Supplementary Information

Flexible, Stable, Semi-Dry Electrode with Low Impedance for Electroencephalography Recording

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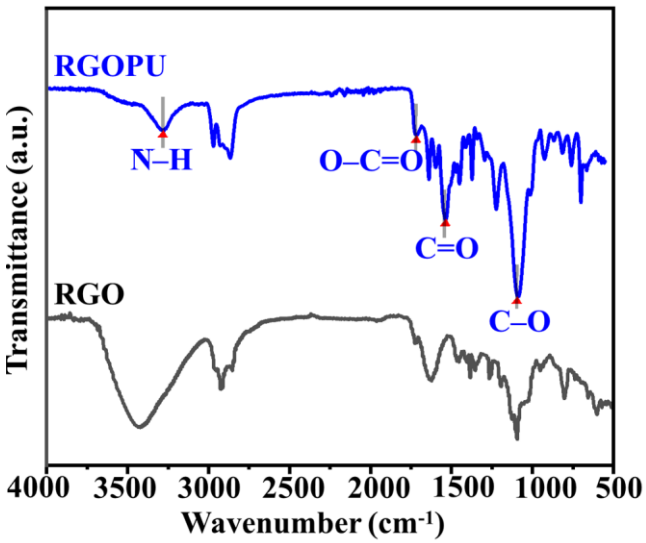


Figure. S1. FT-IR spectra of the RGOPU and RGO.

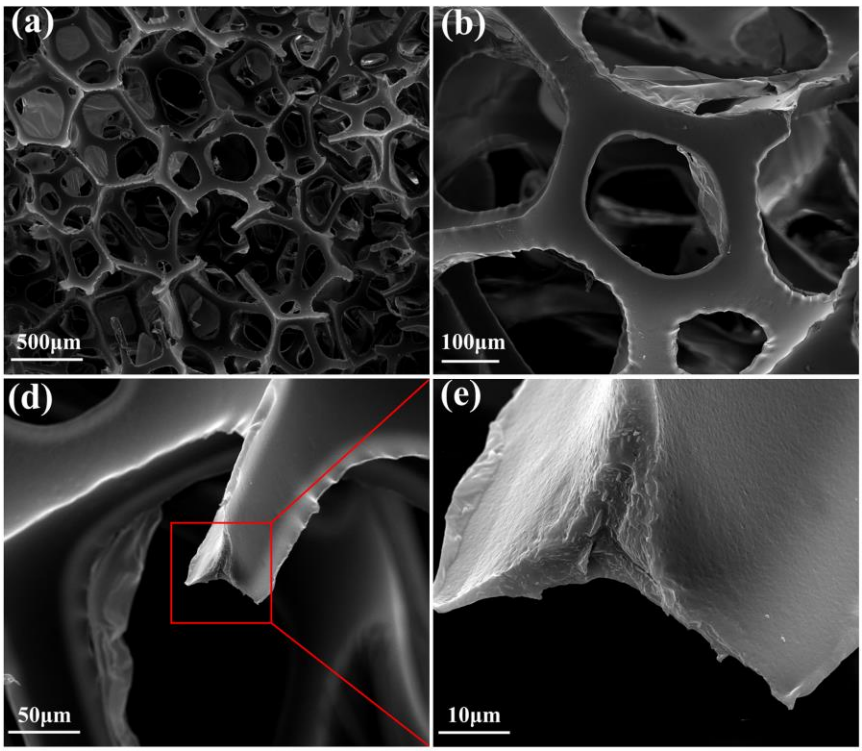


Figure. S2. SEM images of the PU sponge.

