Supporting Information

High-precision *Helicobacter pylori* infection diagnosis using a dual elements multimodal gas-sensing array

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浙江大学医学院附属第二医院人体研究伦理委员会伦理审查批件

项目受理号：研2023-0062 事件受理号：12023074 批件号：（2023）伦审研第（0143）号

项目名称	基于呼气代谢指纹谱的幽门螺杆菌感染免标记检测技术研究		
申请类型	注册研究：☐ 药物临床试验 ☐ 器械临床试验 ☐ 特医食品临床试验 非注册研究：☒ 临床科研 ☐ 上市后产品研究		
药/械分类	/	试验分期	/
申办方	浙江大学医学院附属第二医院		
CRO	/		
承担科室	消化内科	主要研究者PI	潘爱武
☒ 负责 ☐ 参加	组长单位：/	组长单位PI	/

审查文件

序号	材料名称	版本号	语言/版本日期
1	浙大二院人体研究申请表	V1.0	中文 /2023-01-30
2	临床研究方案	V1.0	中文 /2023-01-30
3	受试者知情同意书	V1.0	中文 /2023-01-18
4	病历报告表		中文 /
5	GCP培训证书	V1.0	中文 /2023-01-30
6	主要研究者简历及参加人员简介	V1.0	中文 /2023-01-30
7	研究者岗位职责	V1.0	中文 /2023-01-30
8	临床研究项目负责人承诺书		中文 /

审查形式	本次审查：☐ 会议审查 ☒ 快速审查		
审查日期	本次审查日期：2023-02-08	会议地点	/
审查委员	徐荣臻 戴海斌		
审查结论	1. 经本人体伦理审查委员会审查，审查结果：同意。意见和建议： 2. 该研究进行过程中将接受本伦理审查委员会的跟踪审查，跟踪审查频率为研究批准之日起：☐ 6个月 ☒ 12个月 ☐ 其它____ ：		

主任/副主任委员签名：[illegible] 日 期：2023/02/08

浙江大学医学院附属第二医院人体研究伦理委员会（盖章）

研究注意事项：

1. 在研究中请遵守GCP和《赫尔辛基宣言》的原则。
2. 严格遵循批准的方案开展研究，研究过程中对临床研究方案、知情同意书等材料的任何修改及主要研究者变更等，请提交修改申请，得到伦理委员会批准后方可继续实施。
3. 请提前1个月提交跟踪审查申请，本伦理委员会将根据跟踪审查的结果作出新的决定。
4. 按要求书面上报严重不良事件，本伦理委员会将根据严重不良事件报告作出审查决定。
5. 方案违背/偏离、暂停/终止均应提供书面报告。
6. 研究结束提供总结报告。
7. 及时书面报告中心伦理的重要决定。

Figure S1.Approval for ethical review by the human research ethics committee of the Second Affiliated Hospital of Zhejiang University School of Medicine.

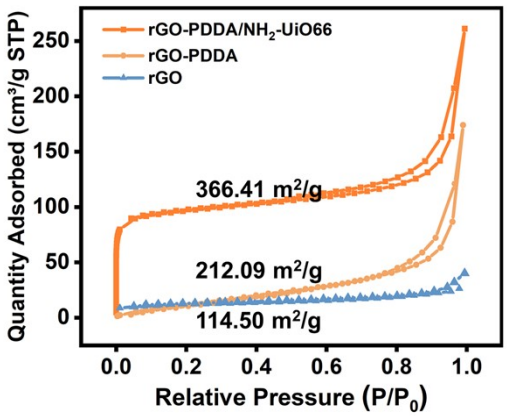

Figure S2. N_2 adsorption–desorption isotherms of rGO, rGO-PDDA and rGO-PDDA/NH_2-UiO66.

