FIG. 1A

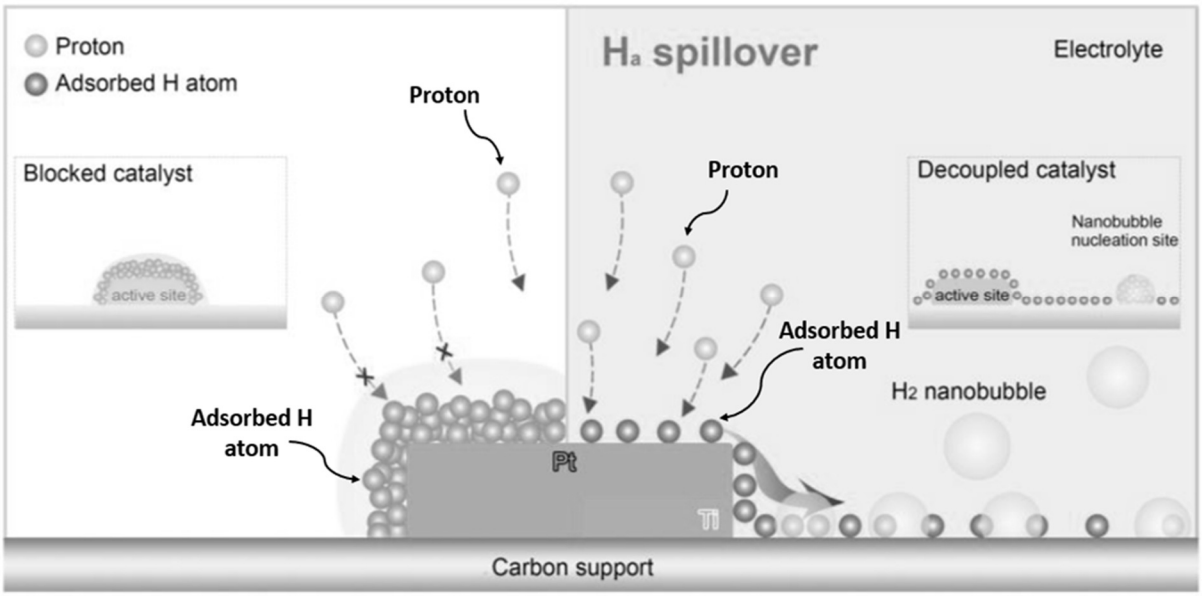
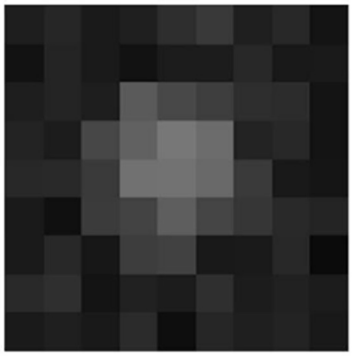

Proton
Adsorbed H atom
Hₐ spillover
Electrolyte
Proton
Blocked catalyst
active site
Proton
Decoupled catalyst
Nanobubble nucleation site
active site
Adsorbed H atom
H2 nanobubble
Adsorbed H atom
Pt
Ti
Carbon support

FIG. 1B



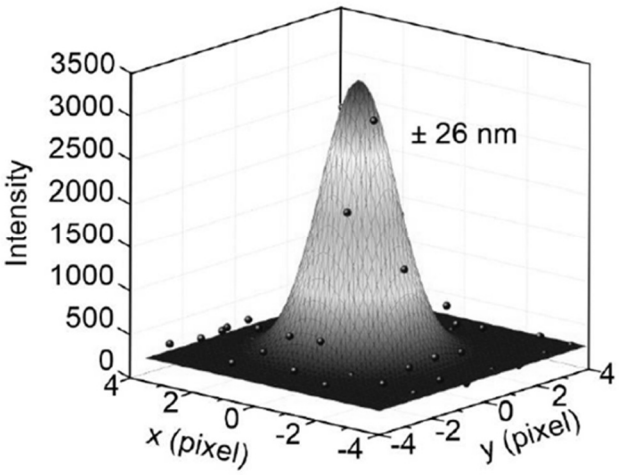
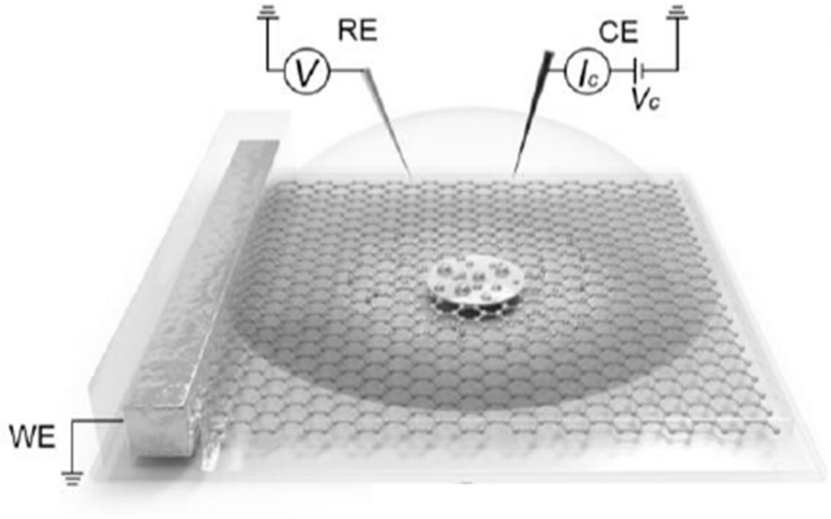

3500
3000
2500
2000
1500
1000
500
0
Intensity
± 26 nm
4
2
0
-2
-4
x (pixel)
-4
-2
0
2
4
y (pixel)

FIG. 2A


RE
CE
V
I_c
V_c
WE

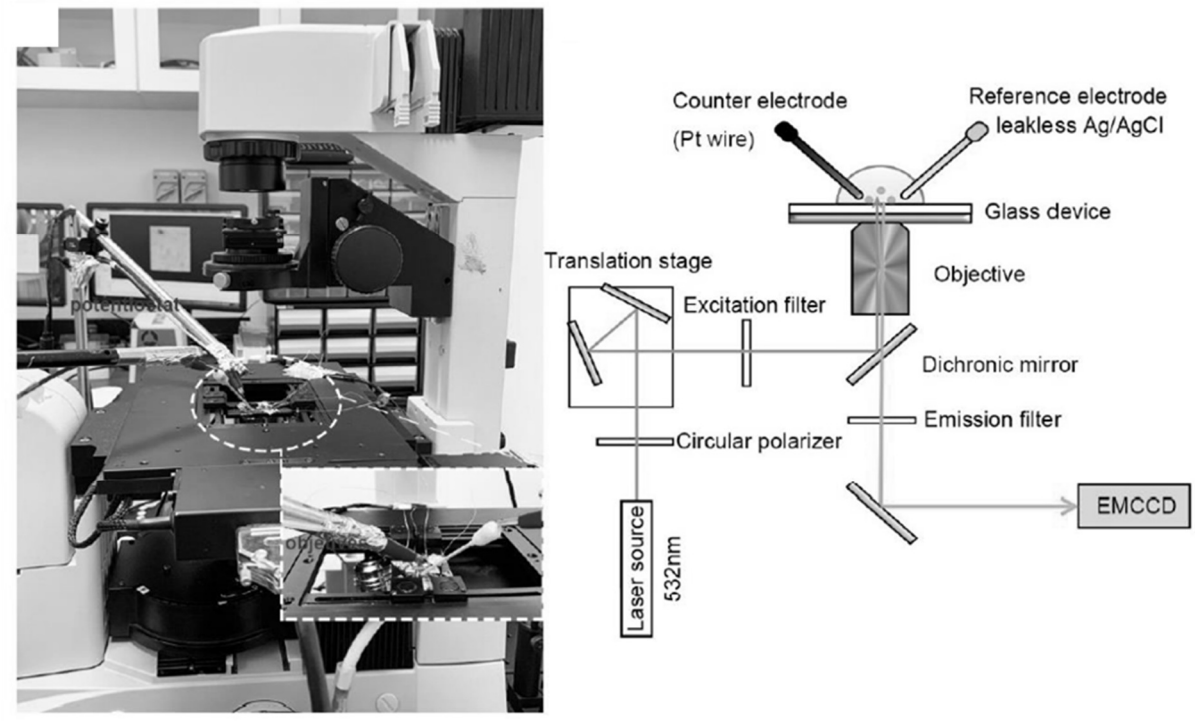

potentiostat
Counter electrode
(Pt wire)
Reference electrode
leakless Ag/AgCl
Glass device
Translation stage
Objective
Excitation filter
Dichronic mirror
Emission filter
Circular polarizer
EMCCD
Laser source
532nm