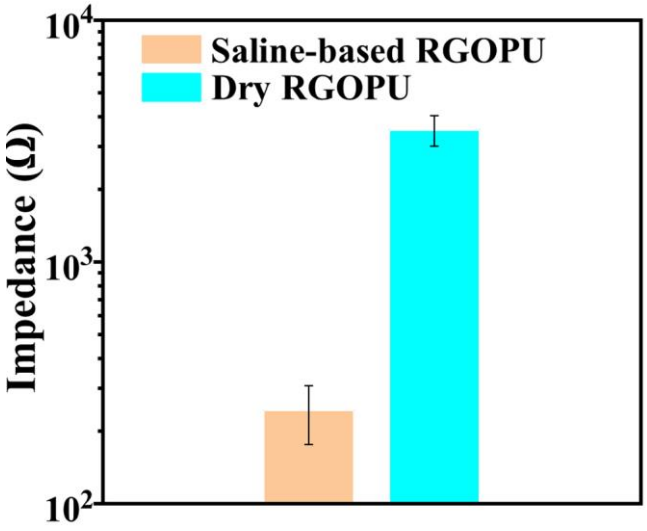


Figure. S3. Impedance of dry RGOPU and saline-based RGOPU.

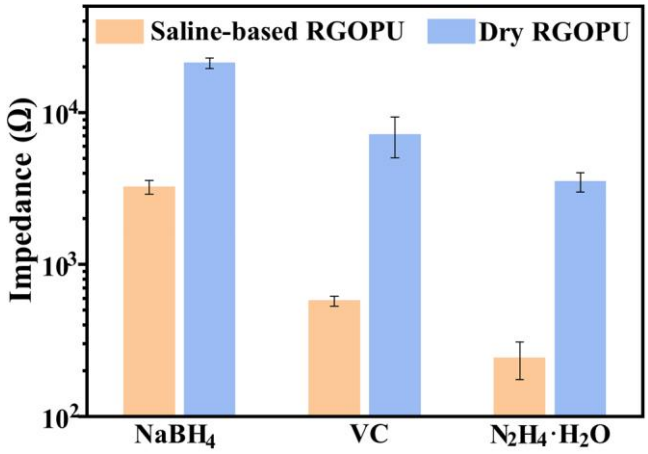


Figure. S4. Comparisons of impedance of the RGOPU prepared by different reducing agents, including $N_2H_4 \cdot H_2O$ (used in this paper), $NaBH_4$ and vitamin C (VC).

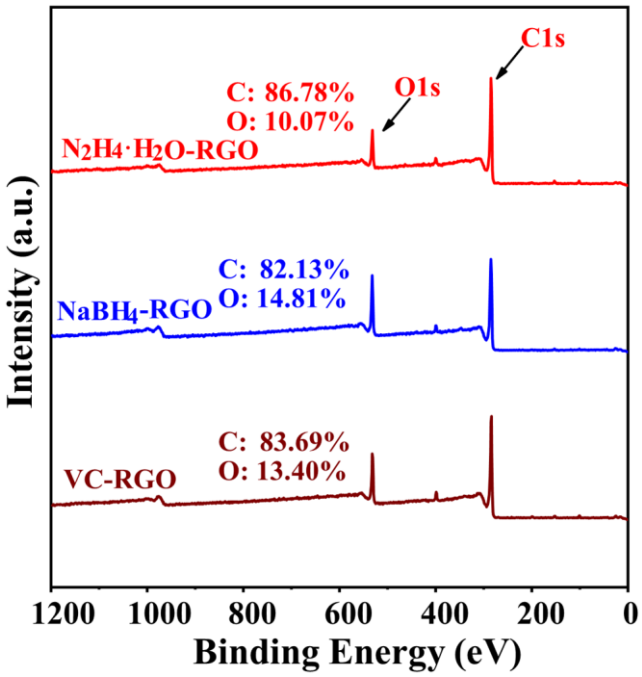


Figure. S5. XPS full-spectra of the RGOPU prepared by different reducing agents including $N_2H_4 \cdot H_2O$, $NaBH_4$ and vitamin C (VC).

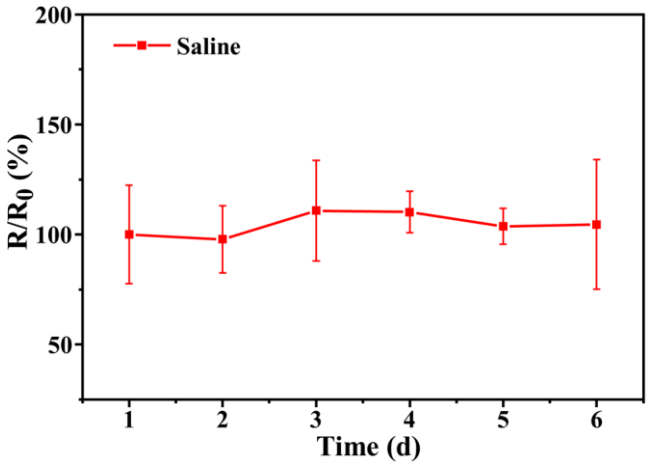


Figure. S6. Long-term impedance variation of RGOPU in saline.