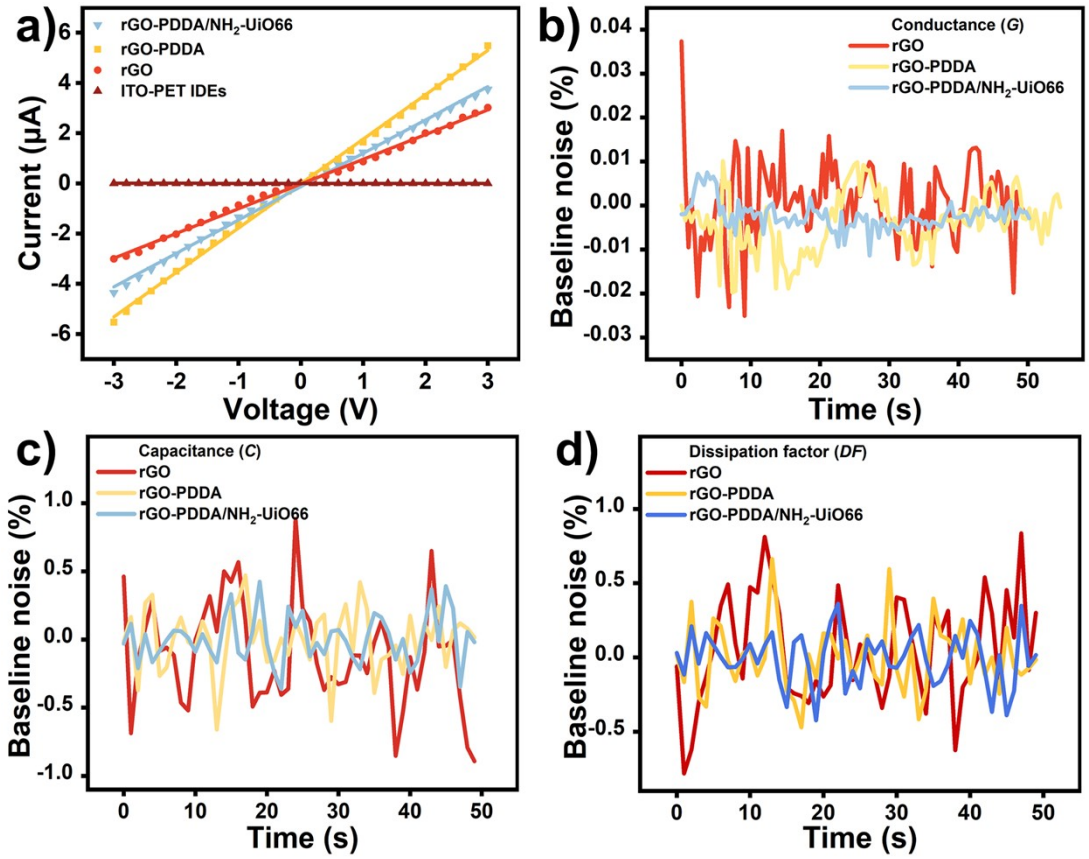

Figure S3. (a) *I–V* curves of rGO, rGO-PDDA, rGO-PDDA/NH_2-UiO66 and baseline noise fabricated on ITO-PET IDEs under b) *G*, c) *C*, d) *DF* signals.