FIG. 2B

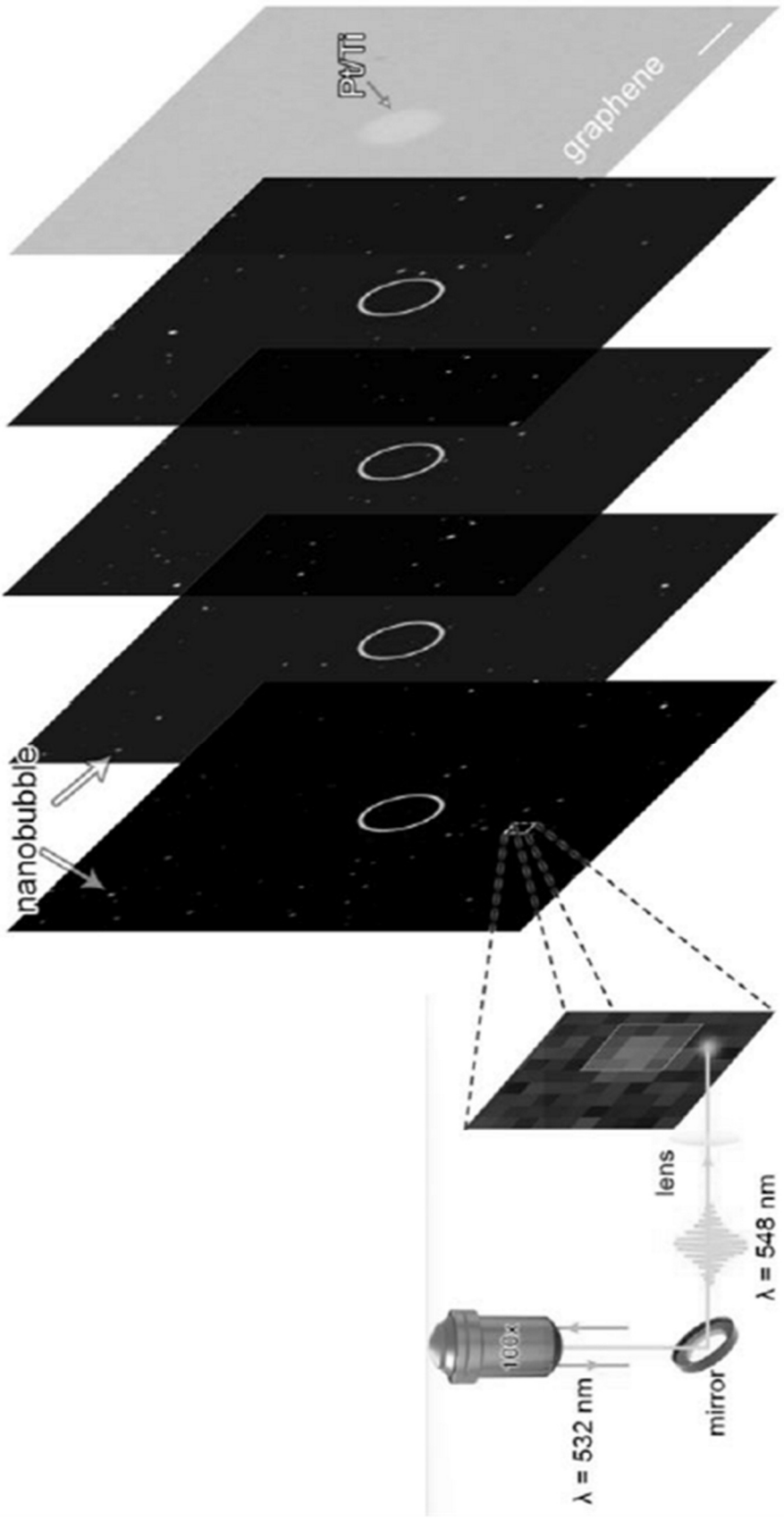


FIG. 2C

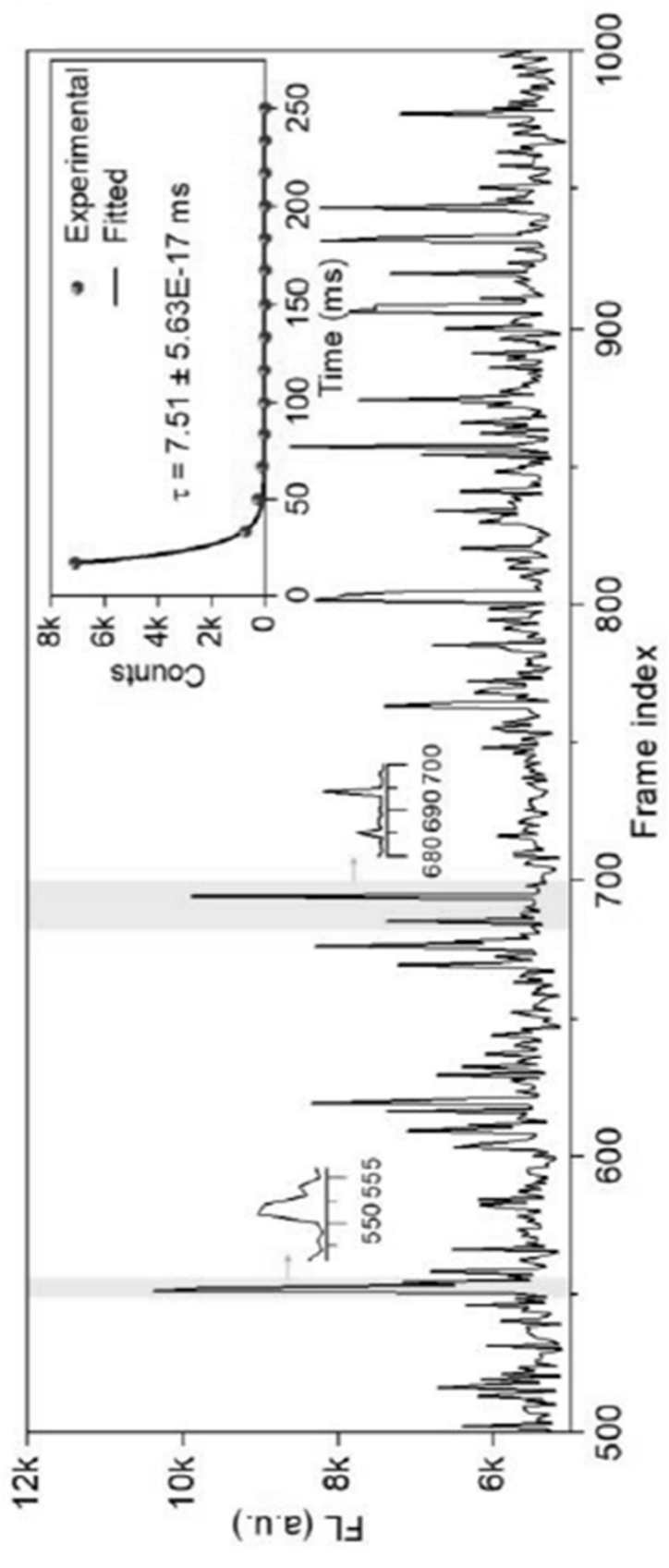

12k
10k
8k
6k
FL (a.u.)
500
600
700
800
900
1000
Frame index
550 555
680 690 700
Counts
8k
6k
4k
2k
0
0
50
100
150
200
250
Time (ms)
Experimental
Fitted
τ = 7.51 ± 5.63E-17 ms

FIG. 2D

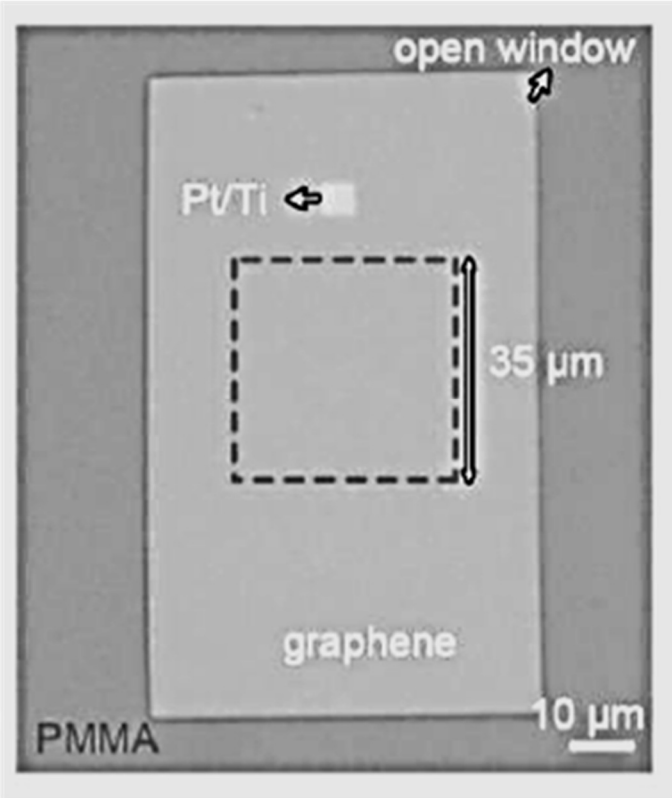
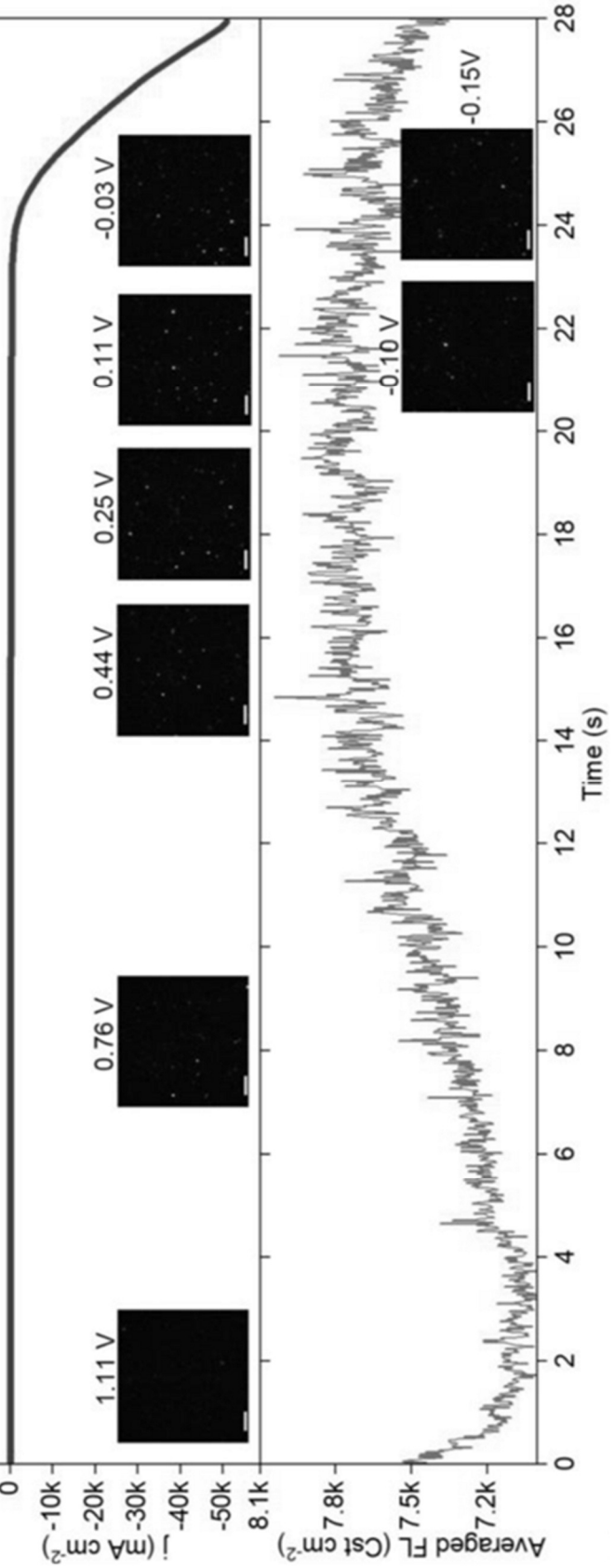


FIG. 2E


Overpotential ($V_{vs\ RHE}$)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
1.11 V
0.76 V
0.44 V
0.25 V
0.11 V
-0.03 V
-0.10 V
-0.15V
j (mA cm^{-2})
0
-10k
-20k
-30k
-40k
-50k
Averaged FL (Cst cm^{-2})
8.1k
7.8k
7.5k
7.2k
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
Time (s)

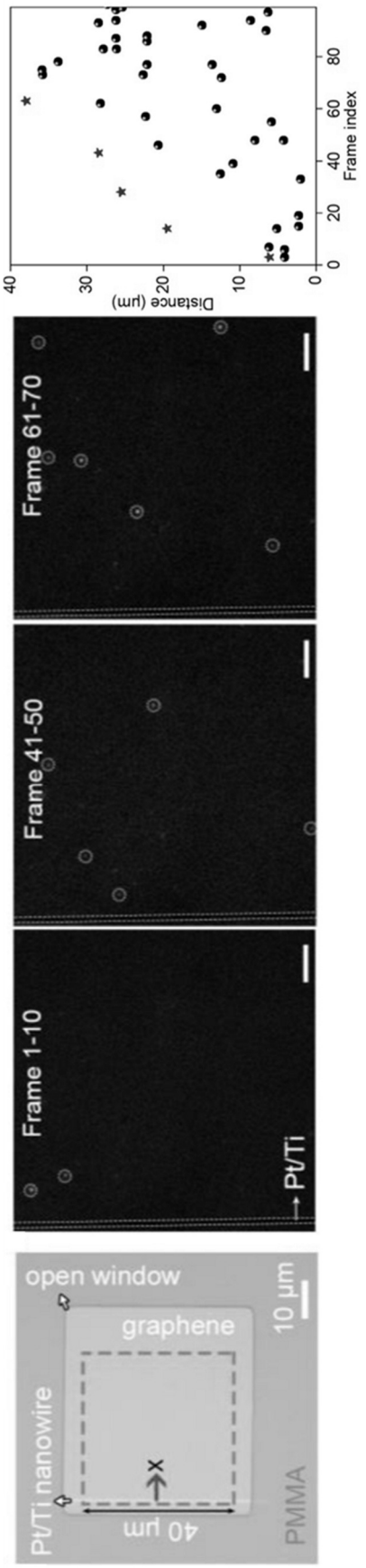

Distance (μm)
Frame index
Frame 61-70
Frame 41-50
Frame 1-10
Pt/Ti
open window
graphene
10 μm
Pt/Ti nanowire
40 μm
PMMA

