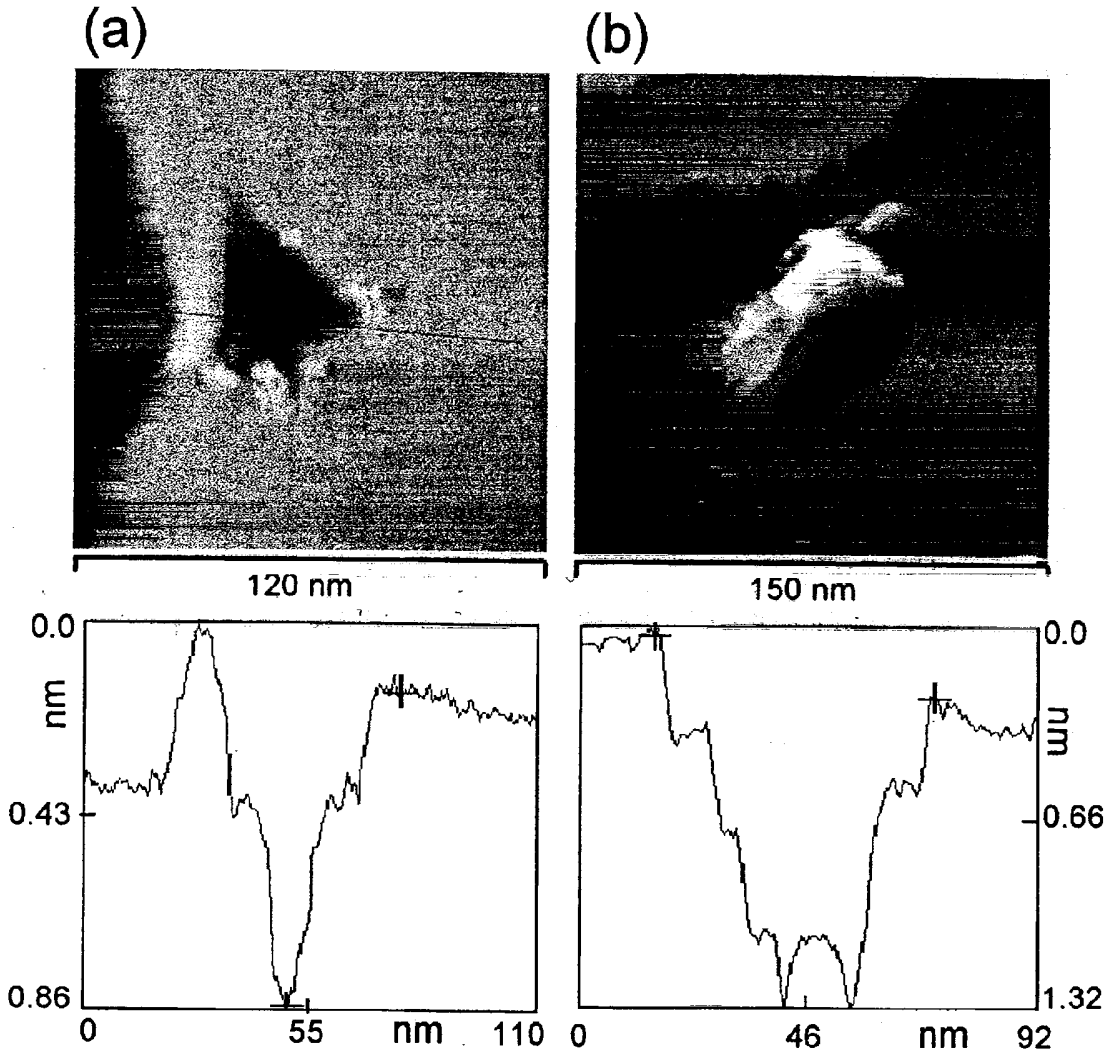


Fig. 4

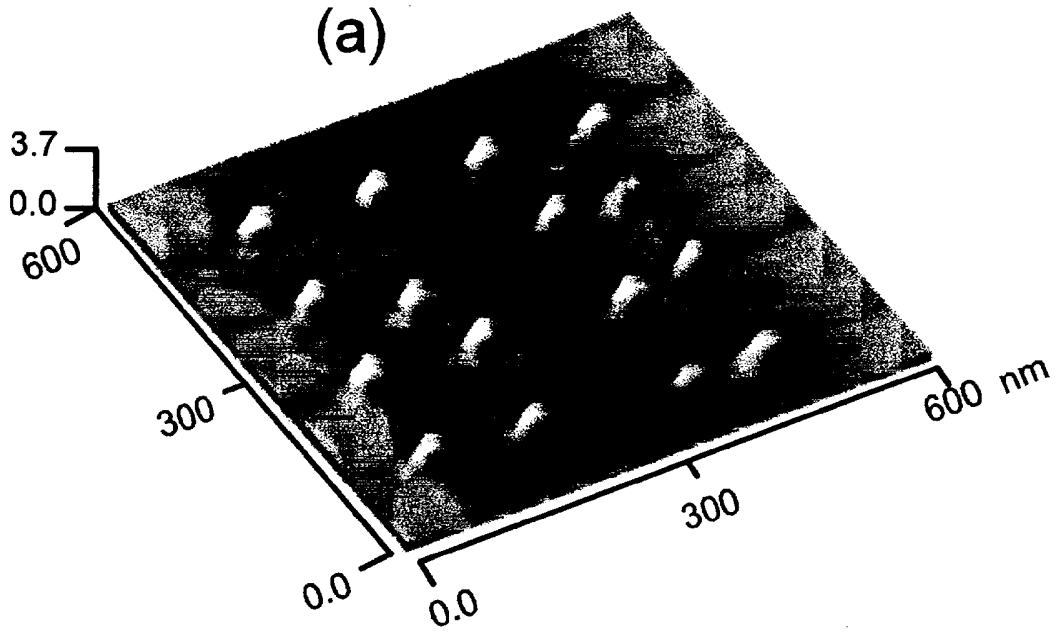


