# Claims

1. A wearable device for non-invasive continuous glucose monitoring, comprising:

    - a sweat-interface substrate adapted to be applied on human skin and to collect sweat from the skin surface;

    - at least one interdigitated electrode (IDE) sensor disposed on or within the substrate, the IDE sensor configured to produce an electrical signal correlated to a glucose concentration in the collected sweat;

    - an electronic circuit operatively connected to the IDE sensor, the electronic circuit including an analog front-end for reading the sensor's electrical signal and a wireless transmitter for transmitting data; and

    - a power source integrated with the device to provide power to the electronic circuit;

      wherein the device is configured to continuously monitor glucose in sweat and wirelessly transmit glucose data for external processing or display.

2. The device of claim 1, wherein the IDE sensor is an enzymatic glucose sensor comprising an enzyme that selectively reacts with glucose to generate the electrical signal, the enzyme being immobilized on the interdigitated electrodes in a sensing layer .

3. The device of claim 2, wherein the enzyme is glucose oxidase (GOx) or glucose dehydrogenase (GDH), and the sensing layer further comprises a polymer or hydrogel matrix entrapping the enzyme and, optionally, a redox mediator to facilitate electron transfer .

4. The device of claim 1, wherein the IDE sensor is a non-enzymatic glucose sensor comprising a catalytic surface on the interdigitated electrodes that directly oxidizes glucose without biological enzymes, the catalytic surface including one or more of: metal nanoparticles, metal alloys, metal oxides, carbon nanostructures, or conductive polymers .

5. The device of claim 4, wherein the catalytic surface comprises a nanocomposite of a carbon material selected from graphene, laser-induced graphene, carbon nanotubes, or carbon ink, combined with metal particles selected from gold, platinum, palladium, copper, nickel, or combinations/alloys thereof , such that glucose is electrooxidized at the interdigitated electrodes at a reduced overpotential.

6. The device of claim 1, wherein the IDE sensor is configured to measure glucose via impedance, capacitance, or resonant frequency changes, rather than amperometric current, caused by the presence of glucose in sweat altering the dielectric or ionic properties of the medium between the interdigitated electrodes .

7. The device of claim 6, wherein the interdigitated electrodes are coupled to an oscillator or resonance circuit so that the device's measured resonant frequency or impedance spectrum shifts in response to glucose concentration changes in the sweat, thereby providing a glucose-dependent sensor signal .

8. The device of claim 1, wherein the IDE sensor comprises a hybrid sensing mechanism that combines enzymatic and non-enzymatic components or multiple transduction modes to detect glucose, optionally including a configuration wherein the device operates as a glucose fuel cell generating an electrical current from sweat glucose as a power source and sensor signal simultaneously .

9. The device of claim 1, wherein the interdigitated electrodes are formed with a geometry and dimensions selected from: (a) a finger spacing (pitch) between adjacent electrode digits in the range of 1 μm to 1 mm; (b) an electrode trace width in the range of 1 μm to 500 μm; (c) an electrode thickness or height in the range of 0.1 μm (thin film) up to 100 μm (thick plated or fiber electrodes); and (d) a finger length sufficient to cover a sensing area between 1 $mm^2$ and 25 $cm^2$, wherein the aspect ratio of length to gap is at least 5:1 to ensure overlapping electric fields.

10. The device of claim 1, wherein the interdigitated electrodes comprise materials selected from the group consisting of: gold, platinum, palladium, silver, copper, aluminum, carbon (graphitic or glassy carbon), printed carbon ink, graphene, graphene oxide or reduced graphene oxide, carbon nanotubes, MXene, conductive metal oxides, and conductive polymers, and wherein at least a portion of the electrodes may be coated with a secondary material (including any of the aforementioned or enzyme or mediator coatings) to enhance biocompatibility or catalytic activity .

11. The device of claim 1, wherein the sweat-interface substrate is a flexible polymer film supporting the IDE sensor and electronics, enabling conformal contact with skin.

12. The device of claim 1, wherein the sweat-interface substrate is a textile or fabric, and the interdigitated electrodes are formed by conductive fibers or threads integrated into the textile structure, thereby creating an embroidered or woven IDE sensor within a wearable fabric article .