FIG. 2F

FIG. 2G

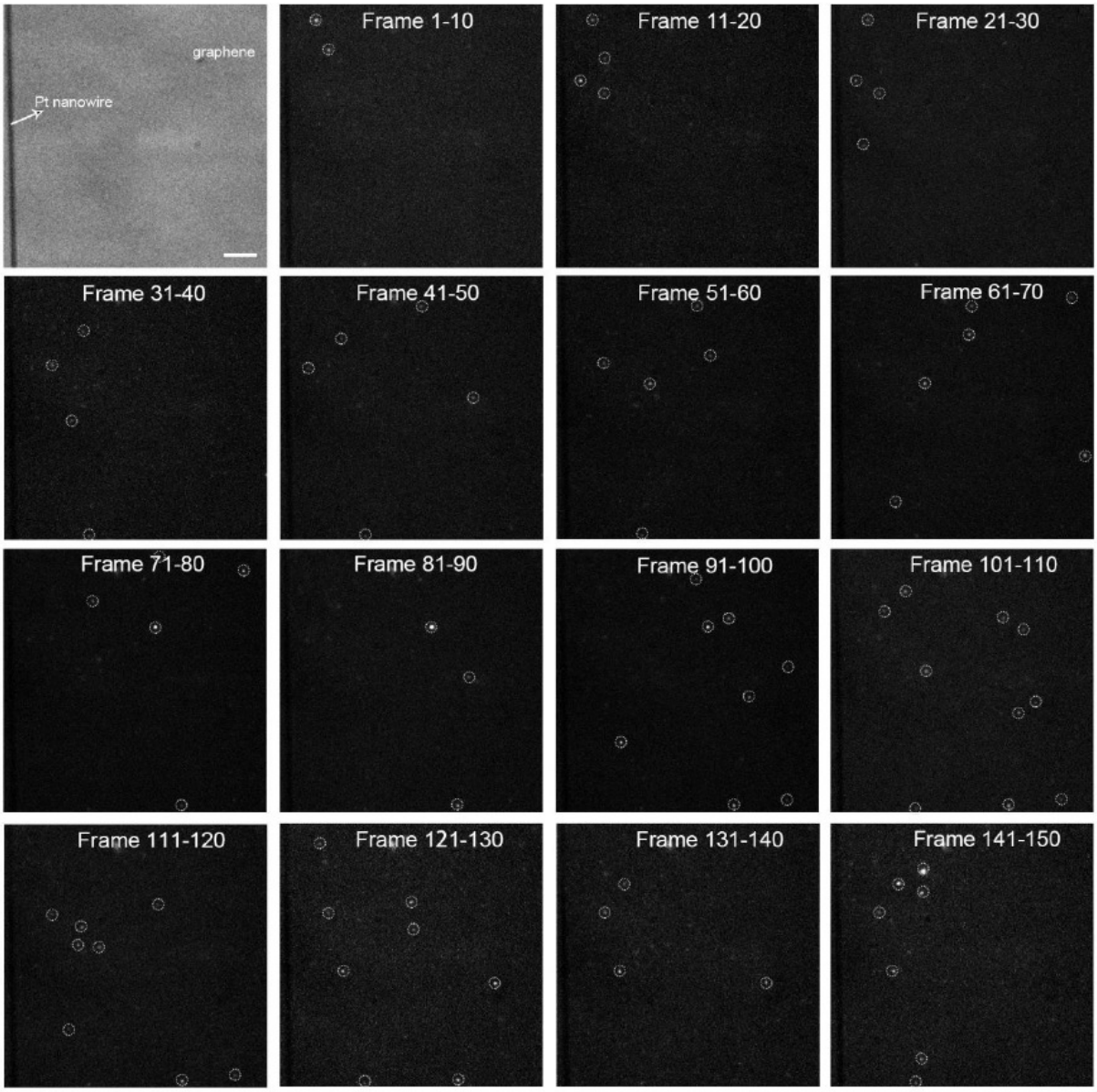

graphene
Pt nanowire
Frame 1-10
Frame 11-20
Frame 21-30
Frame 31-40
Frame 41-50
Frame 51-60
Frame 61-70
Frame 71-80
Frame 81-90
Frame 91-100
Frame 101-110
Frame 111-120
Frame 121-130
Frame 131-140
Frame 141-150

FIG. 2H

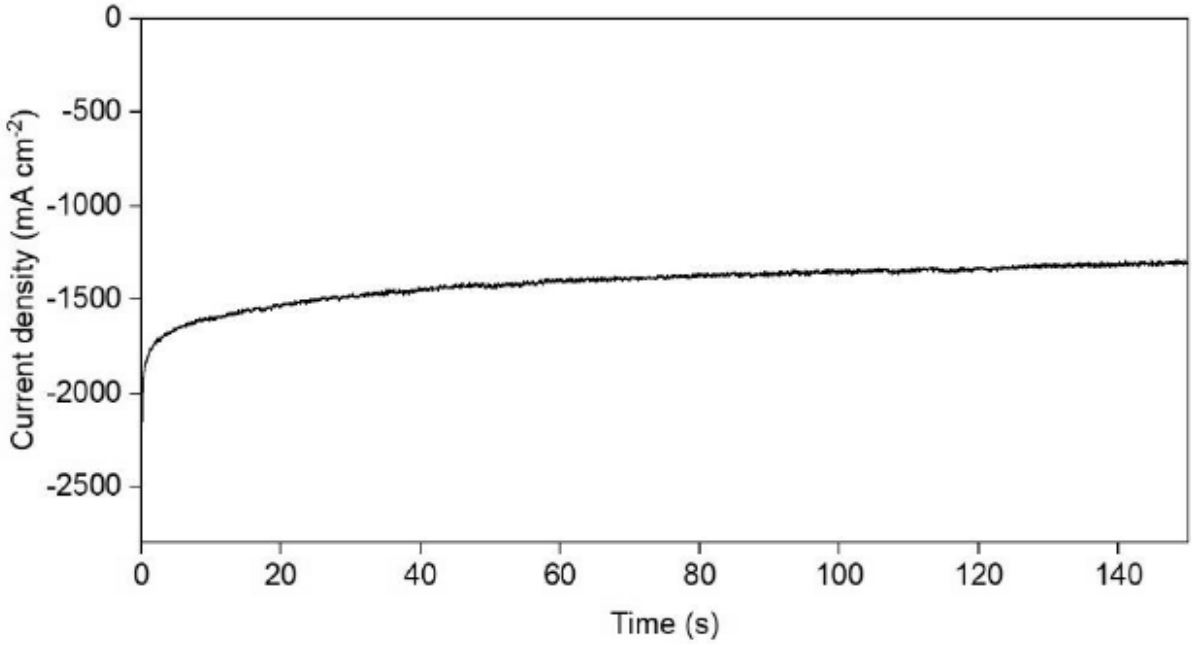

0
-500
-1000
-1500
-2000
-2500
Current density (mA cm-2)
0
20
40
60
80
100
120
140
Time (s)

FIG. 3A

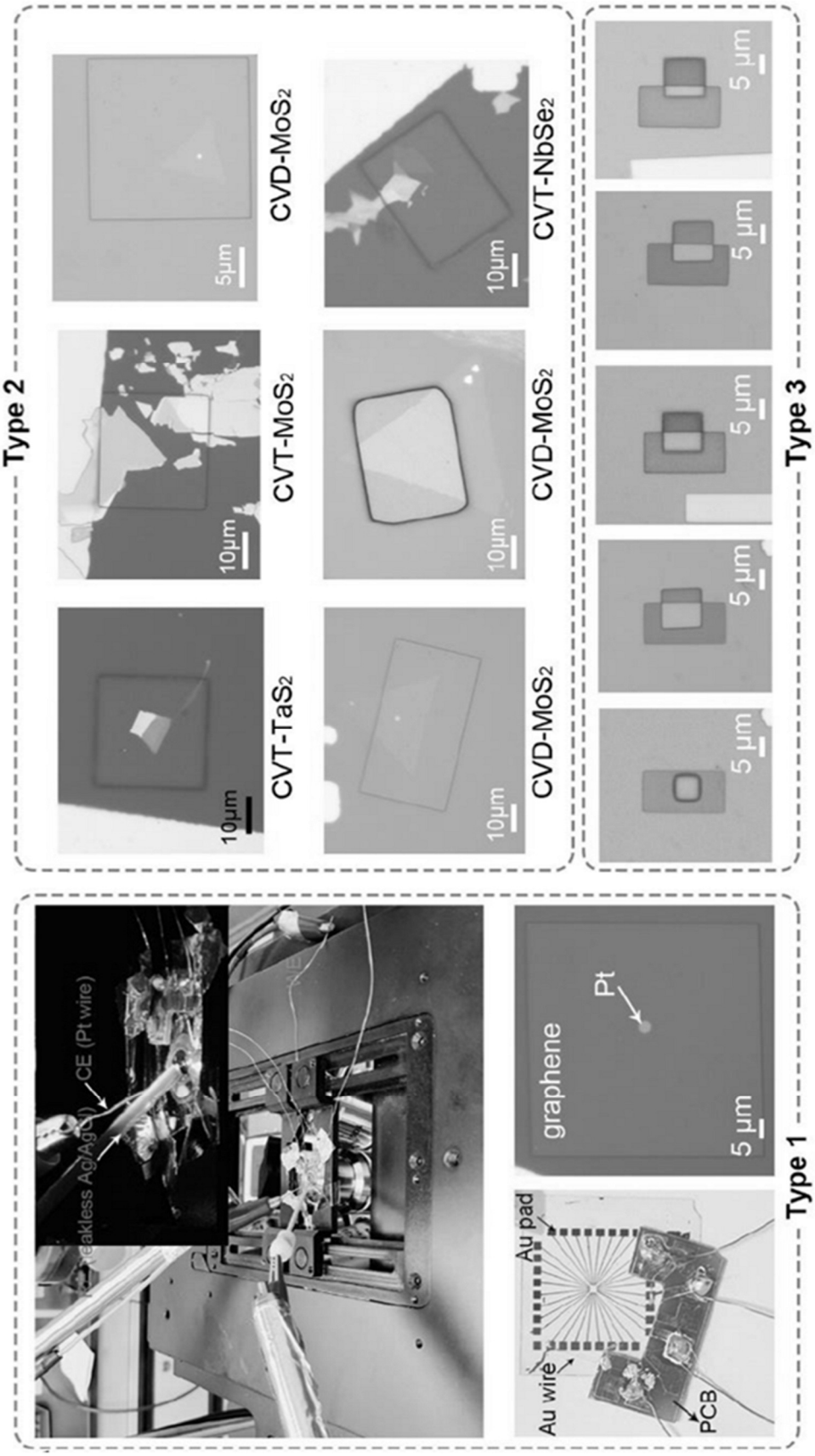

Type 2
CVT-TaS2
CVT-MoS2
CVD-MoS2
CVD-MoS2
CVT-MoS2
CVT-NbSe2
10μm
10μm
10μm
10μm
5μm
10μm
Type 1
Type 3
Au pad
Au wire
PCB
graphene
Pt
5 μm
5 μm
5 μm
5 μm
5 μm
5 μm

FIG. 3B

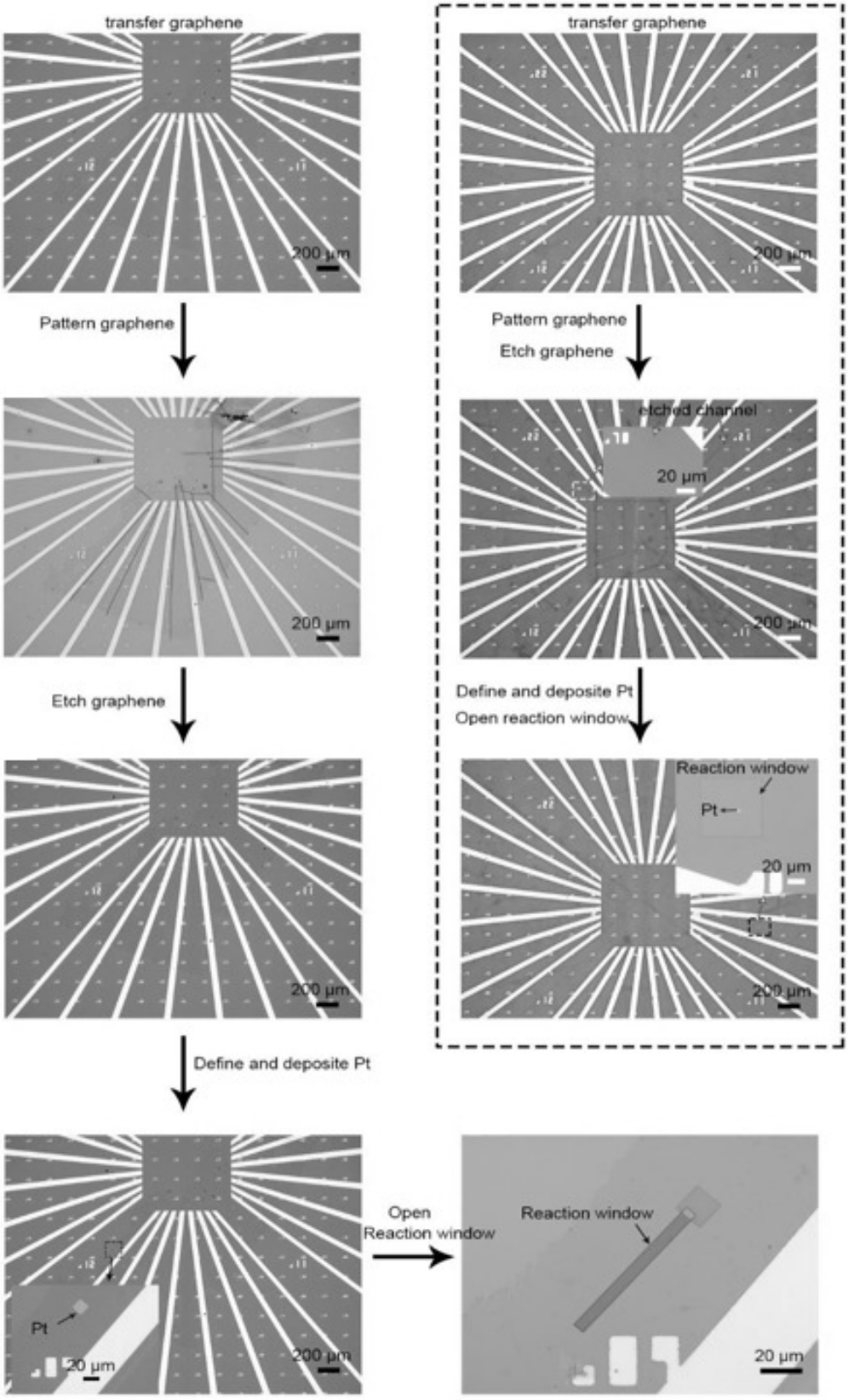

transfer graphene
200 μm
Pattern graphene
200 μm
Etch graphene
200 μm
Define and deposite Pt
Pt
20 μm
200 μm
Open
Reaction window
Reaction window
20 μm
transfer graphene
200 μm
Pattern graphene
Etch graphene
etched channel
20 μm
200 μm
Define and deposite Pt
Open reaction window
Reaction window
Pt
20 μm
200 μm