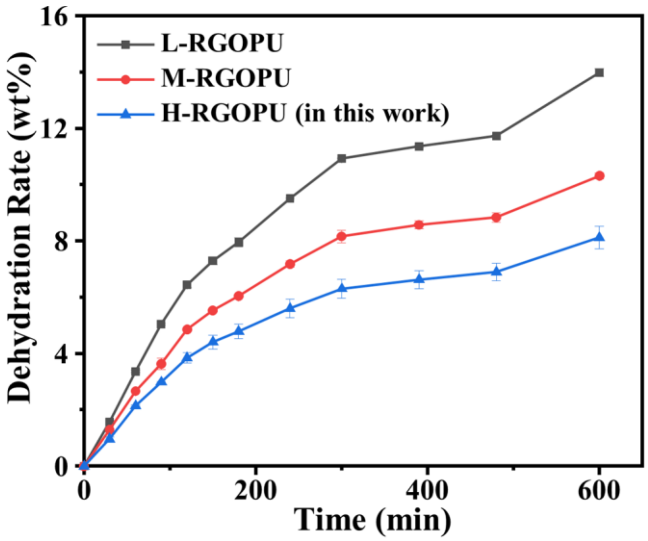


Figure. S7. Dehydration rates of saline-based RGOPU samples with different pore densities (L: low pore density; M: medium pore density; H: high pore density).

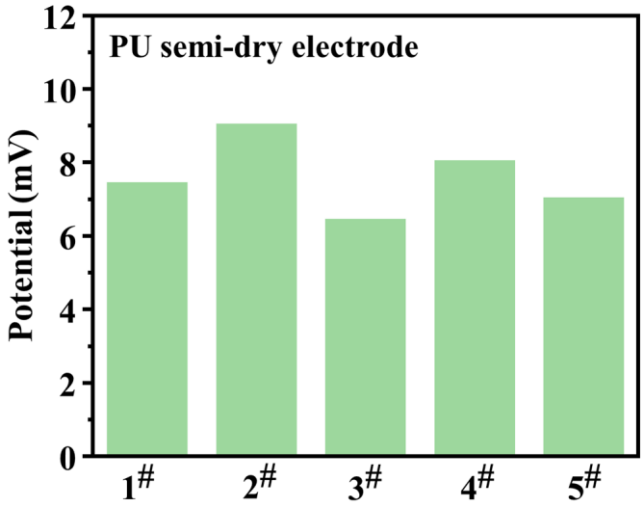


Figure. S8. Electrode potential of the saline-based PU semi-dry electrode.

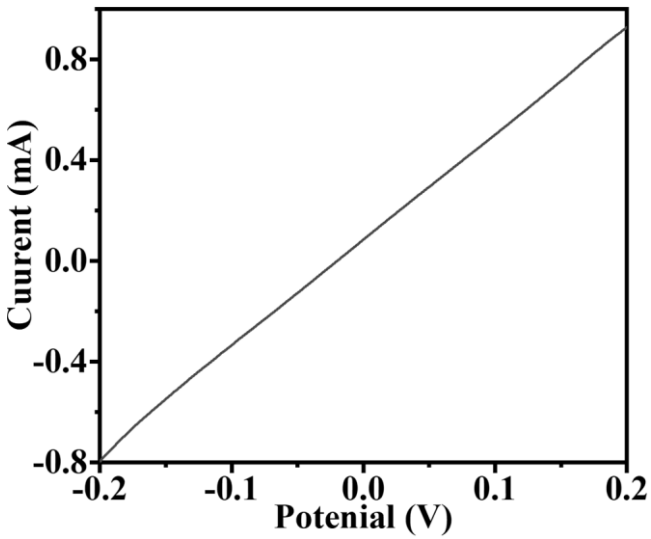


Figure. S9. CV curve of the saline-based RGOPU semi-dry electrode under applied potential of -0.2~0.2 V.