Fig. 5(a)

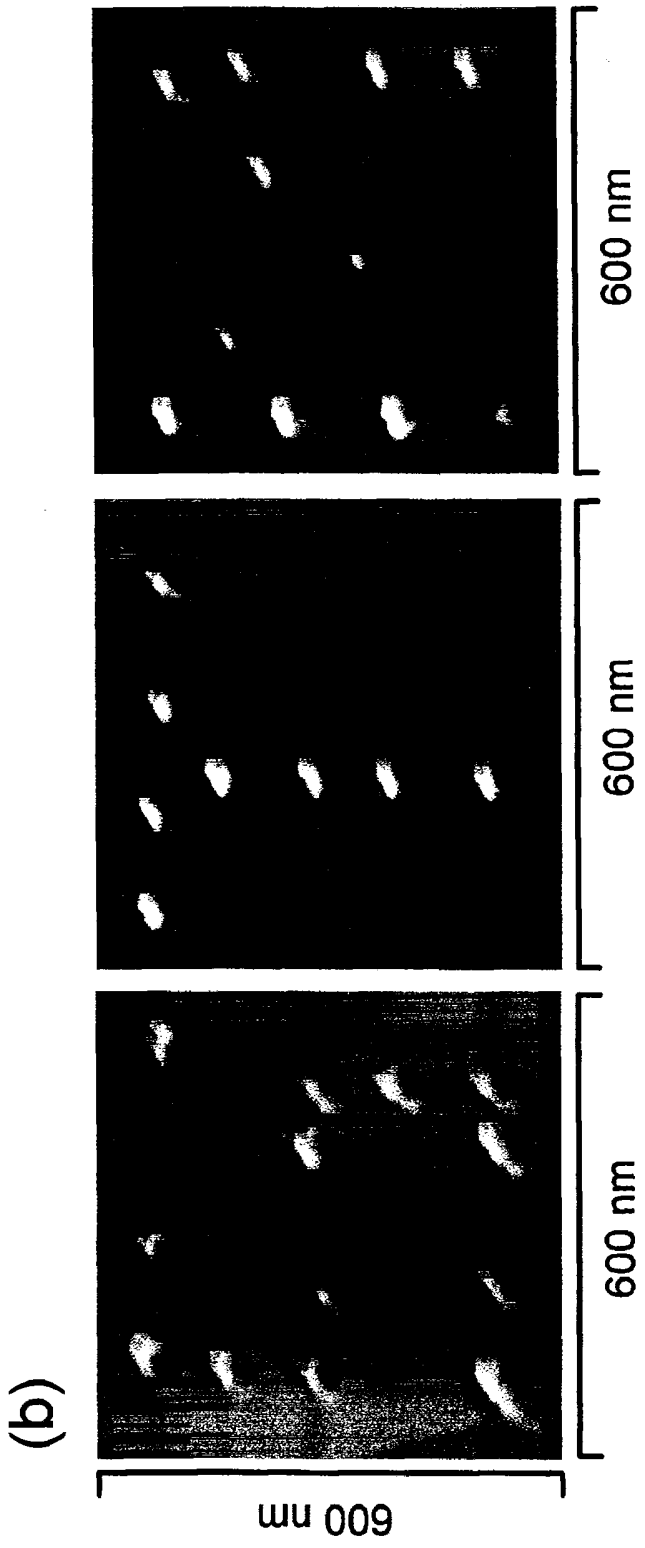


Fig. 5(b)