FIG. 4

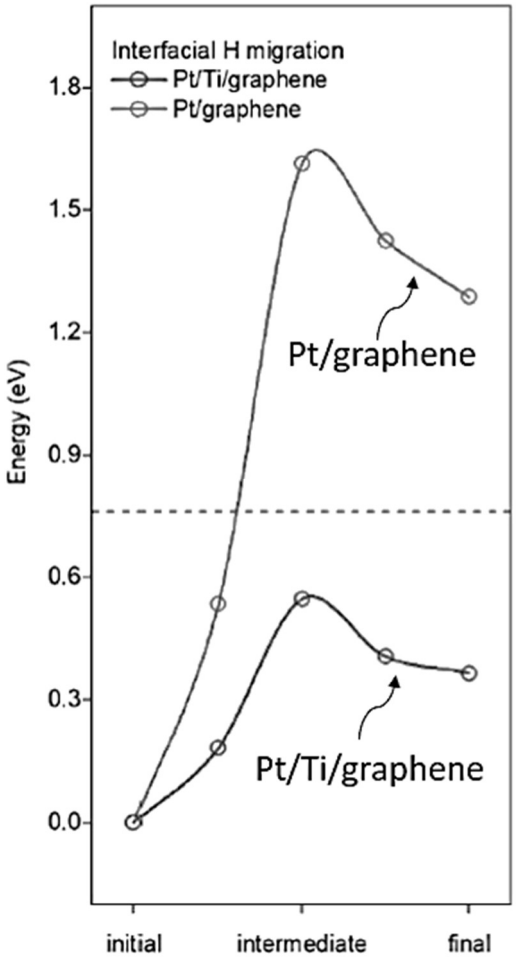

Interfacial H migration
Pt/Ti/graphene
Pt/graphene
1.8
1.5
1.2
0.9
0.6
0.3
0.0
Energy (eV)
Pt/graphene
Pt/Ti/graphene
initial
intermediate
final

FIG. 5

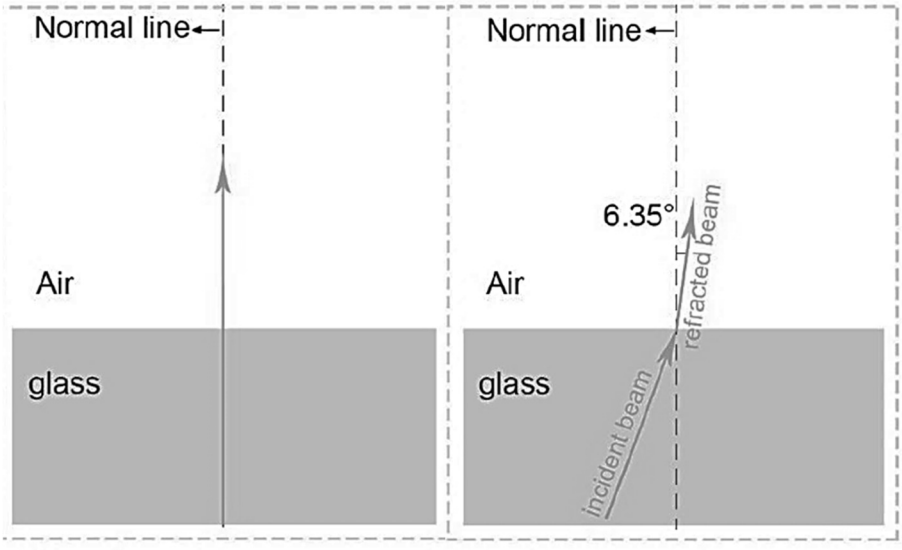

Normal line
Air
glass
Normal line
6.35°
refracted beam
Air
glass
incident beam

FIG. 6

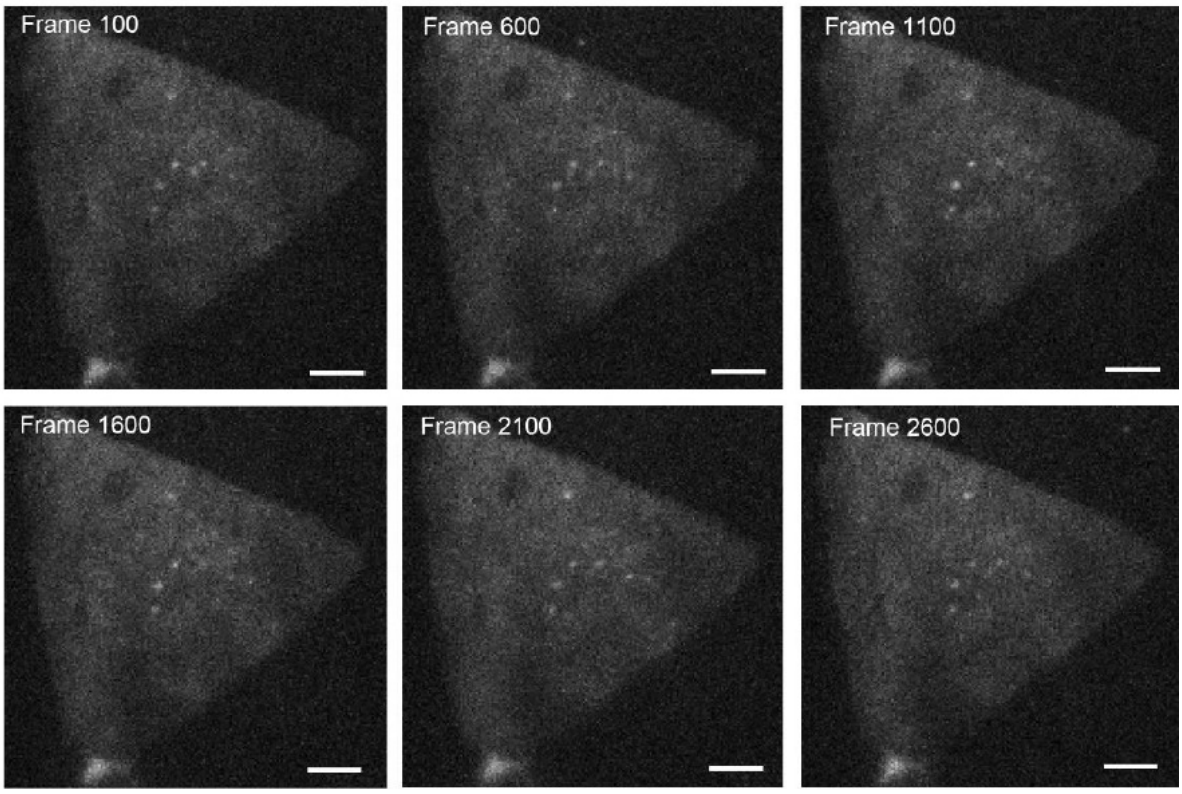

Frame 100
Frame 600
Frame 1100
Frame 1600
Frame 2100
Frame 2600

FIG. 7

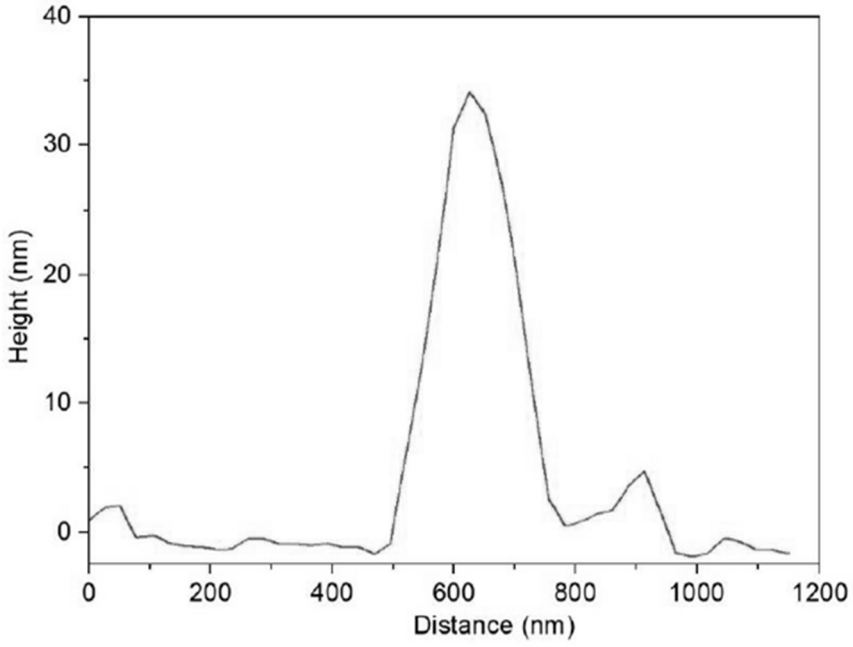

Height (nm)
Distance (nm)
0
10
20
30
40
0
200
400
600
800
1000
1200

FIG. 8

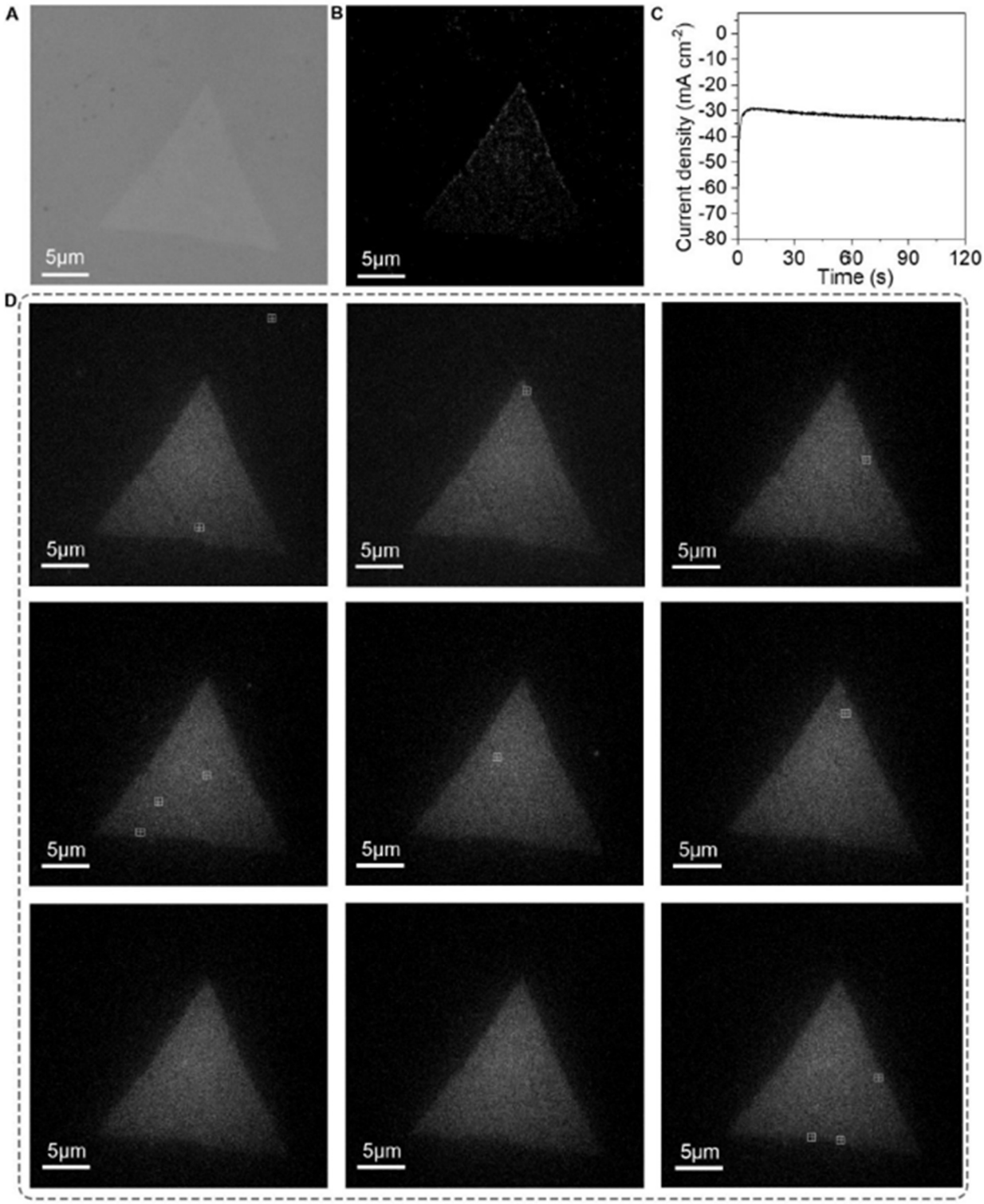

A
B
C
D
5μm
Current density (mA cm^{-2})
0
-10
-20
-30
-40
-50
-60
-70
-80
0
30
60
90
120
Time (s)