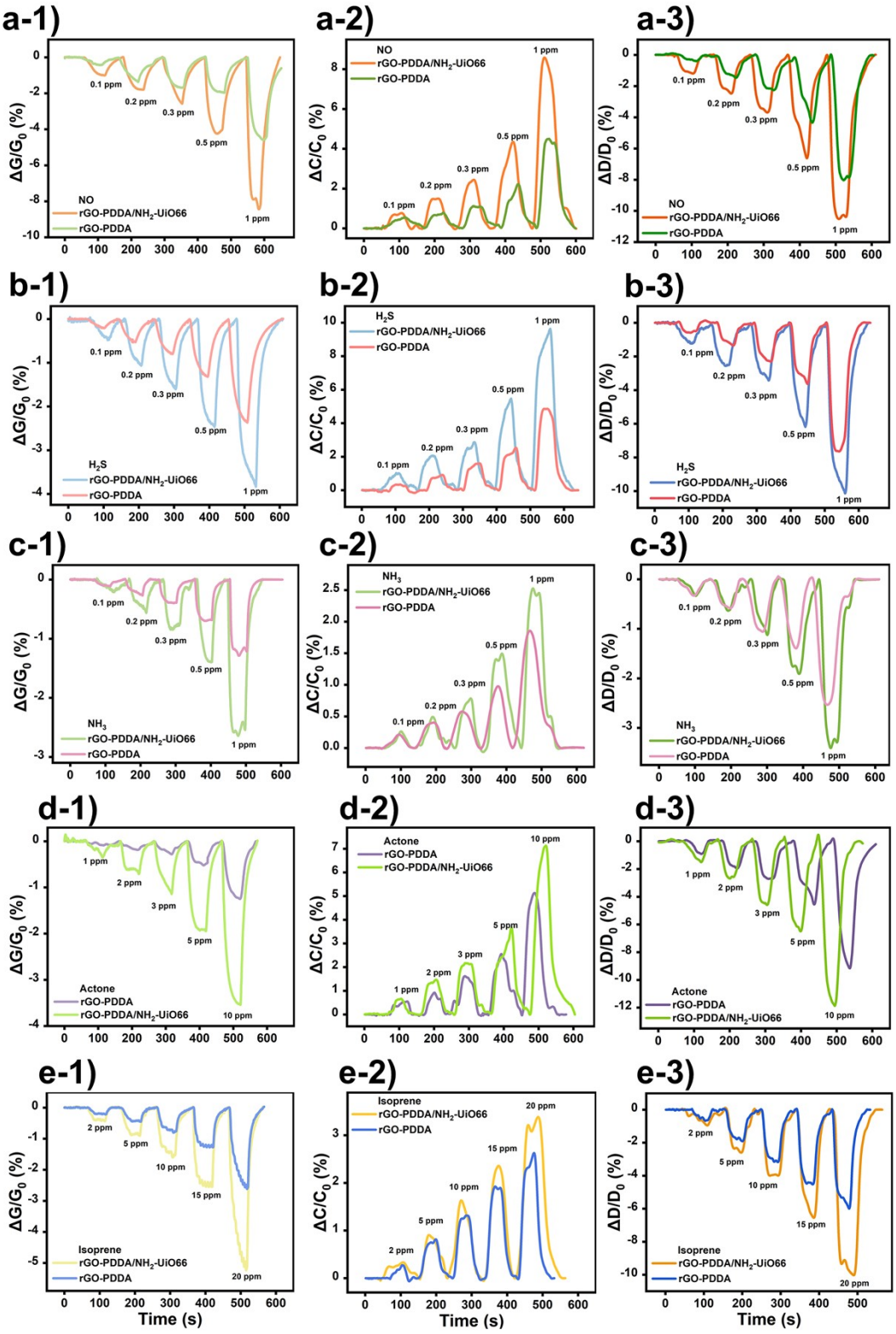

Figure S4. Dynamic response curves of two sensing elements towards a) NO, b)H_2S, c) NH_3, d) Ace and f) Iso under 1) *G*, 2) *C* and 3) *DF* signals.

