

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	ANSYS was used for the finite element analysis. Bluehill universal software was used to monitor all stress-strain curves and evaluate adhesive strength of the materials. Keysight and ZIVE smart manager softwares were utilized for the electrical and electrochemical characterization. 3D slicer was utilized to measure the beam profile. Cheetah 6.4.1 was used to collect in vivo experimental data.
Data analysis	Origin Pro 8.5, GraphPad Prism 7, and MATLAB R2020a were used to analyze and/or plot the data. The mean value, median value, standard error of the mean, unpaired one-tailed t-test, Wilcoxon rank sum test, and one way ANOVA (Tukey test) of all bar graph and boxplots were calculated and plotted using GraphPad Prism 7 or MATLAB R2020a. Chemdraw Ultra 12.0 was used for presenting chemical structures. Caseviewer was used to analyze immunohistological data. Adobe illustrator, Adobe photoshop, Rhinoceros 5, and Keyshot 5 were used for schematic illustrations of the Figures.

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](#)

The datasets generated during and/or analysed during this work are available from the corresponding author upon reasonable request.

Human research participants

Policy information about [studies involving human research participants and Sex and Gender in Research](#).

Reporting on sex and gender

N/A

Population characteristics

N/A

Recruitment

N/A

Ethics oversight

N/A

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](https://www.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

A minimum of 3 independent experiments were carried out for all in vitro and ex vivo studies in Figs. 2 and 3, and related supporting figures. 5 animals were employed for acute in vivo test, and 60 channels of electrodes for each materials sample are used for statistics in fig. 4. 6 animals were used for awake in vivo test, and 8 pairs of data set was used for power analysis in fig. 5. 2 seizure animals were used for in vivo demonstration of closed-loop in Fig. 6.

Data exclusions

No data was excluded from the manuscript.

Replication

In vivo animal experiments in Figs. 4 and 5 for quantified verification were carried out in quintuplicate minimally.

Randomization

Samples and animals were chosen at random for each experimental group.

Blinding

Investigators were not blinded to the experimental conditions, as knowledge of this information was essential to conduct the studies.

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

Antibodies

Antibodies used	Primary Antibodies: mouse anti-Iba-1 (Abcam, Cambridge, UK; 1:200), and rabbit anti-GFAP (Abcam, Cambridge, UK; 1:200) Secondary Antibodies: Cross-Adsorbed Secondary Antibody, anti-mouse Alexa Fluor™ 594 (Invitrogen, Waltham, MA, USA; 1:500) for GFAP, and Cross-Adsorbed Secondary Antibody, anti-rabbit Alexa Fluor™ 488 (Invitrogen; 1:500) for Iba1
Validation	All antibodies are commercially available and have been tested by the manufacturer. Vendors and catalog numbers are listed above and validation can be found there. Monoclonal Anti-Glial Fibrillary Acidic Protein (GFAP) antibody produced in mouse (clone G-A-5) (Abcam, Cambridge, UK) Manufacturer-validated to react with rat, human, and pig. Monoclonal Anti-Iba1 antibody produced in rabbit (clone GT10312) (Abcam, Cambridge, UK) Manufacturer-validated to react with mouse, human, rat.

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	Sparague Dawley rat (DBL, Cheongju, Republic of Korea), male, 6-8 weeks
Wild animals	None.
Reporting on sex	The study did not consider sex-based information
Field-collected samples	The study did not involve field-collected samples.
Ethics oversight	The Korea Institute of Science and Technology Institutional Animal Care and Use Committee (IACUC) approved the protocols used in this study (KIST-2021-12-159).

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