FIG. 9

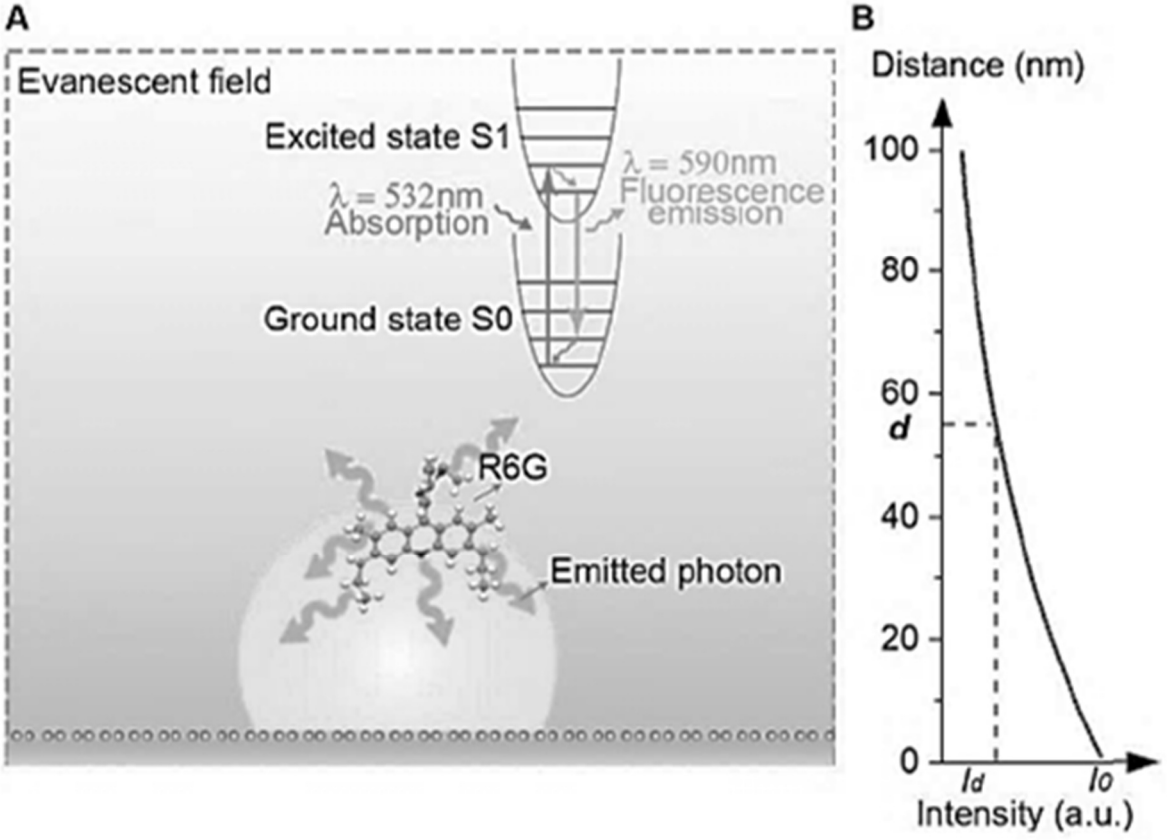

A
Evanescent field
Excited state S1
λ = 532nm
Absorption
λ = 590nm
Fluorescence
emission
Ground state S0
R6G
Emitted photon
B
Distance (nm)
100
80
60
d
40
20
0
Id
Io
Intensity (a.u.)

FIG. 10

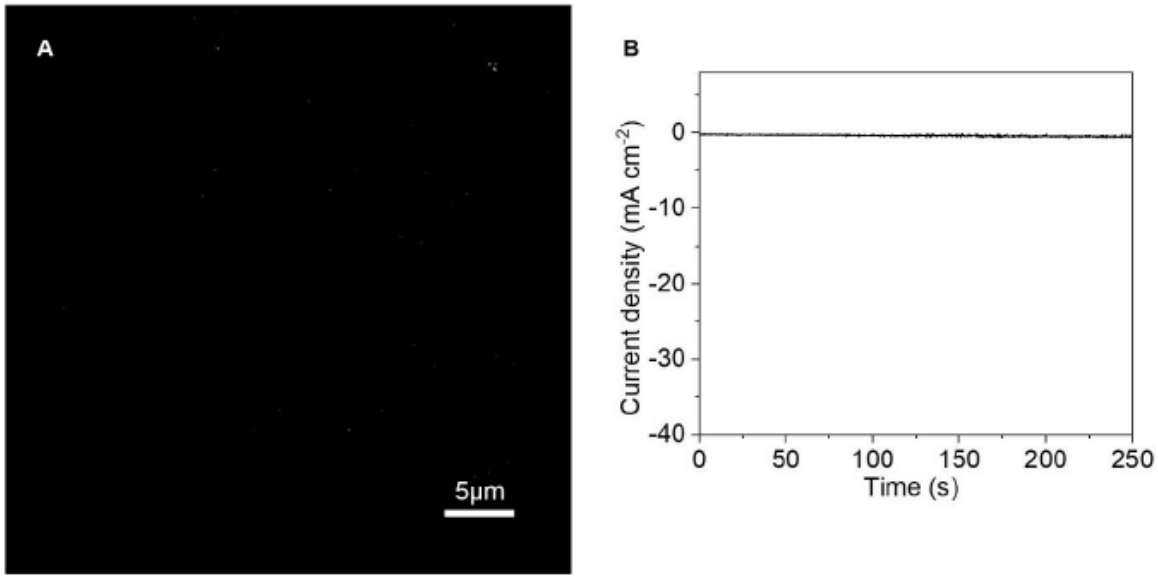

A
5μm
B
Current density (mA cm-2)
0
-10
-20
-30
-40
0
50
100
150
200
250
Time (s)

FIG. 11

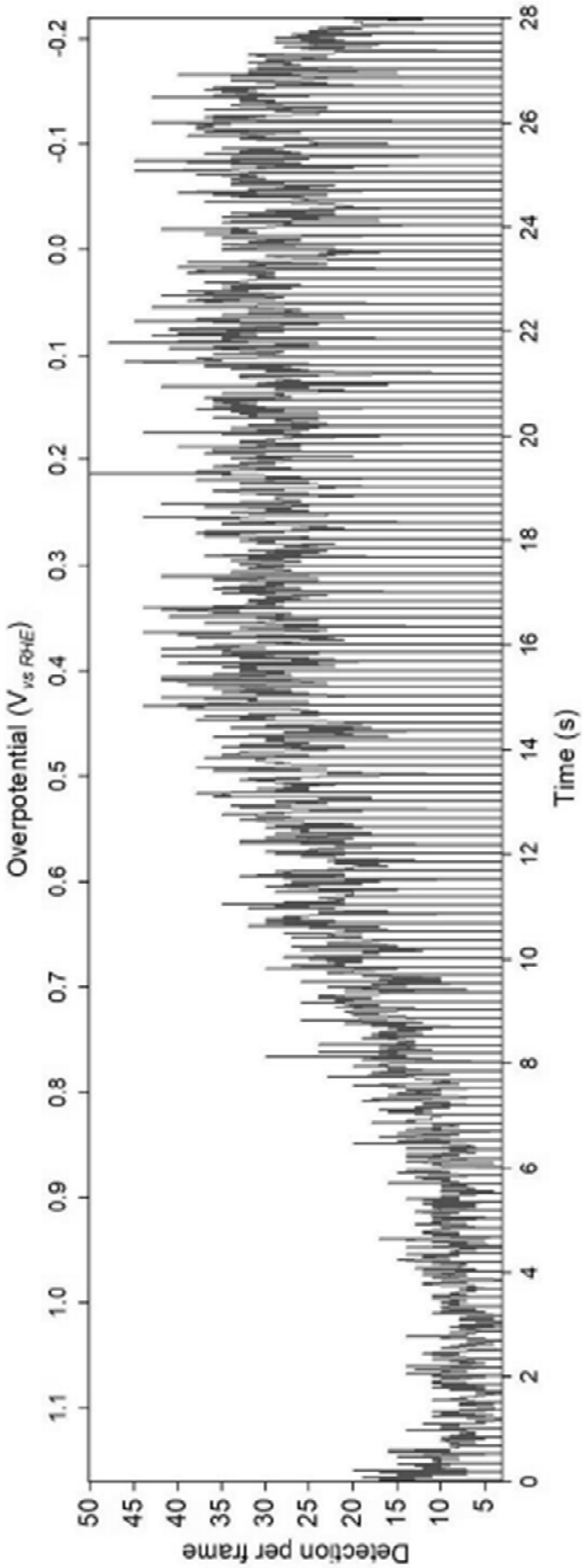

Overpotential ($V_{vs\ RHE}$)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
Time (s)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
Detection per frame
50
45
40
35
30
25
20
15
10
5