13. The device of claim 1, wherein the sweat-interface substrate comprises a hydrogel layer or other absorbent material that adheres to the skin and accumulates sweat, the interdigitated electrodes being in fluid communication with the hydrogel such that

glucose in the hydrogel is sensed by the electrodes.

14. The device of claim 1, further comprising microfluidic channels or structures on or in the substrate that route sweat from at least one skin-contacting inlet or region to the location of the IDE sensor, thereby managing sweat flow and collection for the sensor .

15. The device of claim 14, wherein the microfluidic structures include one or more of: capillary channels of millimeter or sub-millimeter cross-section that guide sweat; hydrophilic porous materials or wicks to draw sweat into the device ; a defined volume chamber for sweat analysis; and vapor barriers or valves to reduce evaporation and control the refresh rate of sweat at the sensor.

16. The device of claim 14, wherein the microfluidic structures further include a means for measuring sweat rate or volume, including any of: a flow sensor, an optical or electronic sensor that detects how quickly a microchannel fills with sweat, or paired IDE structures wherein one acts as a reference or flow monitor by measuring impedance changes as sweat progresses through a channel.

17. The device of claim 1, further comprising one or more auxiliary sensors integrated into the patch for environmental or physiological parameters, wherein said auxiliary sensors are selected from: a temperature sensor for measuring skin or sweat temperature; a pH sensor for measuring sweat pH; a conductivity or electrolyte sensor for measuring sweat ionic strength (such as sodium or chloride concentration); a humidity sensor; or a motion/acceleration sensor.

18. The device of claim 17, wherein the auxiliary sensors include both a pH sensor and a temperature sensor, co-located with the glucose IDE sensor, to provide real-time pH and temperature readings of the sweat, enabling compensation of the glucose measurement based on these readings .

19. The device of claim 17, wherein the pH sensor comprises an interdigitated or planar electrode coated with a pH-sensitive material (such as an iridium oxide layer or a polymer containing pH-indicator groups), and the temperature sensor comprises either a resistive temperature detector, thermistor, diode, or thin-film transistor whose output reflects the local temperature.

20. The device of claim 1, wherein the analog front-end of the electronic circuit includes a transimpedance amplifier or potentiostat for converting sensor signals to a voltage, and a guard amplifier or guard electrode arrangement to maintain high input impedance by driving a guard at substantially the same potential as the sensing node, thereby reducing leakage currents and noise in the measurement.

21. The device of claim 1, wherein the electronic circuit further comprises an analog-to-digital converter (ADC) and a microcontroller or processor configured to

digitize the sensor signal and execute on-device processing of glucose data.

22. The device of claim 1, wherein the wireless transmitter is a Bluetooth or Bluetooth Low Energy module configured to broadcast or communicate the glucose data to a mobile device in real time.

23. The device of claim 1, wherein the power source is a flexible thin-film battery or a micro-battery attached to the patch, or a micro-supercapacitor integrated into the patch structure.

24. The device of claim 23, wherein the power source comprises a textile-integrated supercapacitor formed by conductive yarn or fabric coated with a high-capacitance material (such as MXene or graphene), which is capable of being charged and discharged to power the device .

25. The device of claim 1, further comprising a charging interface or energy harvester, wherein the device can replenish its power source via one or more of: a wireless inductive charging coil, a photovoltaic (solar) cell on the patch, a thermoelectric generator using body heat, or a connector for wired charging.

26. A system for non-invasive continuous glucose monitoring, comprising:

- the wearable device of claim 1; and

- a remote computing device in wireless communication with the wearable device, the remote computing device configured to receive glucose data from the wearable device and to perform processing and user interaction,

  wherein the system as a whole is configured to provide calibrated glucose readings and alerts to a user.

27. The system of claim 26, wherein the remote computing device is a smartphone running a companion application that receives the data via Bluetooth and displays current glucose values, historical trends, and alert notifications to the user.

