nature portfolio

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Reporting Summary

Nature Portfolio wishes to improve the reproducibility of the work that we publish. This form provides structure for consistency and transparency in reporting. For further information on Nature Portfolio policies, see our Editorial Policies and the Editorial Policy Checklist.

Statistics

For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

n/a	Confirmed
☐	☒ The exact sample size (*n*) for each experimental group/condition, given as a discrete number and unit of measurement
☐	☒ A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly
☐	☒ The statistical test(s) used AND whether they are one- or two-sided *Only common tests should be described solely by name; describe more complex techniques in the Methods section.*
☒	☐ A description of all covariates tested
☒	☐ A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons
☐	☒ A full description of the statistical parameters including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals)
☐	☒ For null hypothesis testing, the test statistic (e.g. *F*, *t*, *r*) with confidence intervals, effect sizes, degrees of freedom and *P* value noted *Give P values as exact values whenever suitable.*
☒	☐ For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings
☒	☐ For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes
☒	☐ Estimates of effect sizes (e.g. Cohen's *d*, Pearson's *r*), indicating how they were calculated

Our web collection on statistics for biologists contains articles on many of the points above.

Software and code

Policy information about availability of computer code

Data collection	For spectroscopy measurement, FILMeasure v8 software was used for data collection. For transistors and circuits characterization, Kickstart v2.4 software was used for data collection.
Data analysis	For GIWAXS data, Igor v6.38B01 software was used for data analysis. For reflection spectroscopy data, FILMeasure v8 software was used for data analyis. For cell experiment, the number of live/dead cells on the samples was quantified using ImageJ software (the version number is not applicable). For KPFM and AFM data, Gwyddion v2.59 software was used for data analysis. Origin v2018b software was used for the analysis of other data.

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Portfolio guidelines for submitting code & software for further information.

Data

Policy information about availability of data

All manuscripts must include a data availability statement. This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A description of any restrictions on data availability
- For clinical datasets or third party data, please ensure that the statement adheres to our policy

All data are available in the main text or the supplementary materials. Source data has been deposited in Science Data Bank with the following link: https://www.scidb.cn/s/IVFzEr

Human research participants

Policy information about studies involving human research participants and Sex and Gender in Research.

Reporting on sex and gender	This information has not been collected.
Population characteristics	ECG and EMG samples were collected from a healthy male volunteer aged 28.
Recruitment	No participants were recruited in this study.
Ethics oversight	Ethics Committee of the First Affiliated Hospital of Xi'an Jiaotong University.

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

☒ Life sciences ☐ Behavioural & social sciences ☐ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see nature.com/documents/nr-reporting-summary-flat.pdf

Life sciences study design

All studies must disclose on these points even when the disclosure is negative.

Sample size	Sample size calculation was performed before the experiments. For different experiments, sample sizes were chosen as follow: For OECT reproducibility characterization, n=60 different devices were measured. We determined this to be sufficient to show the variation and reproducibility of different experiments and devices. For the experiment about the influence of PEI ratio on device performance, n=5 different devices per condition were measured. We determined this to be sufficient to show the relation between the PEI ratio and device performance, because the observed deviation between the devices in same condition is not large. For TOF-SIMS measurement, X-ray measurement, KPFM measurement, spectra measurement, electron transit time measurement, nonvolatile memory experiment, spiking neuron experiment, one sample were measured in one single experiment. This is because all of these experiment were repeated successfully and show similar material/device/circuit characteristics. For cell culture experiments, n=5 different samples was chosen for each nerve interface. We determined this to be sufficient owing to the low observed variability between different samples. For soft electrode (nerve interface) implantation and electrical stimuli experiments and CMAN-assisted conditioned reflex experiment, we only use one sample per condition to avoid 1) the potential physical injury to the mouse from long-term testing under anaesthetic and 2) undesired variation between different mouses.
Data exclusions	Data were not excluded from analysis.
Replication	To ensure robust reproducibility: The basic OECT performance data presented in this manuscript were repeated three times per experimental condition (see Fig. S2). The TOF-SIMS measurement, X-ray measurement, KPFM measurement, spectra measurement, electron transit time measurement, nonvolatile memory experiment, spiking neuron experiment, cell culture and H&E experiment and animal implantation experiments were performed for at least two times per experimental condition. The CMAN-assisted conditioned reflex experiment was performed once per condition to avoid 1) the potential physical injury to the mouse from long-term testing under anaesthetic, and 2) undesired variation between different mouses. All replications were successful.
Randomization	For experiments other than animal and cell experiments, all the samples, fabricated devices and circuits were not allocated into groups, thus no randomization exists. For cell culture experiment, the PC-12 cells that passed quality control were analyzed equally with no sub-sampling and thus, there was no requirement for randomization. Specially, for animal experiments, adult male mouse with similar weight were selected for BBL and BBL/PEI CMAN to reduce the undesired individual difference, thus randomization cannot be fully achieved for these experiments.

Blinding	For material, device, circuits characterizations and animal/cell experiments, the investigators were blinded to the materials, processing conditions during the data collection and analysis.

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

n/a	Involved in the study
☒	☐ Antibodies
☐	☒ Eukaryotic cell lines
☒	☐ Palaeontology and archaeology
☐	☒ Animals and other organisms
☒	☐ Clinical data
☒	☐ Dual use research of concern

Methods

n/a	Involved in the study
☒	☐ ChIP-seq
☒	☐ Flow cytometry
☒	☐ MRI-based neuroimaging

Eukaryotic cell lines

Policy information about cell lines and Sex and Gender in Research

Cell line source(s)	PC-12 (rat, 100235, origin source is BeNa Culture Collection).
Authentication	Cell lines have been authenticated by vendor (BeNa Culture Collection) using the cell morphology analysis technology.
Mycoplasma contamination	Cell lines were not tested for mycoplasma contamination but no indication of contamination was observed.
Commonly misidentified lines (See ICLAC register)	No commonly misidentified cell lines were used.

Animals and other research organisms

Policy information about studies involving animals; ARRIVE guidelines recommended for reporting animal research, and Sex and Gender in Research

Laboratory animals	Adult male C57BL/6J mice aged 25-90 week were used for animal experiments. The housing temperature is 25℃ and the humidity is 50%-60%.
Wild animals	No wild animals were used in this study.
Reporting on sex	Sex information of the animals has not been collected.
Field-collected samples	No field-collected samples were used in this study.
Ethics oversight	All the animal experiments performed in this research were approved by the Ethics Committee of the First Affiliated Hospital of Xi'an Jiaotong University under the protocols of 2022-1203.

Note that full information on the approval of the study protocol must also be provided in the manuscript.