FIG. 12

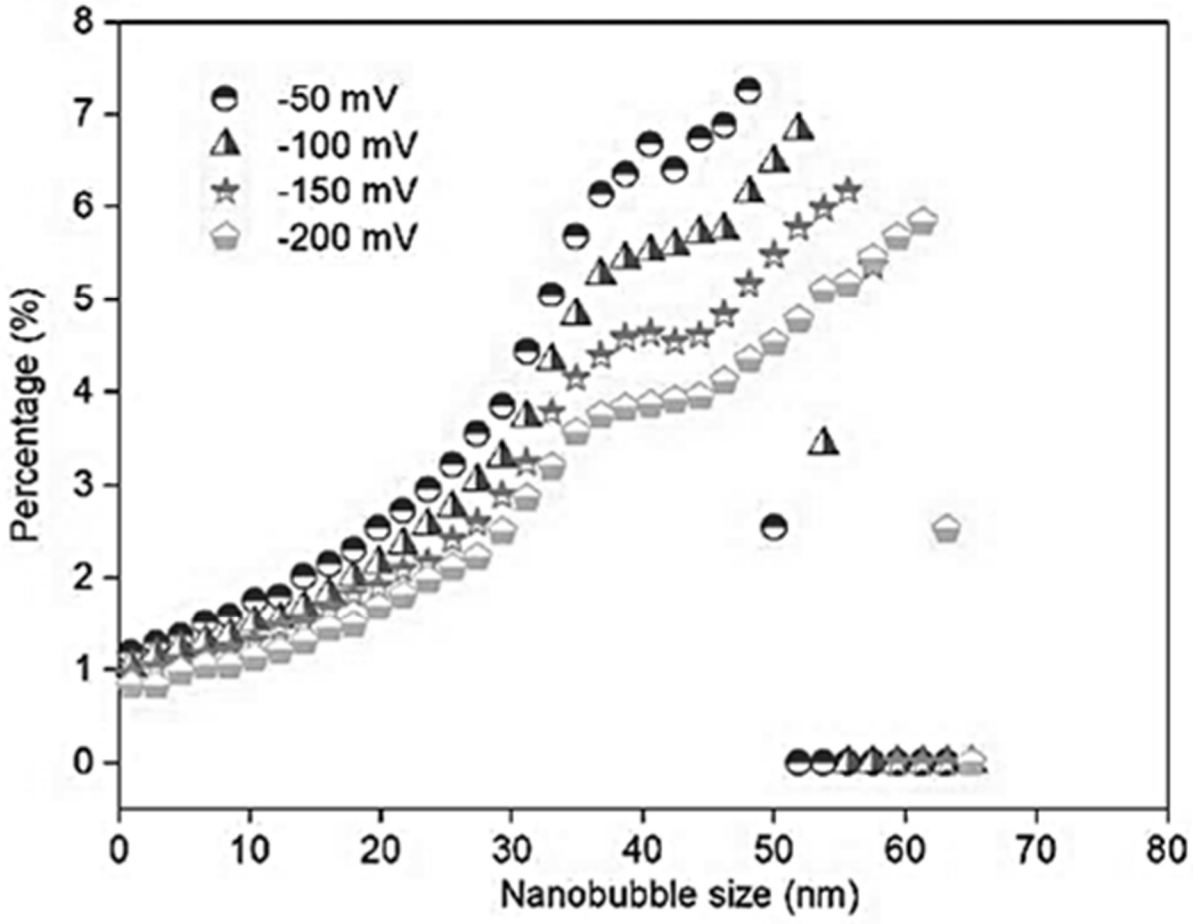


FIG. 13A

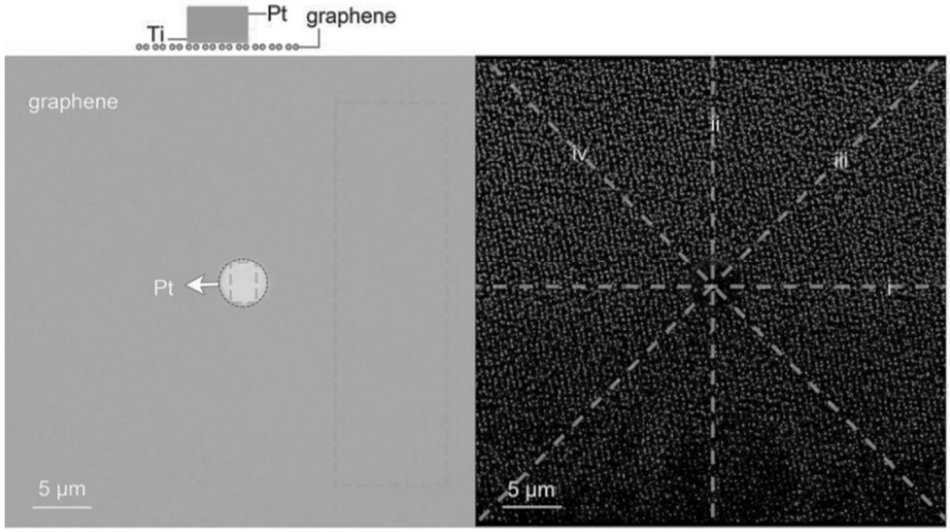


FIG. 13B

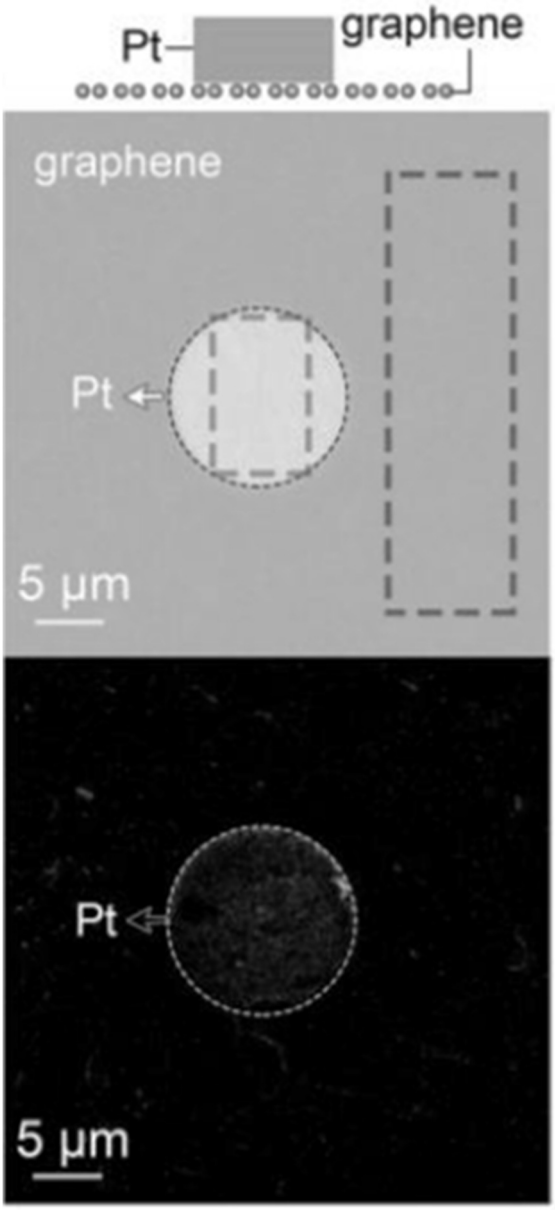


FIG. 13C

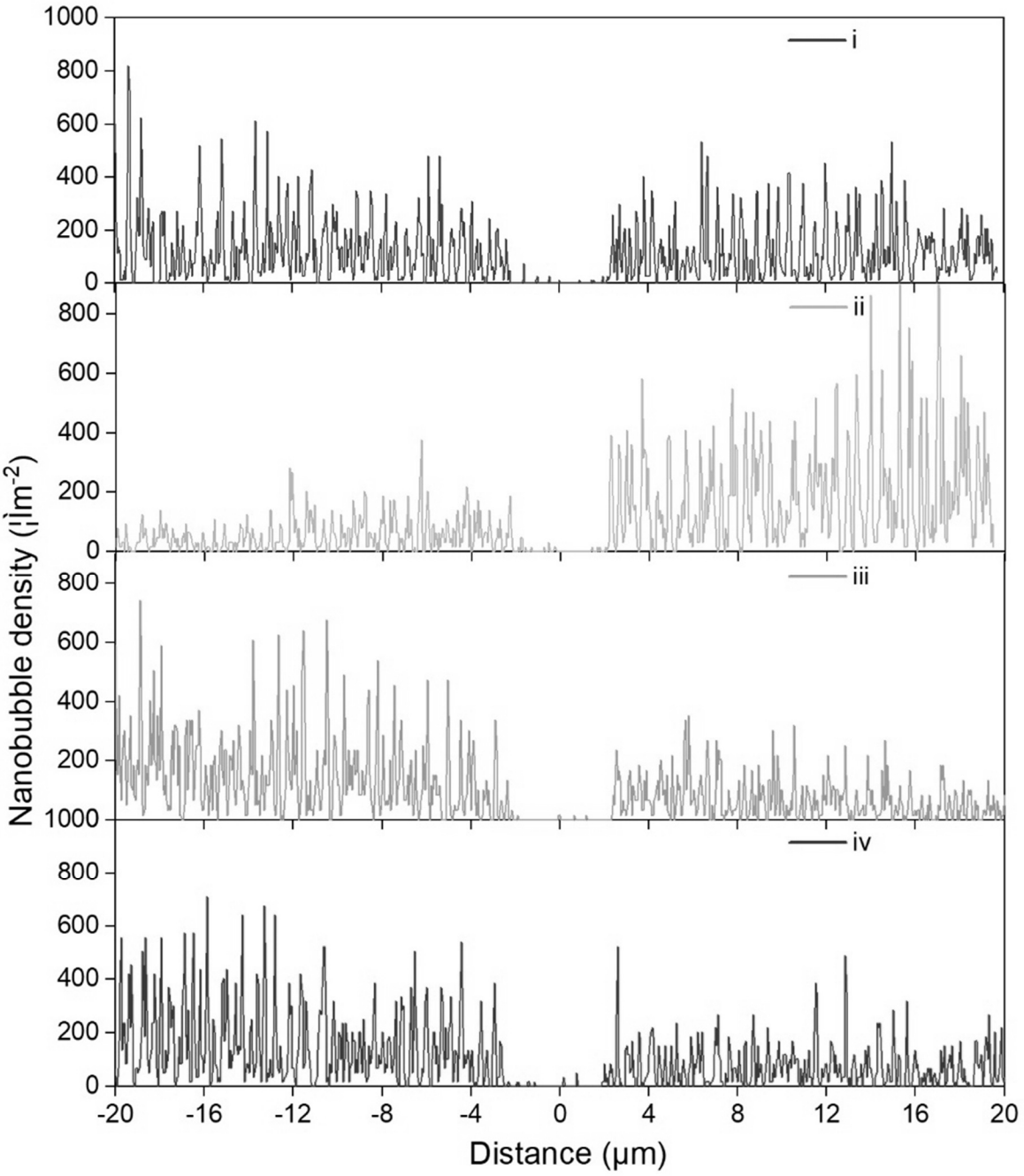

Nanobubble density (/μm-2)
Distance (μm)
i
ii
iii
iv
1000
800
600
400
200
0
-20
-16
-12
-8
-4
0
4
8
12
16
20

FIG. 13D

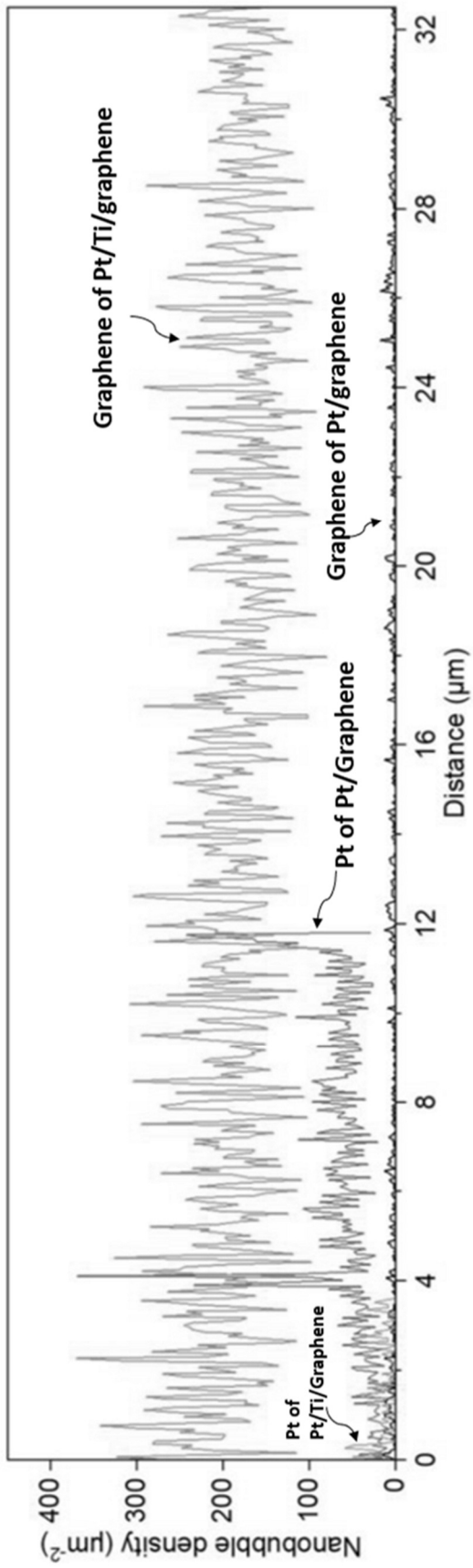

Nanobubble density (μm-2)
400
300
200
100
0
0
4
8
12
16
20
24
28
32
Distance (μm)
Pt of Pt/Ti/Graphene
Pt of Pt/Graphene
Graphene of Pt/graphene
Graphene of Pt/Ti/graphene

FIG. 14A

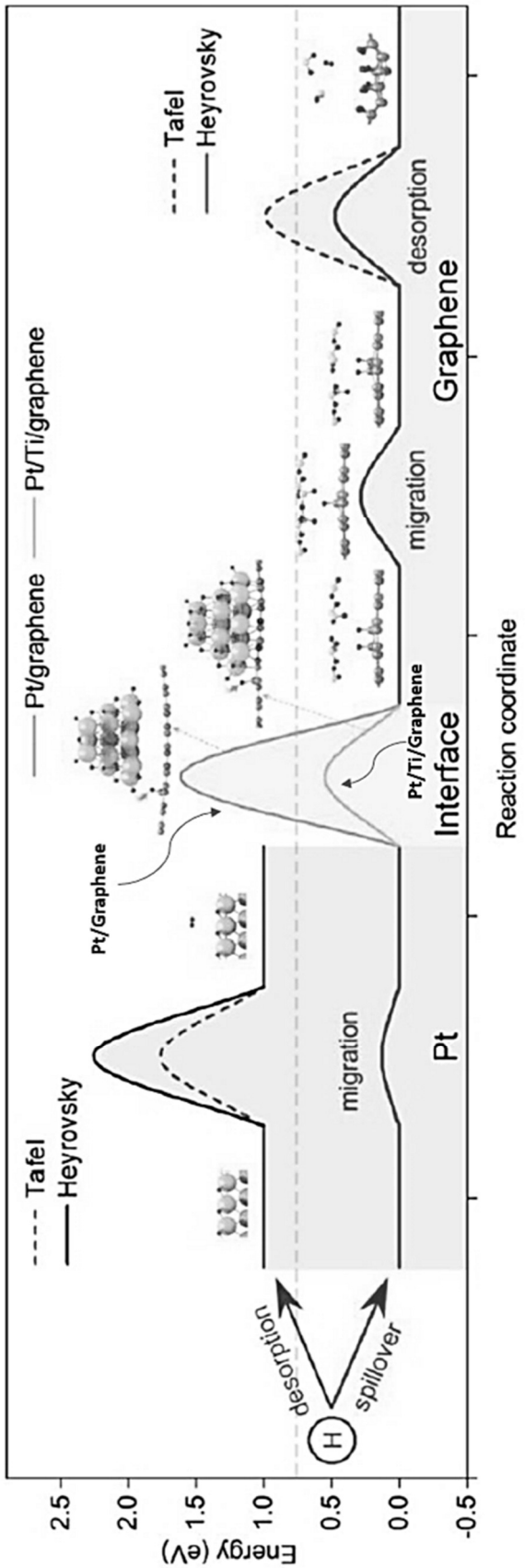

Tafel
Heyrovsky
Pt/graphene
Pt/Ti/graphene
Pt/Graphene
migration
desorption
Pt
Interface
Graphene
Pt/Ti/Graphene
H
spillover
Energy (eV)
Reaction coordinate