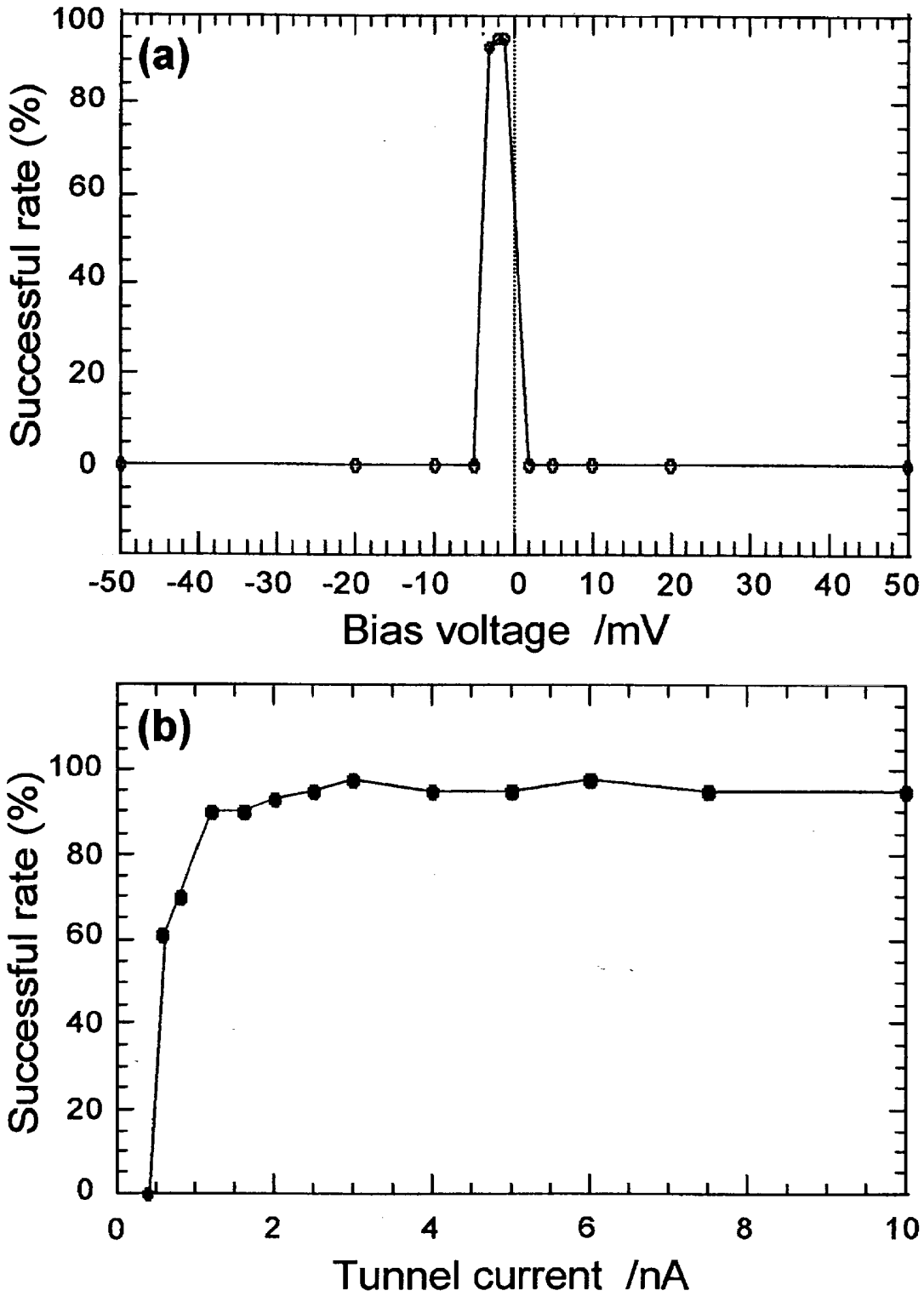

(a)
Successful rate (%)
100
80
60
40
20
0
-50 -40 -30 -20 -10 0 10 20 30 40 50
Bias voltage /mV
(b)
Successful rate (%)
100
80
60
40
20
0
0 2 4 6 8 10
Tunnel current /nA