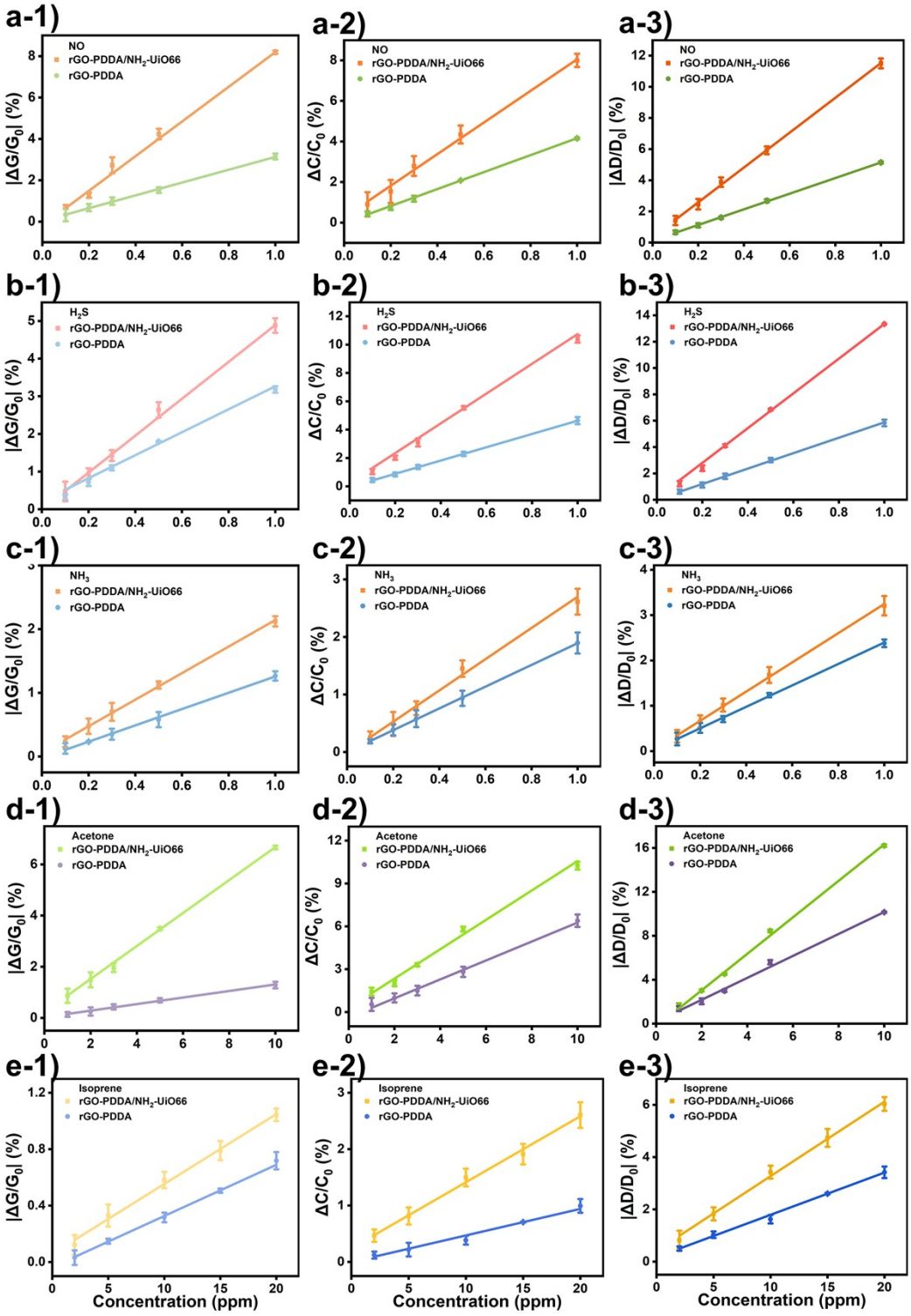

Figure S5. Linear fitting curves of two sensing elements towards a) NO, b) H_2S, c) NH_3, d) Ace and f) Iso under 1) *G*, 2) *C* and 3) *DF* signals.

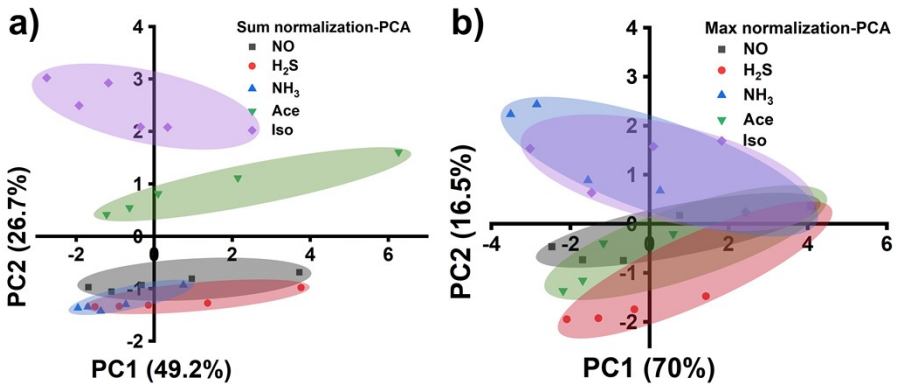

Figure S6. PCA results of 3*3 matrix multimodal GSA using a) Sum normalization, b) Maximum normalization.

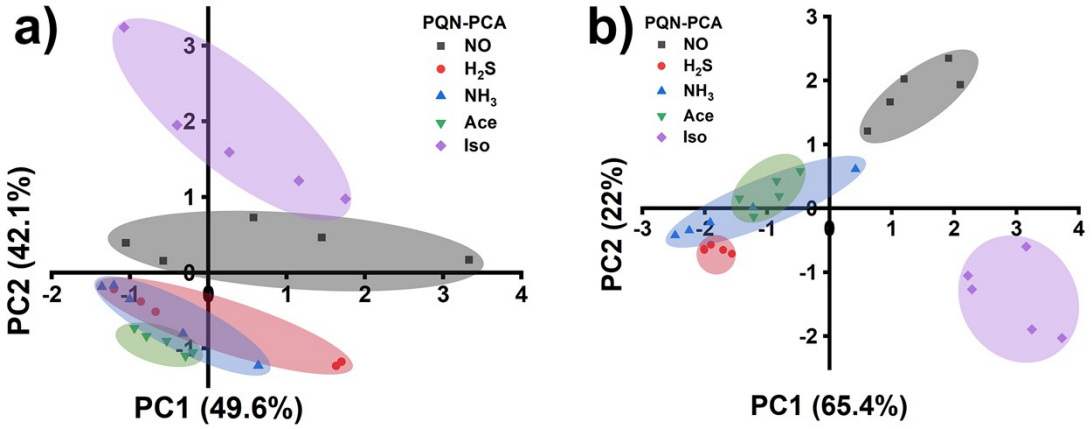

Figure S7. PCA results of a) 1*3 matrix GSA and b) 3*2 matrix multimodal GSA.