FIG. 14B

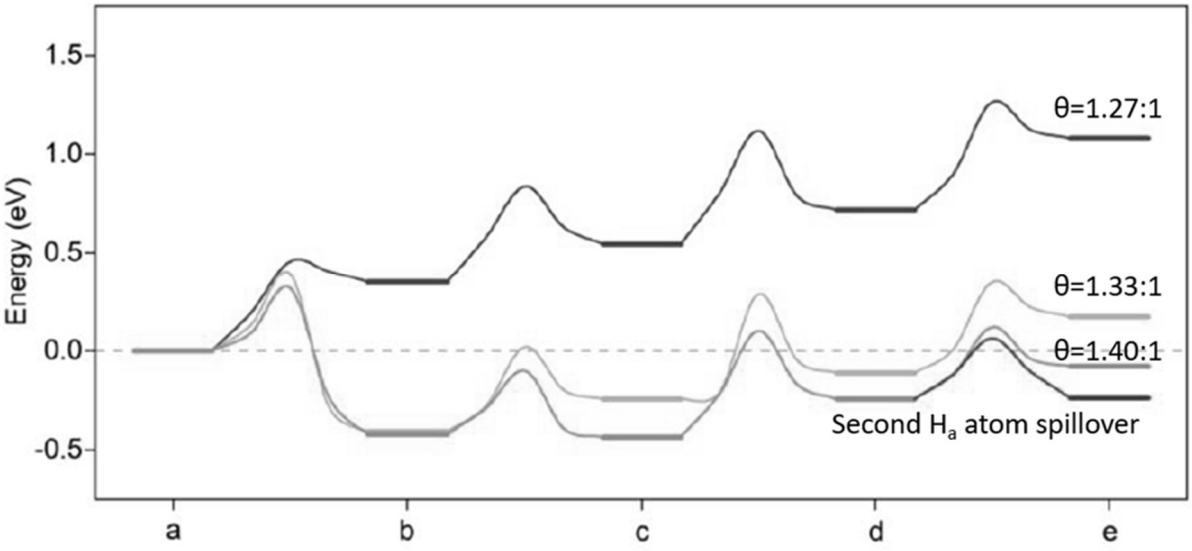


FIG. 14C

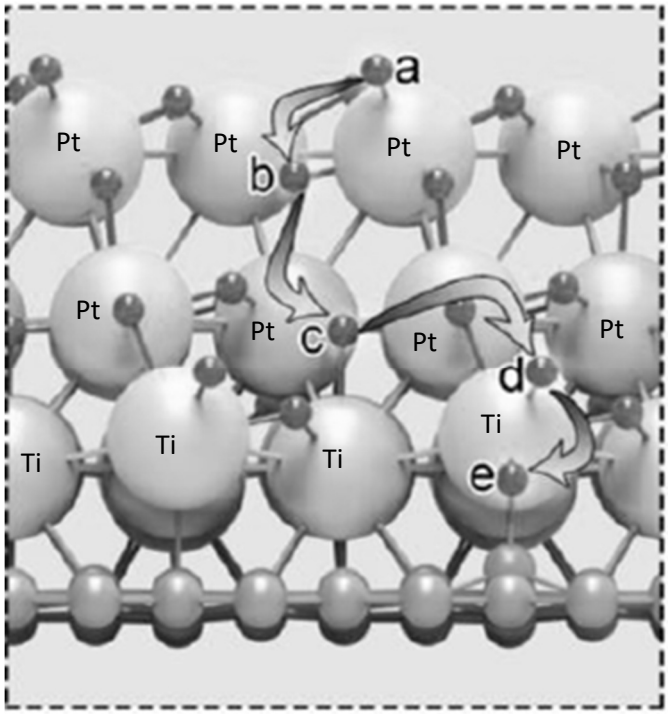


FIG. 15

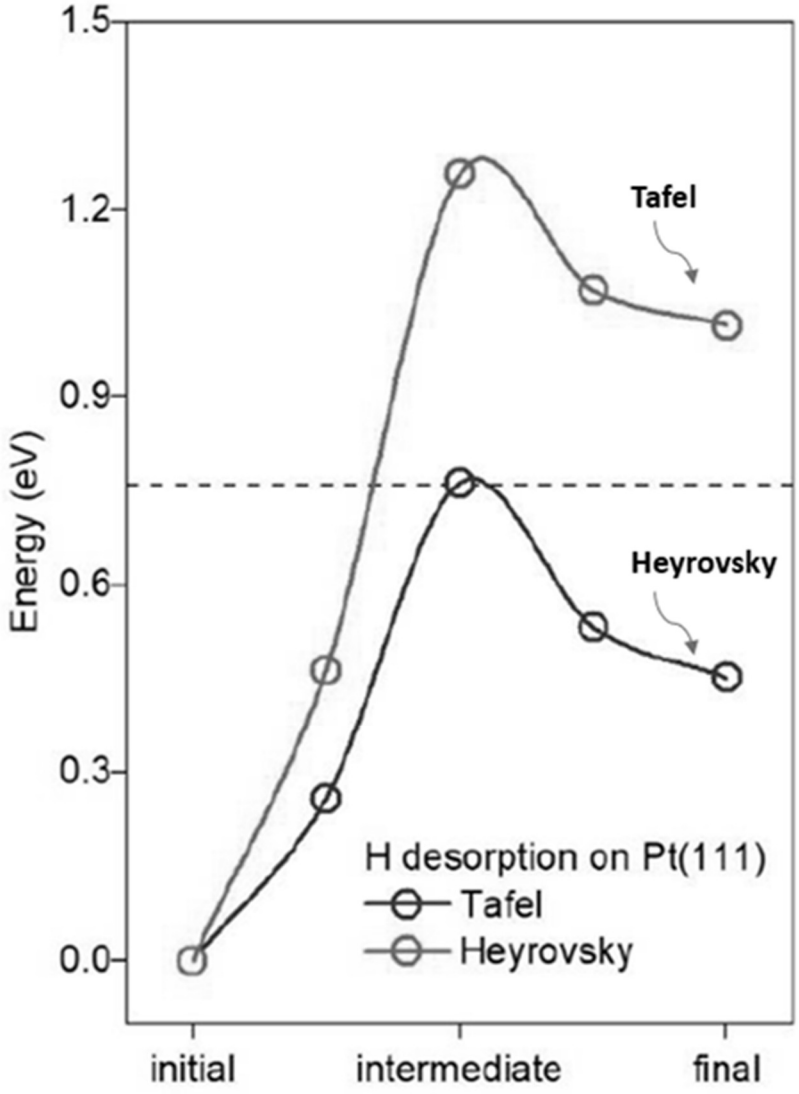

1.5
1.2
0.9
0.6
0.3
0.0
Energy (eV)
Tafel
Heyrovsky
H desorption on Pt(111)
Tafel
Heyrovsky
initial
intermediate
final

FIG. 16

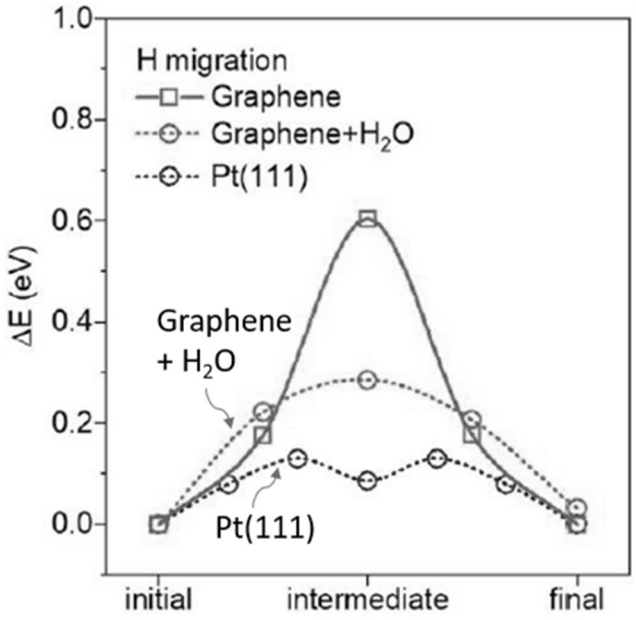

H migration
Graphene
Graphene+H2O
Pt(111)
ΔE (eV)
1.0
0.8
0.6
0.4
0.2
0.0
Graphene
+ H2O
Pt(111)
initial
intermediate
final

FIG. 17

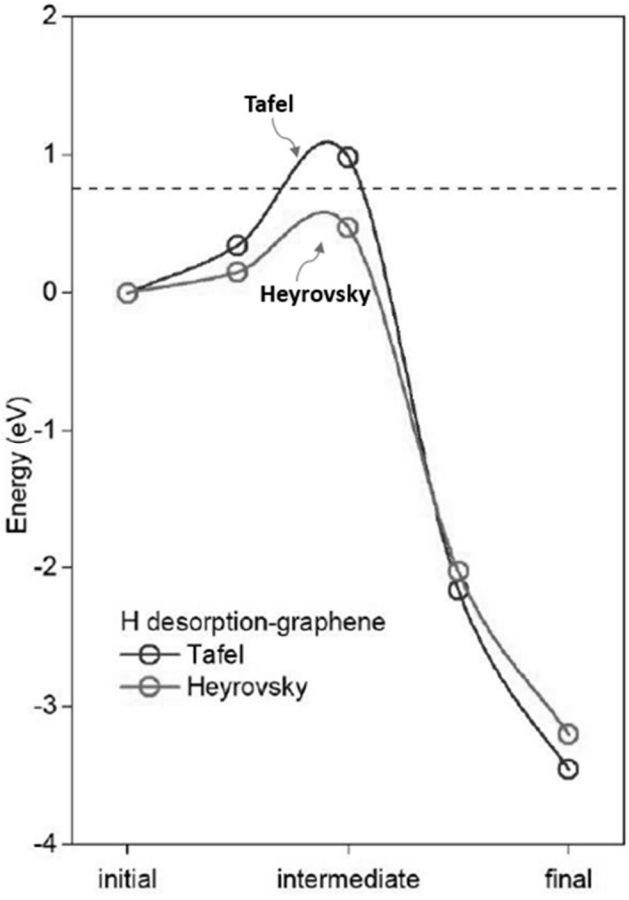

Tafel
Heyrovsky
Energy (eV)
2
1
0
-1
-2
-3
-4
H desorption-graphene
Tafel
Heyrovsky
initial
intermediate
final

FIG. 18

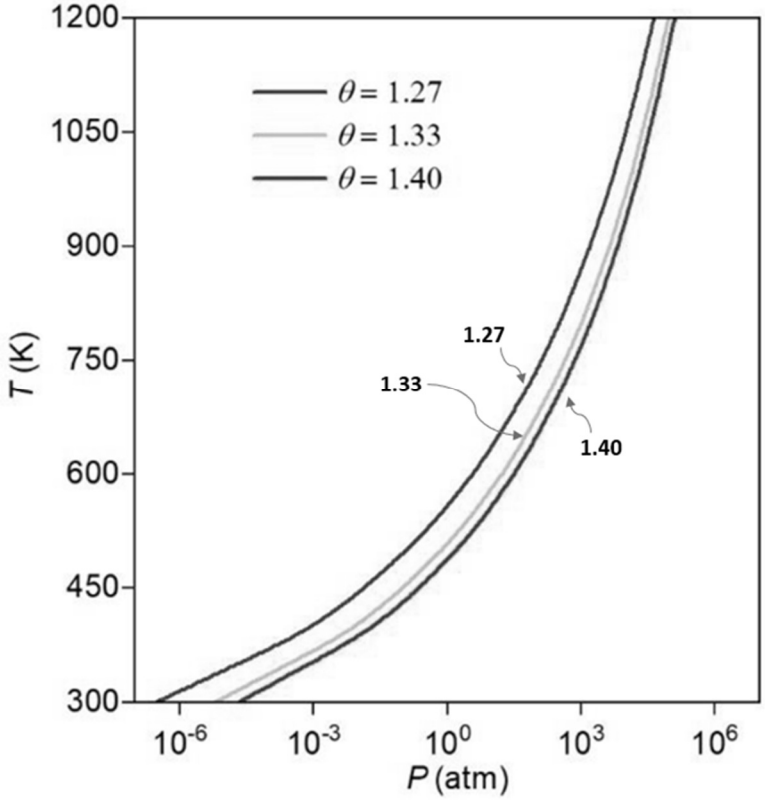

1200
1050
900
750
600
450
300
T (K)
θ = 1.27
θ = 1.33
θ = 1.40
1.27
1.33
1.40
10-6
10-3
100
103
106
P (atm)