Fig. 6(a) & (b)

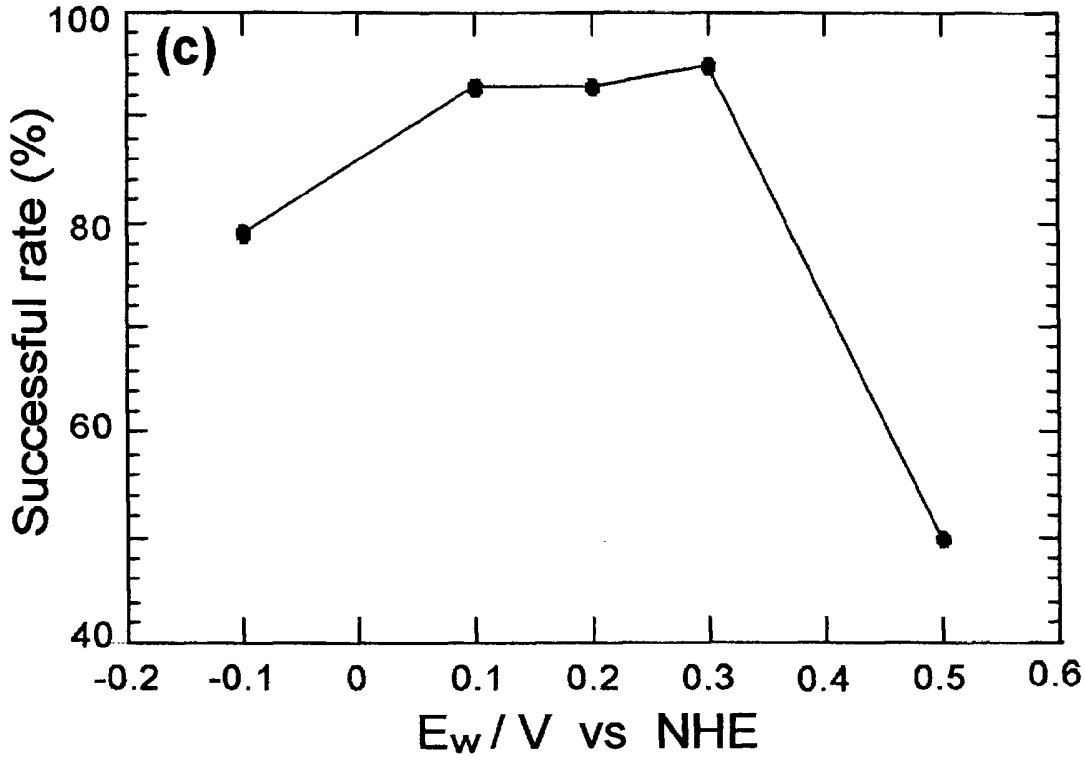


Fig. 6(c)