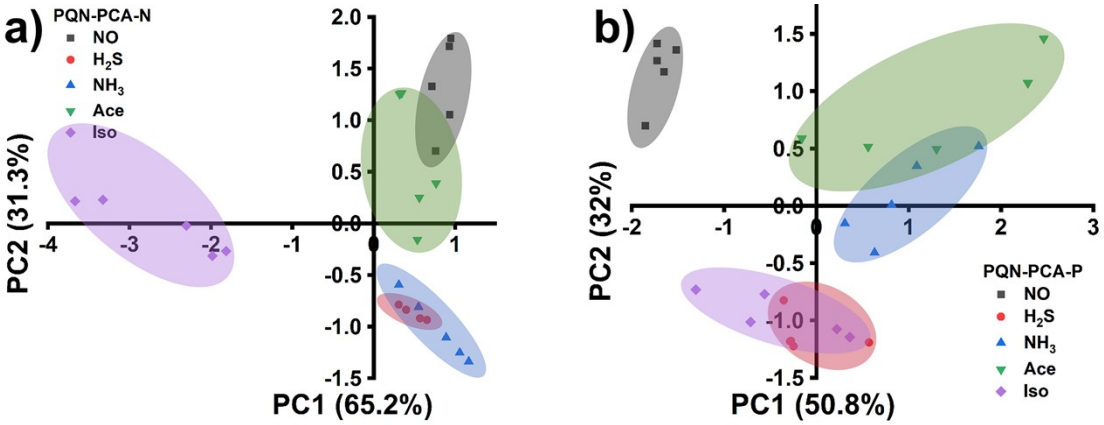

Figure S8. PCA results of single-element gas sensor: a) rGO-PDDA/NH_2-UiO66 and b) rGO-PDDA.

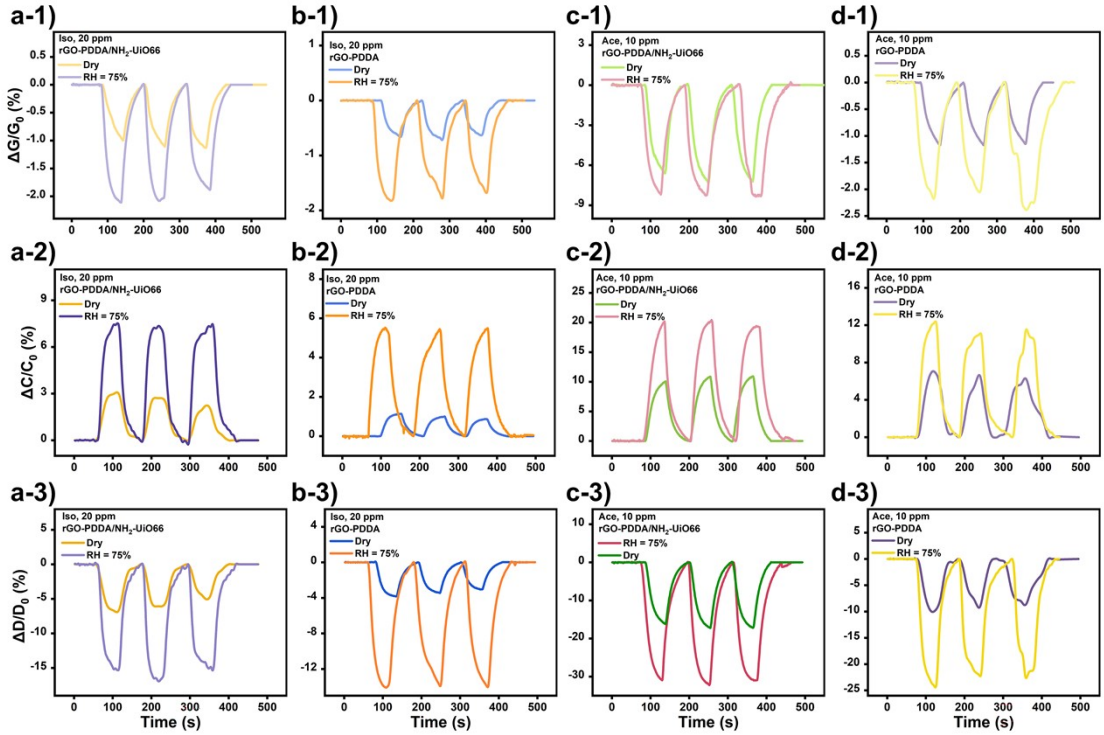

Figure S9. a-b) Dynamic response curves of two sensing elements towards Iso at dry and RH = 75% under 1) *G*, 2) *C* and 3) *DF* signals. c-d) Dynamic response curves of two sensing elements towards Ace at dry and RH = 75% under 1) *G*, 2) *C* and 3) *DF* signals.