28. The system of claim 26, wherein the remote computing device (or an associated cloud server) is programmed to execute a calibration algorithm that adjusts the received glucose data based on at least temperature and pH data from the wearable device, thereby outputting a compensated glucose reading that is substantially independent of sweat pH or temperature variations .

29. The system of claim 26, wherein the remote computing device is further configured to implement an alert system that generates an alarm when the glucose data indicates a glucose level outside a target range or a rate of change exceeding a threshold, and

wherein the user can customize alert thresholds via the application.

30. The system of claim 26, further comprising a drug delivery module operatively linked to the remote computing device, wherein the remote device, upon detecting a glucose level or trend, can trigger the drug delivery module to dispense a medication (such as insulin or another hypoglycemic agent) to the user, thereby forming a closed-loop or semi-closed-loop therapeutic system.

31. A method of continuously monitoring glucose levels non-invasively, comprising:

    - collecting sweat from a user's skin into a wearable patch containing an interdigitated electrode glucose sensor;

    - measuring an electrical response from the interdigitated electrode sensor that corresponds to a glucose concentration in the collected sweat;

    - measuring at least one additional parameter selected from sweat pH, sweat temperature, sweat rate, or sweat conductivity, concurrently with measuring the glucose sensor response;

    - calculating a glucose level by applying a calibration or compensation to the sensor's electrical response, the calibration accounting for the at least one additional parameter measured, to yield an estimate of blood-equivalent glucose concentration ; and

    - providing the glucose level to a user in real time via a display or an alert.

32. The method of claim 31, wherein collecting sweat comprises guiding sweat through a microfluidic structure to the glucose sensor, and the method further comprises mitigating evaporation of sweat during measurement by retaining sweat in an enclosed or semi-enclosed microfluidic channel or porous medium .

33. The method of claim 31, wherein measuring the electrical response includes performing one of: chronoamperometry by biasing the interdigitated electrodes at a fixed potential and recording current over time; open-circuit potential measurement of a potentiometric sensor; or impedance spectroscopy or frequency measurement of a resonant sensor.

34. The method of claim 31, wherein the at least one additional parameter includes sweat pH and temperature, and calculating the glucose level comprises applying a predetermined correction factor or algorithm that adjusts for pH and temperature effects on the glucose sensor's output .

35. The method of claim 31, further comprising measuring a second analyte in the sweat that is different from glucose, and using the second analyte to normalize or

cross-calibrate the glucose measurement.

36. The method of claim 35, wherein the second analyte is lactate, and the method includes comparing the glucose and lactate levels to distinguish physiological conditions (exercise vs. resting) or to adjust the glucose reading based on the metabolic context.

37. The method of claim 35, wherein the second analyte is a sweat electrolyte (sodium or chloride), and the method includes adjusting the glucose concentration based on sweat electrolyte concentration to account for sweat dilution or rate changes.

38. The method of claim 31, further comprising applying a time-weighted averaging filter or other smoothing algorithm to the sequence of calculated glucose levels to reduce noise and short-term fluctuations, thereby providing a stable trend to the user.

39. The method of claim 31, further comprising analyzing the glucose level over time to detect a rate of change, and if the rate of change exceeds a predetermined threshold (indicating rapidly rising or falling glucose), generating a proactive alert to the user prior to crossing of absolute glucose thresholds.

40. The method of claim 31, further comprising using a machine learning model to continuously recalibrate or improve the accuracy of the glucose readings, wherein the model learns from past sensor data and reference measurements to correct sensor drift and individual-specific factors .

41. The method of claim 31, further comprising transmitting the glucose level and associated data to a remote server or cloud service, and providing an authorized third party (such as a healthcare provider) access to the data for remote monitoring or analysis.

42. A composition of matter for glucose sensing in sweat, comprising:

    - an interdigitated electrode structure having a plurality of conductive fingers on a substrate; and

    - a functional layer disposed on at least a portion of the electrode structure,

      wherein the functional layer includes one or more of: (i) an enzymatic glucose recognition component comprising glucose oxidase or another glucose-specific enzyme immobilized in a polymer matrix ; (ii) a nanostructured catalyst comprising metallic or carbon-based nanomaterials that facilitate the electrochemical oxidation of glucose ; or (iii) a biosensing polymer that selectively binds glucose and transduces a change in electrical property;

      and wherein the composition is configured such that exposure to a glucose-containing aqueous sample (sweat) produces a detectable electrical

response from the interdigitated electrode structure.