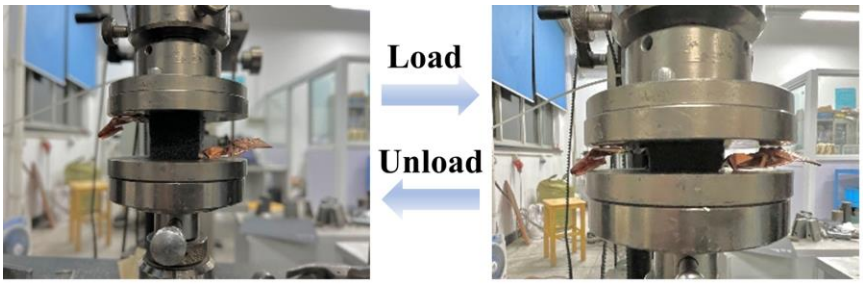


Figure. S10. Photographs of the elasticity test for the RGOPU sample (diameter:11mm; height:18mm) at compression ratios from 20% to 70%.

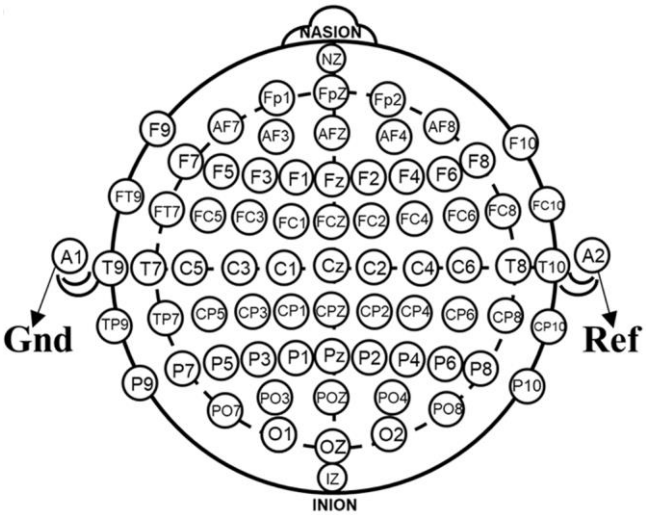


Figure. S11. Position of the electrode.

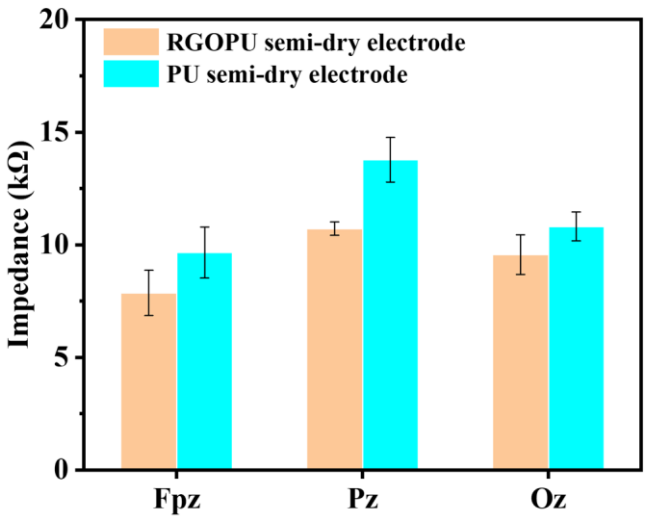


Figure. S12. Contact impedance of a pair of PU semi-dry electrodes at three positions (Fpz, Pz and Oz).