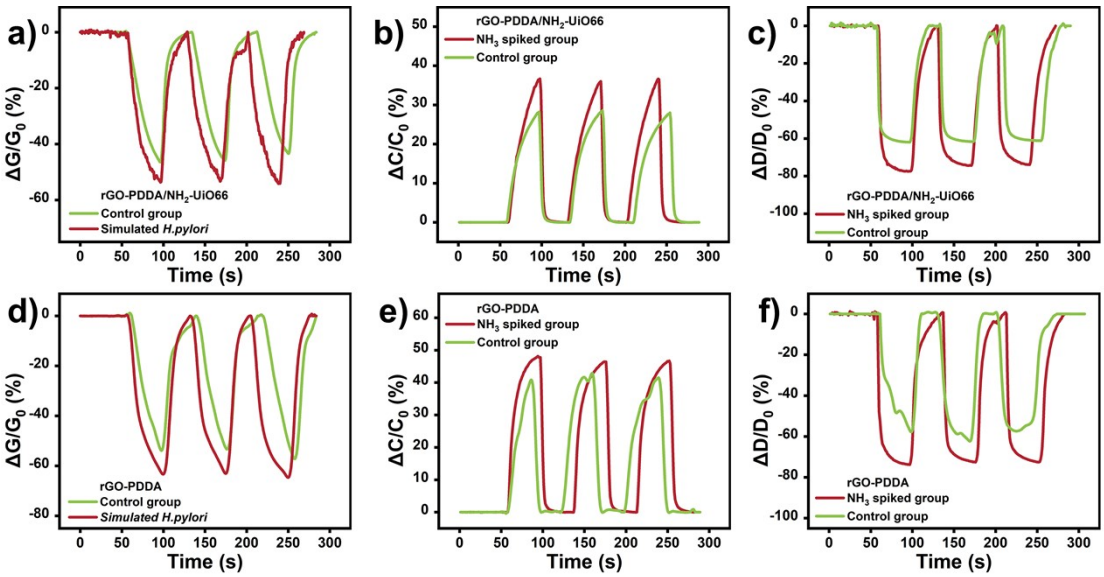

Figure S10. Dynamic response curves of NH_3-spiked EB and control group of rGO-PDDA/NH_2-UiO66 under a) *G*, b) *C*, c) *DF* signals and rGO-PDDA under d) *G*, e) *C*, f) *DF* signals.

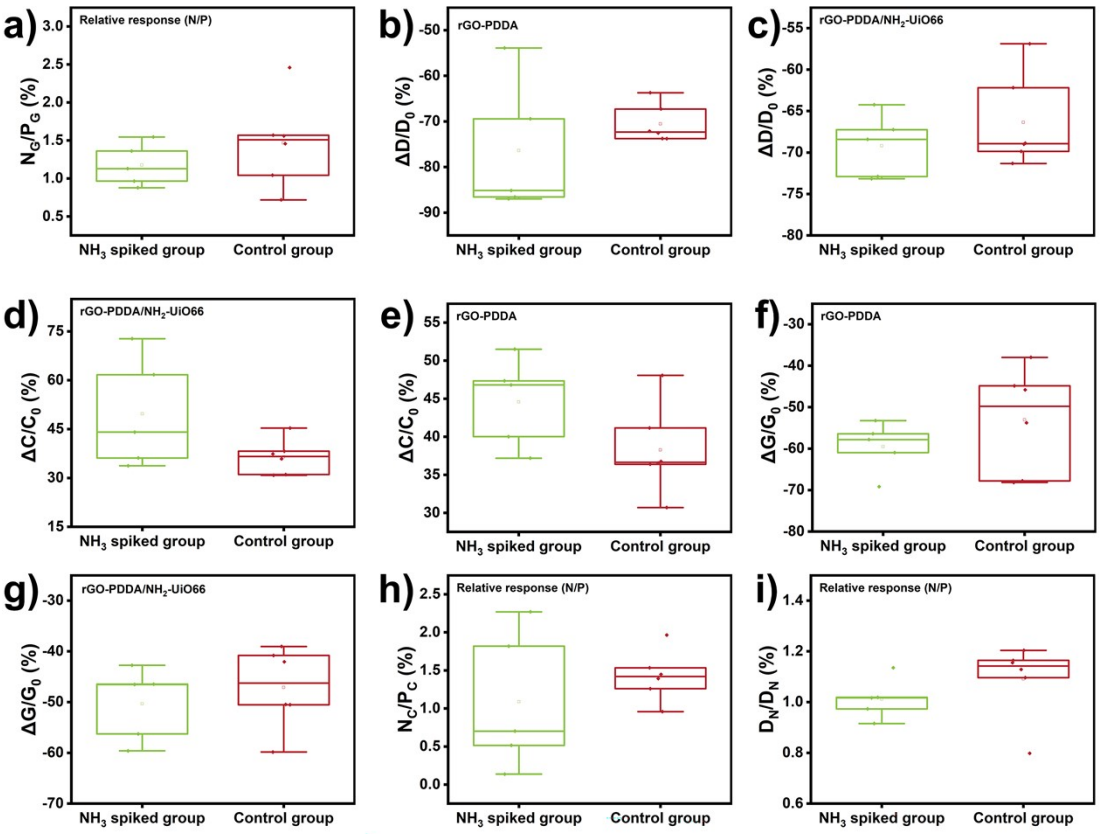

Figure S11. Box charts of responses in NH_3-spiked EB analysis (11 cases study). Responses under *G*, *D*, *DF* signals of a-c) rGO-PDDA/NH_2-UiO66, d-f) rGO-PDDA and g-i) *RR*.