FIG. 19A

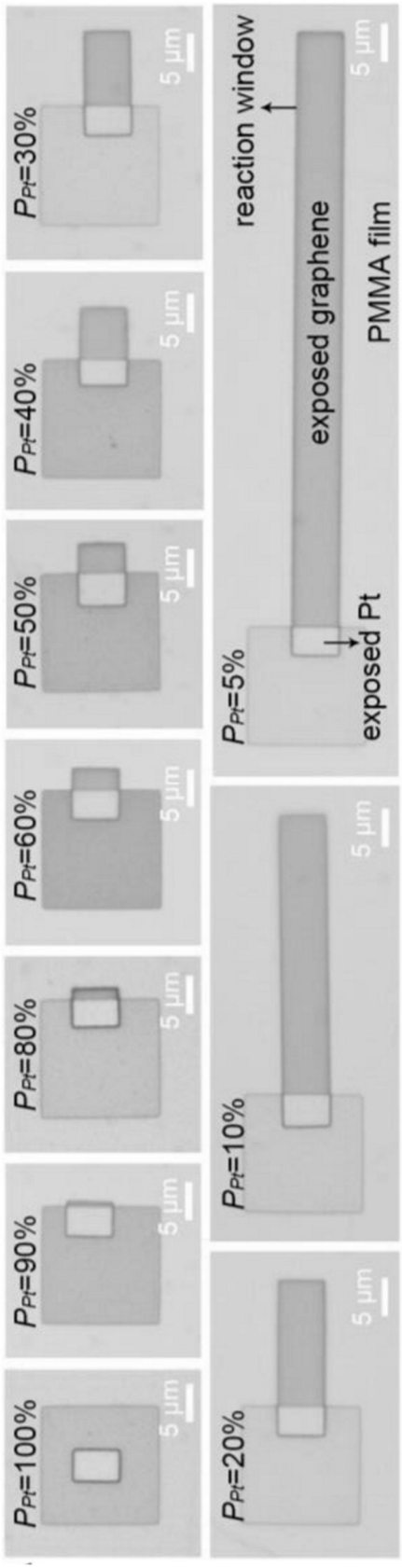

P_{Pt}=100%
P_{Pt}=90%
P_{Pt}=80%
P_{Pt}=60%
P_{Pt}=50%
P_{Pt}=40%
P_{Pt}=30%
P_{Pt}=20%
P_{Pt}=10%
P_{Pt}=5%
5 μm
reaction window
exposed graphene
exposed Pt
PMMA film

FIG. 19B

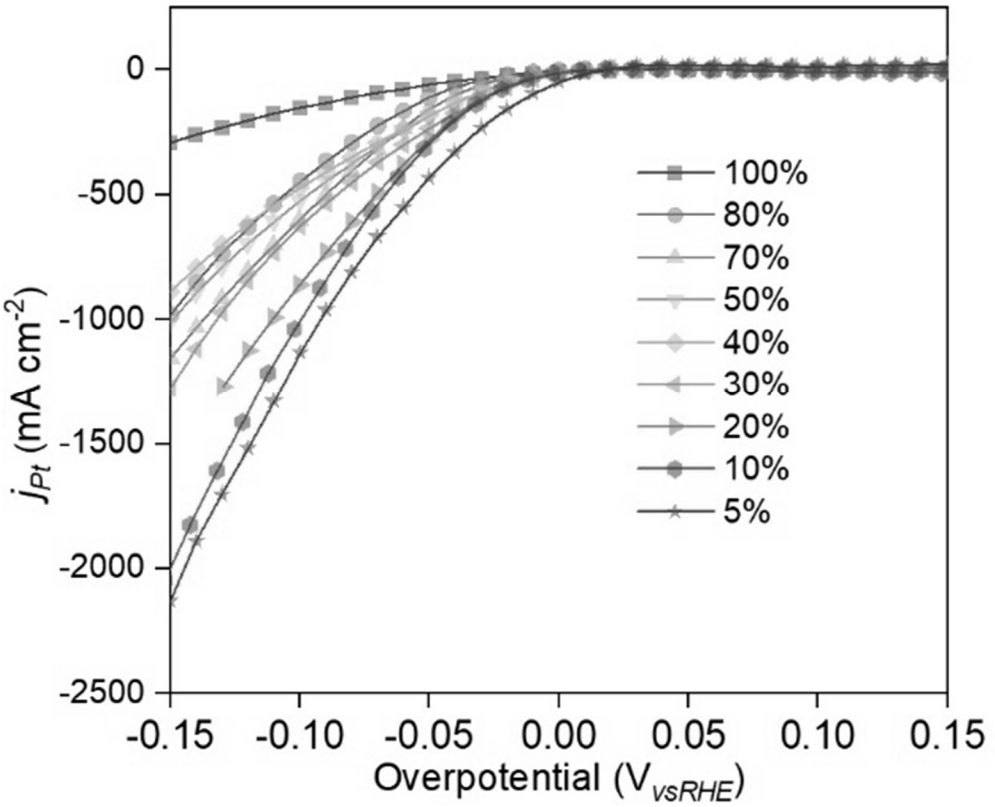


FIG. 19C

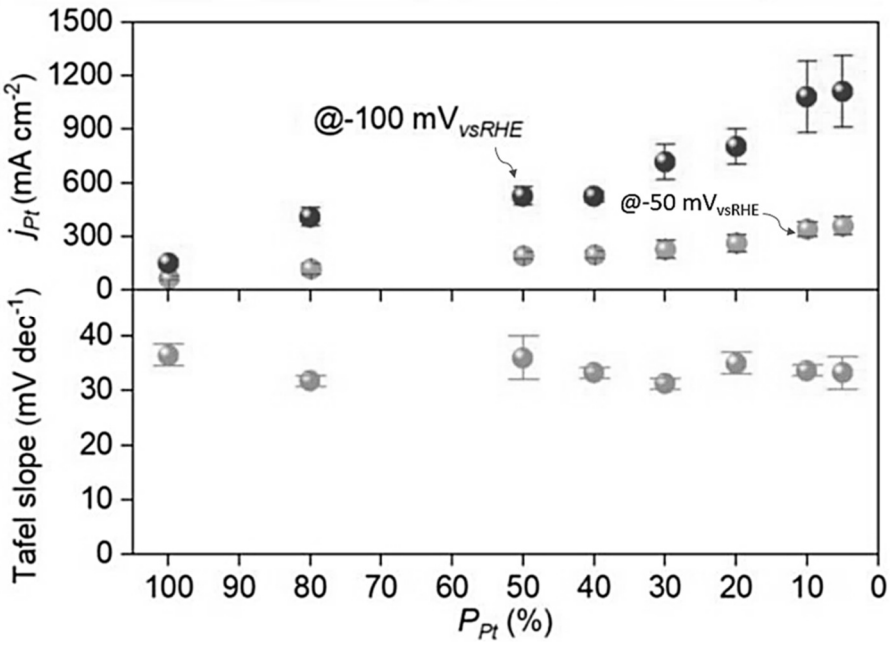


FIG. 19D

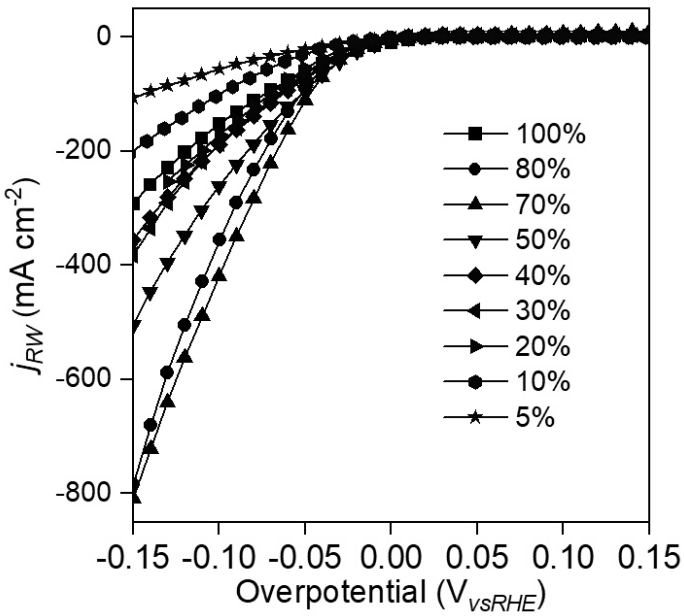


FIG. 19E

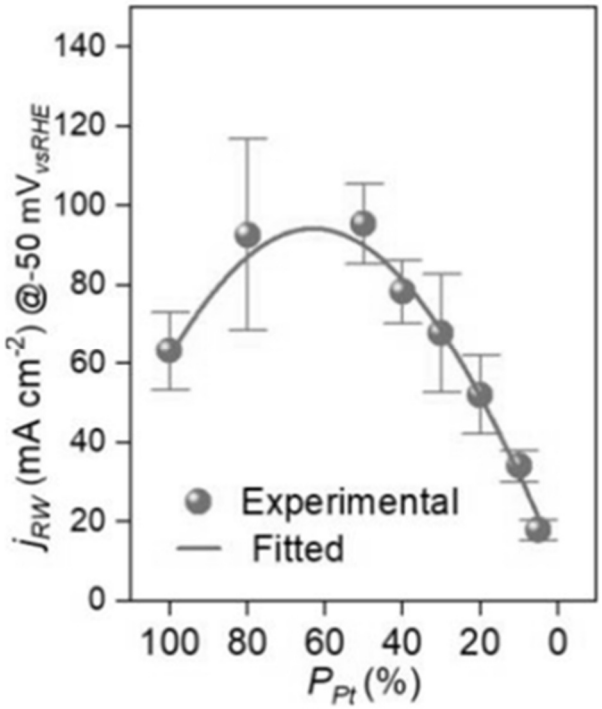
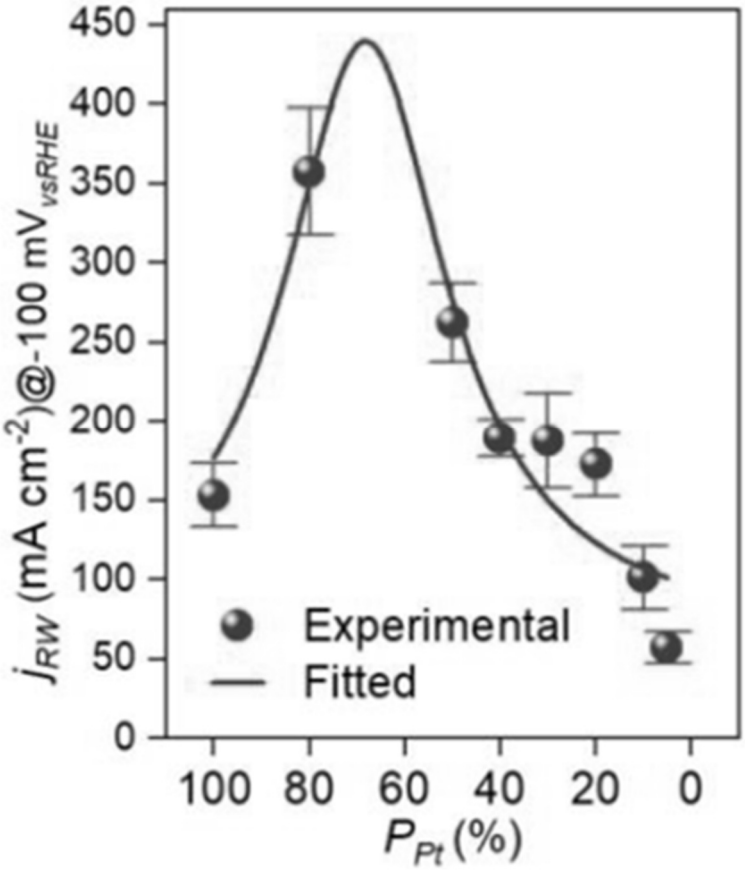


FIG. 19F


450
400
350
300
250
200
150
100
50
0
j_{RW} (mA cm^{-2})@-100 mV$_{vsRHE}$
Experimental
Fitted
100
80
60
40
20
0
P_{Pt} (%)