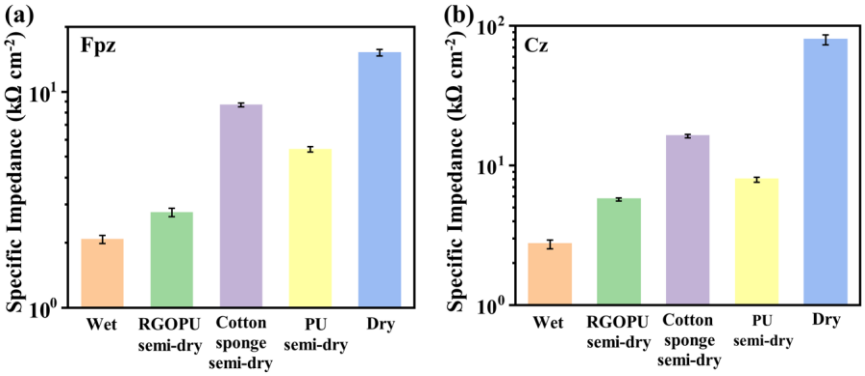


Figure. S13. Specific impedance of a single wet electrode, a single RGOPU semi-dry electrode, a single cotton sponge semi-dry electrode, a single PU semi-dry electrode, and a single dry electrode at (a) Fpz and (b) Cz (measurement frequency: 10 Hz).

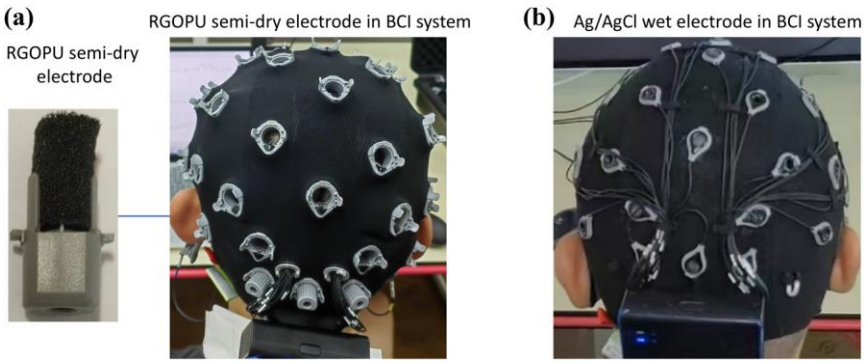


Figure. S14. Devices for EEG acquisition. (a) Devices with RGOPU semi-dry electrodes. (b) Devices with Ag/AgCl wet electrodes.