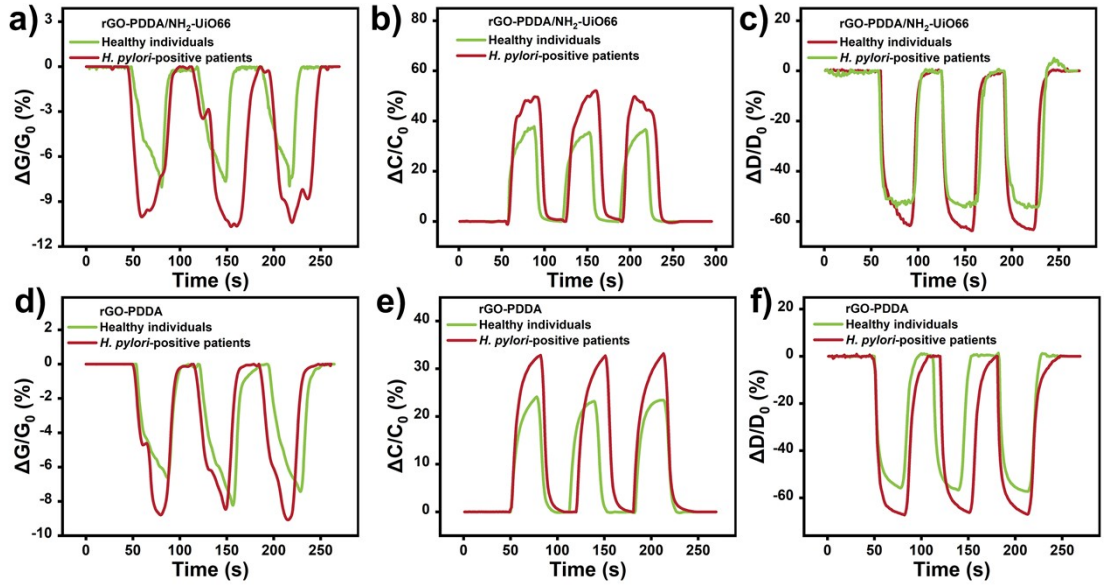

Figure S12. Dynamic response curves of real EB specimens of *H. pylori*-positive patients and healthy individuals of rGO-PDDA/NH_2-UiO66 under a) *G*, b) *C*, c) *DF* signals and rGO-PDDA under d) *G*, e) *C*, f) *DF* signals.

Table S1. Dielectric constants for different gases

Gas	Relative dielectric constant (ε_r)
Air	1.0005364
N_2	1.0005480
NO	1.000600
H_2S	1.00344
NH_3	1.00622
Ace	20.7
Iso	2.18
H_2O	78.5

Table S2. Responses matrix of multimodal GSA towards NO, H_2S, NH_3, Ace and Iso. *G*: conductance, *C*: capacitance, *DF*: dissipation factor, N: rGO-PDDA/NH_2-UiO66, P: rGO-PDDA. N/P: relative response by R_N/R_P.

Gas	Con. (ppm)	N-*G*	N-*C*	N-*DF*	P-*G*	P-*C*	P-*DF*	N/P-*G*	N/P-*C*	N/P-*DF*
	0.1	0.709	0.900	1.417	0.335	0.437	0.663	2.113	2.061	2.136
	0.2	1.279	1.537	2.460	0.759	0.733	1.110	1.685	2.095	2.216
NO	0.3	2.724	2.787	3.880	1.254	1.180	1.600	2.172	2.362	2.425
	0.5	4.236	4.343	5.923	2.225	2.077	2.680	1.903	2.091	2.210
	1.0	8.193	7.997	10.500	4.490	3.537	4.140	1.825	2.261	2.536
	0.1	0.473	1.043	1.227	0.325	0.447	0.620	1.458	2.336	1.979
	0.2	0.943	2.020	2.400	0.715	0.840	1.120	1.318	2.405	2.143
H_2S	0.3	1.427	3.097	4.107	1.099	1.363	1.783	1.299	2.271	2.303
	0.5	2.640	5.543	6.850	1.792	2.287	3.010	1.474	2.424	2.276
	1.0	4.880	9.393	11.341	3.819	4.640	5.830	1.278	2.024	1.945
	0.1	0.234	0.254	0.327	0.127	0.190	0.267	1.842	1.339	1.224
	0.2	0.476	0.487	0.651	0.233	0.387	0.511	2.044	1.260	1.274
NH_3	0.3	0.701	0.762	1.016	0.350	0.579	0.706	2.001	1.316	1.438
	0.5	1.323	1.451	1.680	0.580	0.934	1.233	2.282	1.553	1.362
	1.0	2.122	2.613	3.207	1.265	1.896	2.378	1.677	1.378	1.348
	1	0.863	1.432	1.586	0.137	0.535	1.369	6.291	2.677	1.159
	2	1.487	2.027	3.015	0.250	0.989	2.037	5.938	2.049	1.481
Ace	3	1.964	3.310	4.522	0.433	1.500	3.004	4.531	2.207	1.505
	5	3.485	6.067	8.450	0.689	3.091	5.597	5.058	1.963	1.510
	10	6.660	10.248	16.209	1.125	6.393	10.149	5.918	1.603	1.597
	2	0.607	0.466	0.822	0.093	0.121	0.499	6.533	3.849	1.647
	5	1.648	0.815	1.828	0.444	0.218	1.032	3.713	3.739	1.771
Iso	10	2.907	1.498	3.424	0.949	0.385	1.623	3.064	3.887	2.110
	15	3.950	1.912	4.736	1.519	0.706	2.603	2.601	2.710	1.819
	20	5.221	2.604	6.032	2.155	0.993	3.619	2.423	2.622	1.667