43. The composition of claim 42, wherein the interdigitated electrode structure comprises a material selected from gold, carbon, graphene, or MXene, and the functional layer comprises a porous nanocomposite of said material with noble metal nanoparticles and a percolating network of enzyme or catalytic particles, yielding a high surface area, conductive, and glucose-reactive interface .

44. The composition of claim 42, wherein the functional layer further includes a hydrophilic polymer binder and optional cross-linkers to secure the active components on the electrodes, and optionally includes a perfluorosulfonated ionomer or other permselective membrane applied over the electrode to exclude interferents while allowing glucose diffusion.

45. The composition of claim 42, wherein the interdigitated electrode structure is integrated into a textile fiber or thread, and the functional layer is coated onto the textile-based electrode, forming an embroidered glucose sensor thread that can be woven or incorporated into wearable patches or garments .

46. A computer-readable medium storing program instructions which, when executed by a processor in a glucose monitoring system, cause the system to perform steps comprising:

    - receiving raw sensor data from a sweat-based glucose patch device, the data including at least a glucose sensor signal and auxiliary sensor readings for temperature and pH;

    - applying a calibration algorithm to the raw glucose sensor signal, the algorithm adjusting the glucose signal based on the auxiliary sensor readings to compensate for environmental conditions ;

    - executing a drift-correction routine that uses a machine learning model or historical data to correct any baseline drift or systematic error in the glucose sensor data ;

    - computing a current glucose value and a trend from the calibrated data (optionally using time-weighted averaging);

    - triggering an alert or notification if the glucose value crosses a defined threshold or if a predicted future value is outside a safe range; and

    - displaying or transmitting the computed glucose value and alerts to a user interface for viewing by the user.

47. The computer-readable medium of claim 46, wherein the program instructions further cause the system to perform dual-analyte analysis by concurrently processing a second set of sensor data corresponding to a secondary analyte (such as lactate or sodium) and normalizing or cross-referencing the glucose value with the secondary analyte to improve accuracy and context of the glucose measurement.

48. The computer-readable medium of claim 46, wherein the calibration algorithm includes a multi-point calibration that can be updated when the system receives a reference glucose input (such as a user-entered blood glucose value), and wherein the program adjusts future sensor readings based on the reference to reduce error.

49. The computer-readable medium of claim 46, wherein the program instructions include a closed-loop control module that, upon detecting a glucose reading above or below set limits, can generate a control signal to an insulin pump or drug delivery mechanism to administer a corrective dose, and further wherein safety checks and fail-safes are implemented to prevent over-delivery of medication.

50. A method of using a sweat-based glucose monitoring patch, comprising the steps of:

    - applying the wearable device of claim 1 to a skin site of a person;

    - initiating continuous monitoring such that the device collects sweat and measures glucose levels;

    - pairing the device with a mobile application on a smartphone or another receiver; and

    - managing a health condition based on the monitored glucose levels by observing the data and taking appropriate actions (such as consuming carbohydrates, administering insulin, or seeking medical help when alerted),

      wherein the use of the device provides glucose trend information and alerts without requiring invasive blood sampling, thereby enabling a non-invasive diabetes management regimen.

51. The method of claim 50, wherein the health condition managed is diabetes mellitus, and the method further comprises the step of adjusting insulin therapy in response to the continuously monitored glucose data, as well as sharing the glucose data with healthcare providers for review through the connected data system.

52. The method of claim 50, wherein the device is used during daily activities, exercise, and sleep to provide round-the-clock glucose monitoring, and the method includes replacing or recharging the patch according to a usage schedule while maintaining data continuity

via the system's calibration and data integration features.

53. The method of claim 50, wherein the device is used as part of a clinical study or personalized medicine program to gather detailed glucose profiles, the data being analyzed to gain insights into the user's metabolic responses and to tailor treatment recommendations.