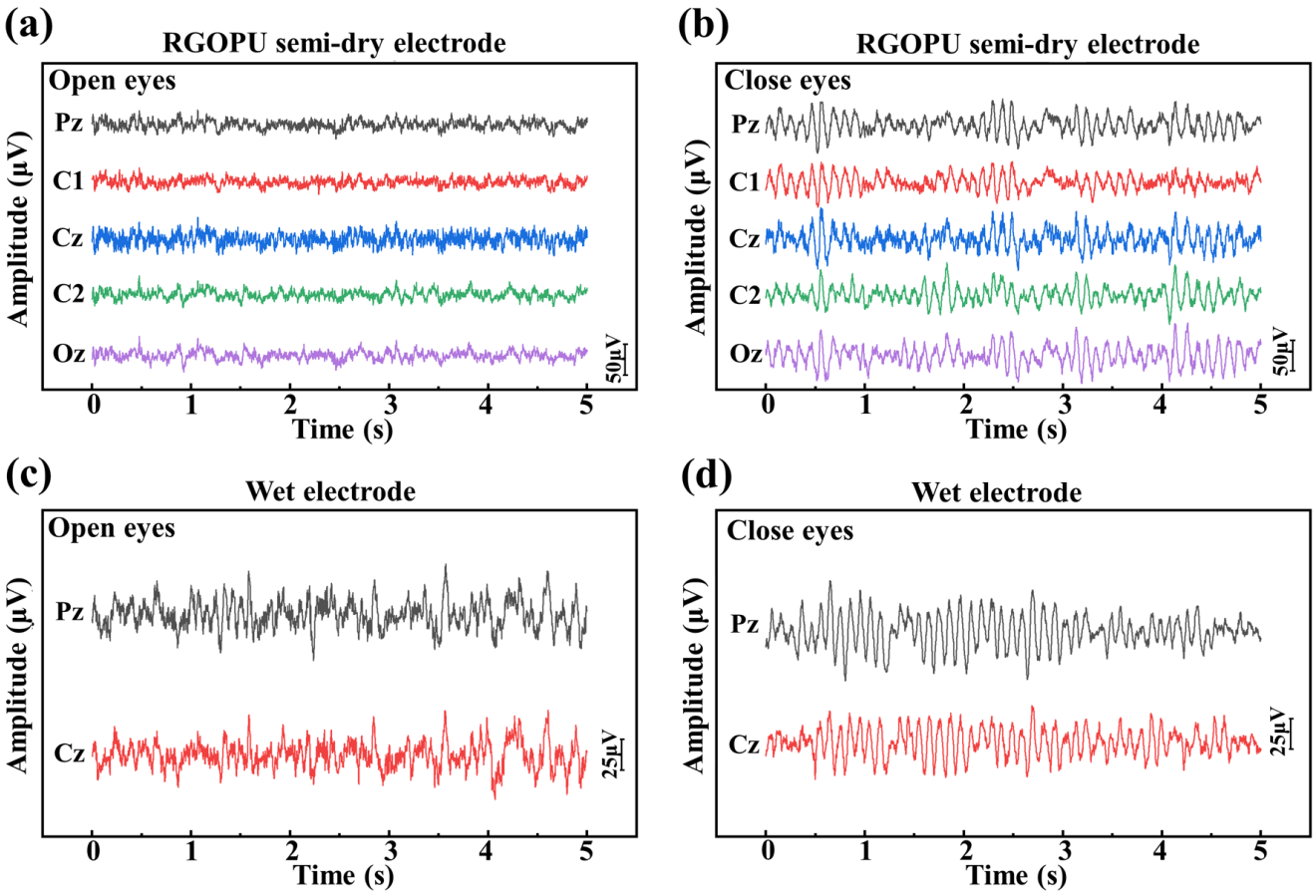


Figure. S15. EEG recordings of the RGOPU semi-dry electrode with (a) EO and (b) EC at Pz, C1, C2, Cz, and Oz. EEG recordings of the Ag/AgCl wet electrode with (c) EO and (d) EC at Pz and Cz.

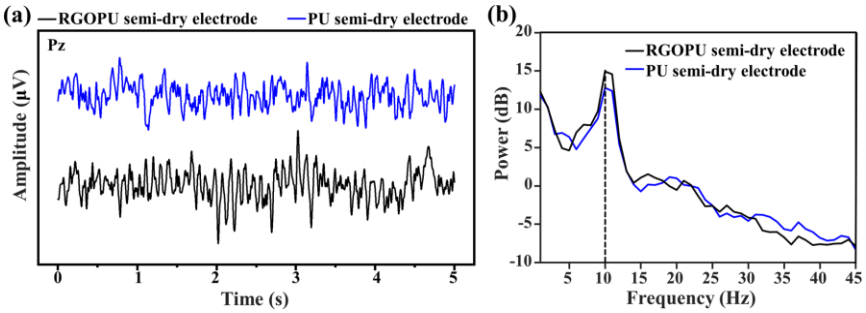


Figure. S16. Comparisons of EEG recordings of RGOPU and PU semi-dry electrodes for EC at Pz. (a) Alpha-wave recordings of RGOPU and PU semi-dry electrodes. (b) Power spectra of RGOPU and PU semi-dry electrodes from (a).

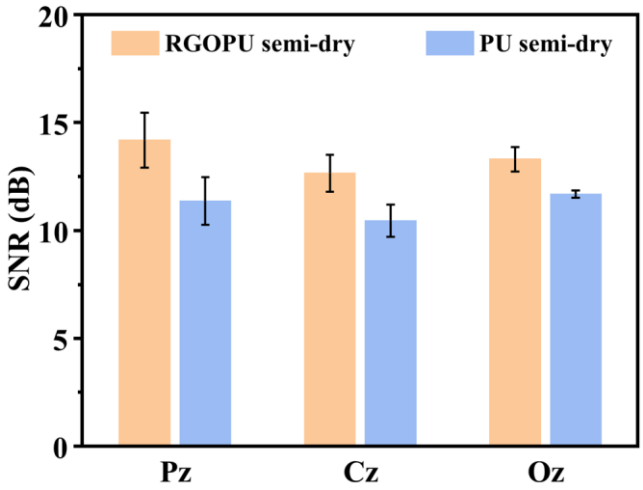


Figure. S17. SNR of the alpha-wave recordings of RGOPU and PU semi-dry electrodes at different positions (Pz, Cz and Oz).