Table S3. LoD of multimodal GSA towards NO, H2S, NH3 and Iso under three signals of a) rGO-PDDA/NH2-UiO66 and b) rGO-PDDA

a)

Gas	Signal	Noise (%)	Sensitivity (% / ppm)	LoD (3N/S) (ppb)
NO	*G*	0.075	8.39	26.98
	C	0.107	8.00	40.12
	DF	0.144	10.21	42.30
H_2S	*G*	0.033	3.87	25.26
	C	0.065	6.60	29.57
	DF	0.071	7.51	28.28
NH_3	*G*	0.016	1.19	41.21
	C	0.010	1.18	24.56
	DF	0.014	2.35	17.45
Ace	*G*	0.005	0.11	121.60
	C	0.029	1.35	64.07
	DF	0.030	1.61	54.89
Iso	*G*	-0.007	0.25	84.09
	C	-0.008	0.10	248.79
	DF	-0.013	0.28	134.11

b)

Gas	Signal	Noise (%)	Sensitivity (% / ppm)	LoD (3N/S) (ppb)
NO	*G*	0.020	4.64	12.74
	C	0.435	3.21	406.64
	DF	0.447	3.73	359.98
H_2S	*G*	0.007	4.77	4.16
	C	0.097	9.29	31.27
	DF	0.093	9.93	27.95
NH_3	*G*	0.037	3.25	34.26
	C	0.075	4.70	47.96
	DF	0.093	5.85	47.71
Ace	*G*	0.037	0.48	234.32
	C	-0.103	0.77	398.97
	DF	-0.067	1.11	181.92
Iso	*G*	0.018	0.11	476.05
	C	0.016	0.05	893.46
	DF	0.024	0.13	531.34

Table S4. Relevant information about qualified volunteers

Serial No.	Age	Gender	Class
1	49	Male	Healthy individual
2	50	Male	Healthy individual
3	75	Male	Healthy individual
4	58	Male	Healthy individual
5	53	Male	Healthy individual
6	28	Male	Healthy individual
7	53	Male	Healthy individual
8	60	Male	Healthy individual
9	40	Male	Healthy individual
10	58	Male	Healthy individual
11	41	Male	Healthy individual
12	74	Male	Healthy individual
13	37	Male	Healthy individual
14	48	Male	Healthy individual
15	61	Male	Healthy individual
16	56	Female	Healthy individual
17	42	Female	Healthy individual
18	41	Female	Healthy individual
19	64	Female	Healthy individual
20	53	Female	Healthy individual
21	56	Male	Healthy individual
22	68	Male	Healthy individual
23	60	Male	Healthy individual
24	37	Male	Healthy individual
25	49	Female	Healthy individual
26	32	Male	Healthy individual
27	57	Female	Healthy individual
28	31	Male	Healthy individual
29	64	Female	Healthy individual
30	36	Male	Healthy individual
31	72	Male	Healthy individual
32	39	Male	Healthy individual
33	32	Male	Healthy individual
34	76	Male	Healthy individual
35	45	Male	*H. pylori* -positive patient
36	23	Female	*H. pylori* -positive patient
37	35	Male	*H. pylori* -positive patient
38	34	Male	*H. pylori* -positive patient
39	36	Male	*H. pylori* -positive patient
40	33	Female	*H. pylori* -positive patient
41	38	Female	*H. pylori* -positive patient
42	34	Male	*H. pylori* -positive patient

Continued Table S4. Relevant information about qualified volunteers

Serial No.	Age	Gender	Class
43	53	Male	*H. pylori* -positive patient
44	62	Male	*H. pylori* -positive patient
45	25	Male	*H. pylori* -positive patient
46	55	Male	*H. pylori* -positive patient
47	54	Female	*H. pylori* -positive patient
48	49	Female	*H. pylori* -positive patient
49	47	Male	*H. pylori* -positive patient
50	46	Male	*H. pylori* -positive patient
51	69	Male	*H. pylori* -positive patient
52	52	Female	*H. pylori* -positive patient