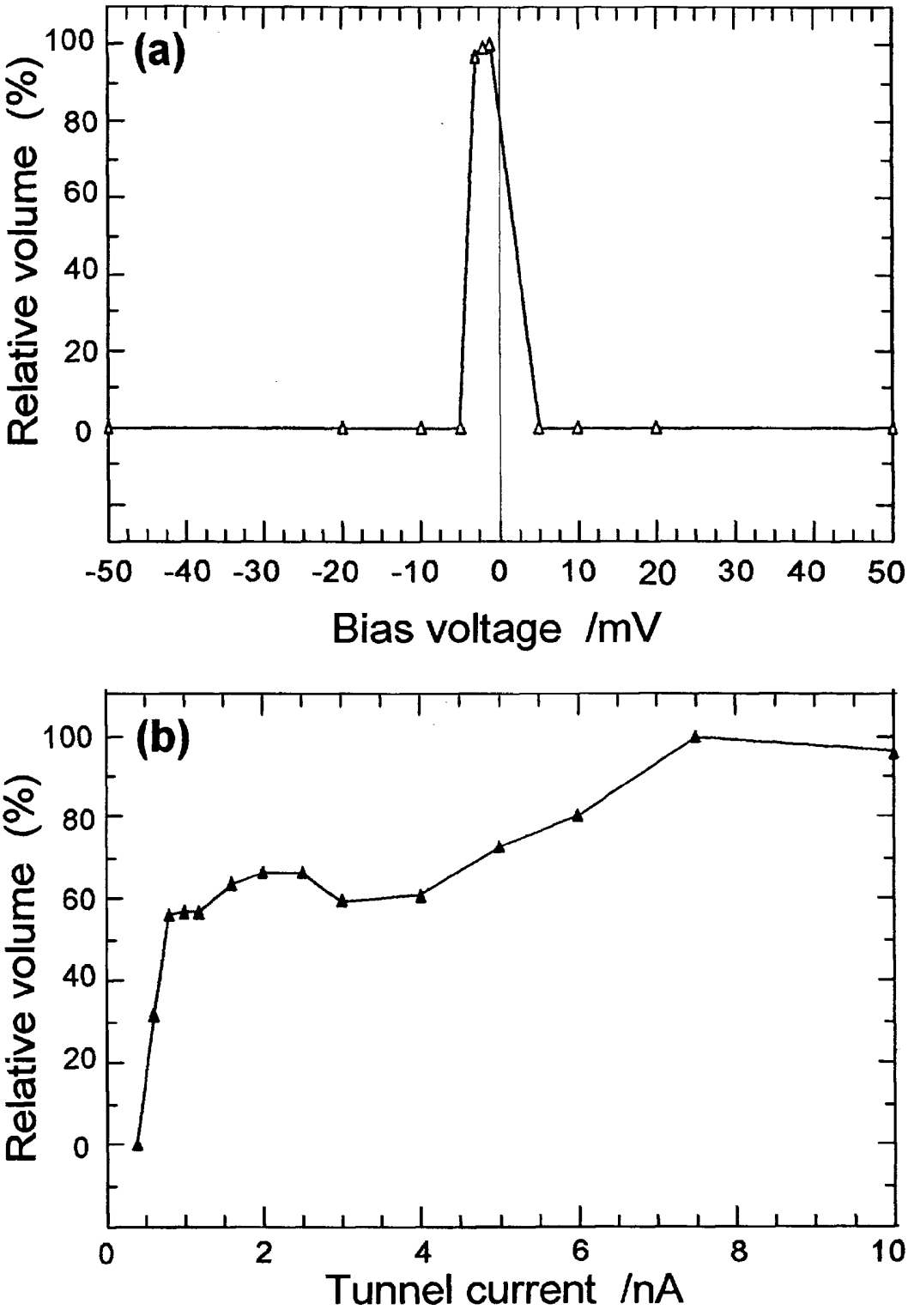

(a)
Relative volume (%)
100
80
60
40
20
0
-50 -40 -30 -20 -10 0 10 20 30 40 50
Bias voltage /mV
(b)
Relative volume (%)
100
80
60
40
20
0
0 2 4 6 8 10
Tunnel current /nA

Fig. 7 (a) & (b)