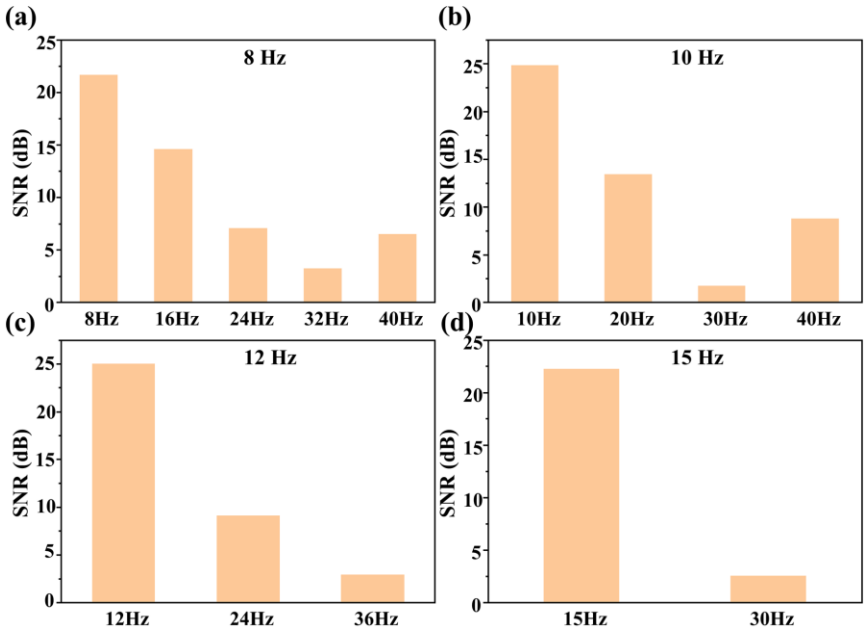


Figure. S18. SNR of harmonics in SSVEP tests at Oz with the stimulus frequencies of (a) 8 Hz, (b) 10 Hz, (c) 12 Hz, and (d) 15 Hz.

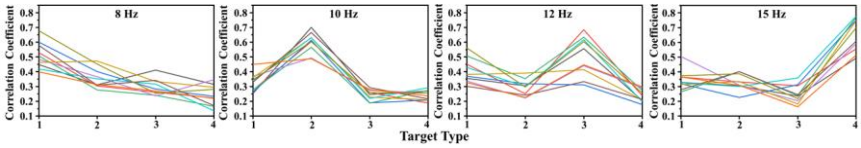


Figure. S19. Correlation coefficient between EEG signals of the RGOPU semi-dry electrode and reference signals at four stimulus frequencies (stimulus 1: 8Hz; stimulus 2: 10 Hz; stimulus 3: 12 Hz; stimulus 4: 15 Hz) in 40 SSVEP trials calculated by CCA method.

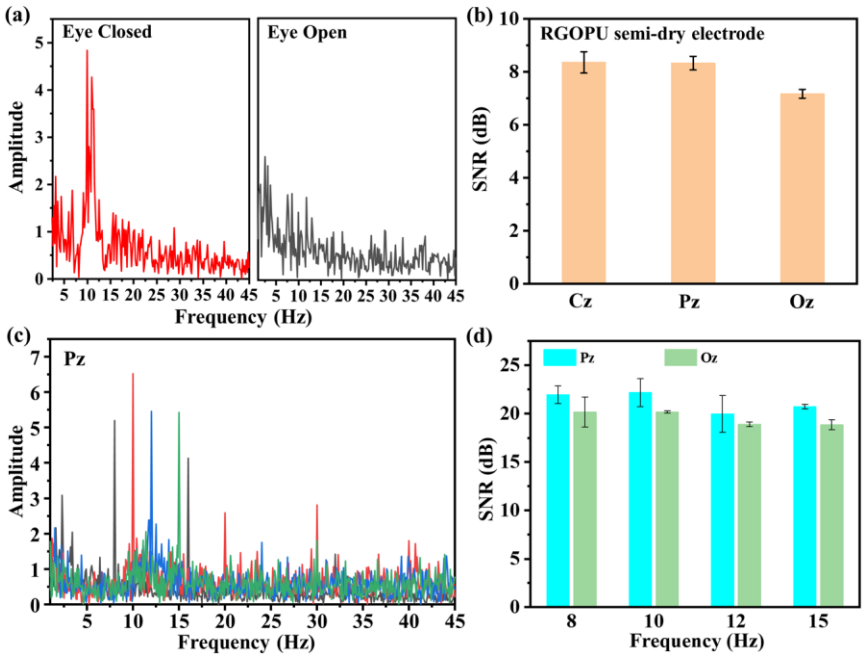
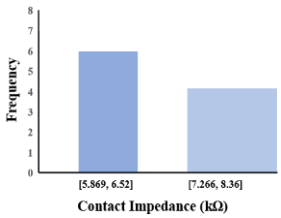


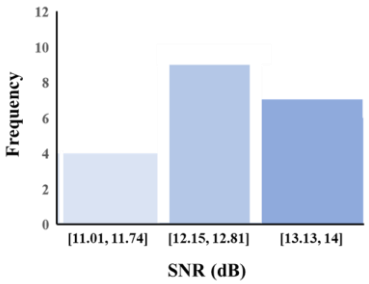
Figure. S20. EEG signals recorded by RGOPU semi-dry electrodes from long-haired subjects. (a) Frequency spectra of EEG signals in EC and EO pattern recorded at Cz. (b) SNR value of alpha-wave recordings at Cz, Pz, and Oz. (c) Frequency spectrum of the SSVEP at Pz at different frequencies. (d0 SNR value of the SSVEP at Pz and Oz at the frequency of 8 Hz, 10 Hz, 12 Hz, and 15 Hz.

Table S1. Data of the skin-contact impedance (measurement frequency: 10 Hz) at Fpz for a pair of RGOPU semi-dry electrodes of different sample numbers, and statistical and analytical results of the data. (Repetitions: 10)

No.	Contact Impedance (kΩ)	Mean ± Standard Deviation		Level of Significance A	Mean Separation Method
1-1	7.266	6.7994 ± 0.8869	6.8369 ± 0.906	No.1 vs No.2 sample: p>0.05 (α=0.05), Not significant Different subjects: p<0.01, Very significant	K-means cluster analysis k=2 
1-2	5.869				
1-3	6.520				
1-4	8.288				
1-5	6.054				
2-1	7.523	6.8744 ± 0.9234			
2-2	5.940				
2-3	6.421				
2-4	8.360				
2-5	6.128				

(The data number are defined as “X-Y”, where the “X” refers to the sample number, “Y” is the number of tests (subject number). E.g. “1-1” refers to the first test (first subject) of the No.1 sample)

Table S2. Data of the SNR values of alpha-wave recordings at Cz for RGOPU semi-dry electrodes of different sample numbers, and statistical and analytical results of the data. (Repetitions: 20)

Number	SNR (dB)	Mean ± Standard Deviation		Level of Significance α	Mean Separation Method
1-1	12.37	12.701 ± 0.8345	12.654 ± 0.844	No.1 vs No.2 sample: p>0.05 (α=0.05), Not significant Different subjects: p<0.01, Very significant	K-means cluster analysis k=3 
1-2	11.74				
1-3	12.52				
1-4	13.47				
1-5	13.13				
1-6	12.17				
1-7	12.79				
1-8	11.19				
1-9	13.63				
1-10	14.00				
2-1	12.29	12.60 ± 0.852			
2-2	11.67				
2-3	12.46				
2-4	13.35				
2-5	12.81				
2-6	12.15				
2-7	12.73				
2-8	11.01				
2-9	13.66				
2-10	13.94				

(The data number are defined as “X-Y”, where the “X” refers to the sample number, “Y” is the number of tests (subject number). E.g. “1-1” refers to the first test (first subject) of the No.1 sample)