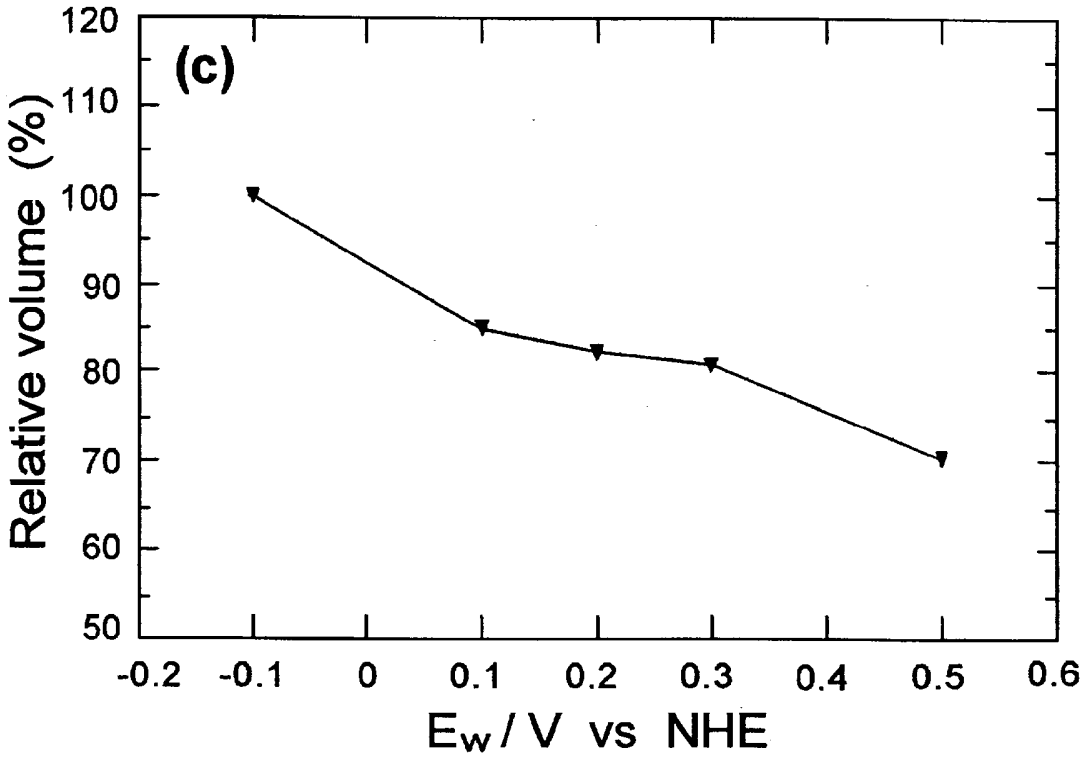

(c)
Relative volume (%)
120
110
100
90
80
70
60
50
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
Ew / V vs NHE

Fig. 7 (c)

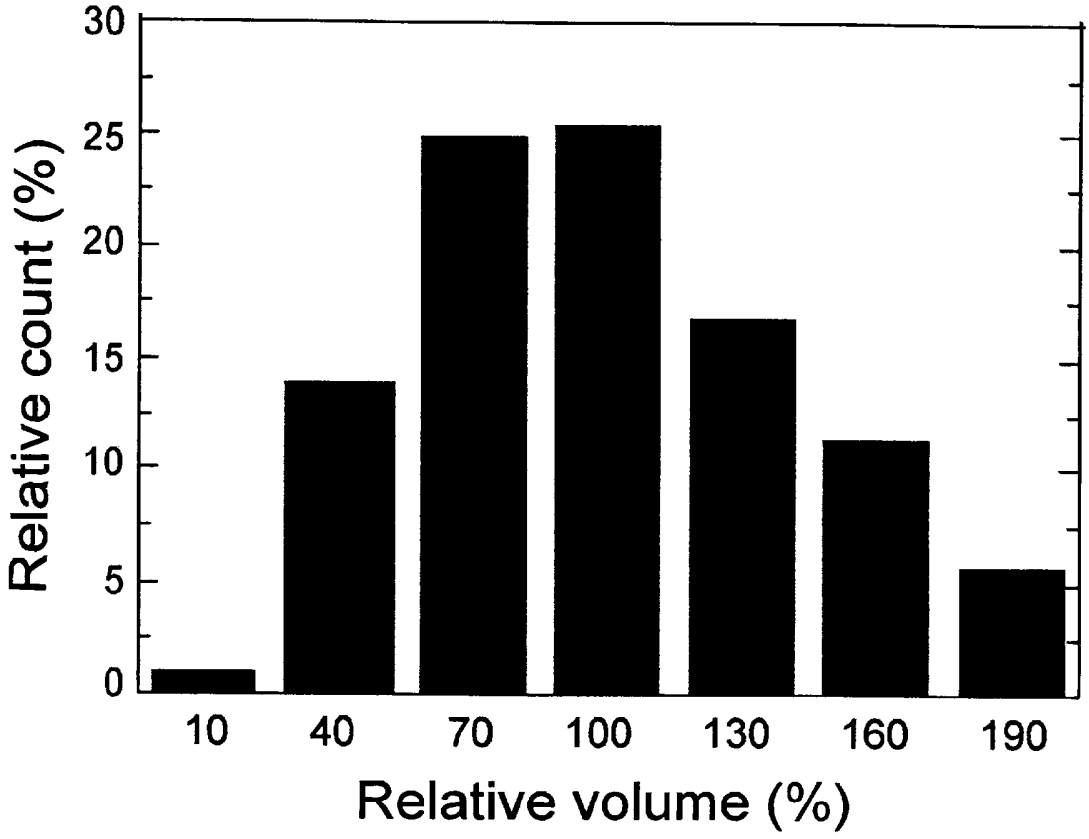

30
25
20
15
10
5
0
Relative count (%)
10
40
70
100
130
160
190
Relative volume (%)

Fig. 8