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ИНОСТРАННЫЙ ЯЗЫК
(АНГЛИЙСКИЙ)

Проектирование и технология радиоэлектронных систем и комплексов

Методические указания для самостоятельной работы
студентов специальности 11.05.01

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ИНОСТРАННЫЙ ЯЗЫК (АНГЛИЙСКИЙ). Проектирование и технология радиоэлектронных систем и комплексов: Методические указания для самостоятельной работы / Санкт-Петербургский горный университет. *Сост. С.А. Бойко, Е.А. Кольцова..* СПб, 2022**.** 36 с.

Данные методические указания составлены для самостоятельной работы по дисциплине «Иностранный язык». Предлагаемый материал направлен на развитие навыков технического перевода, анализа оригинальной литературы по специальности, накопление и усвоение лексического материала в рамках профессиональной тематики и приобретение разговорных навыков по специальности.

Методические указания предназначены для студентов специальности 11.05.01 «Радиоэлектронные системы и комплексы», изучающих иностранный язык.

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ВВЕДЕНИЕ

Данные методические указания для самостоятельной работы по английскому языку предназначены для студентов специальности 11.05.01 «Радиоэлектронные системы и комплексы», специализация «Проектирование и технология радиоэлектронных систем и комплексов». Методические указания составлены в соответствии с учебной программой по дисциплине «Иностранный язык (английский» для формирования иноязычной профессиональной компетенции будущих специалистов.

Предложенные методические материалы предназначены для внеаудиторной работы студентов и состоят из пяти разделов, содержащих информацию о проектировании и технологиях радиоэлектронных систем и комплексов. Каждый текст сопровождается комплексом предтекстовых и послетекстовых заданий и упражнений, направленных на контроль понимания прочитанного материала, формирование умения ориентироваться в оригинальных научно-технических текстах, отработку и закрепление лексико-грамматического материала в устной речи, контроль навыков перевода.

Изучение предложенного материала имеет целью развитие и совершенствование навыков чтения и перевода оригинальной научной литературы по радиоэлектронным системам и комплексам, расширение словарного запаса и приобретение разговорных умений в сфере профессиональной деятельности.

UNIT 1 STRETCHABLE ELECTRONICS

TEXT 1.1 Manufacturing Methods and Mechanisms

1 Read and translate the text.

Mechanical buckling method (MBM) is often used to realize the wavy structural configuration on the surface of elastomeric substrates, making the stiff thin-film layer flexible and stretchable. Generally, brittle semiconductor materials (such as Si, GaAs, InP, lead zirconate titanate) and metals are made into wavy shape through MBM to achieve stretchability.

Recently, wave structures have been developed and extended from the traditional MBM film to arched structures. For example, a highly stretchable lithium-ion batteries (LIB) based on an arched structure could effectively accommodate large strain, but the areal capacity was only 0.11 m Ah cm^{-2}. The arched electrode could bear a 400% strain and exhibited stable electrochemical performances after 500 cycling tests, which are used in the fabrication of stretchable LIBs, and the final LIBs could also bear a 400% strain. The stretchability is nearly three times the maximal value of the stretchable devices based on the previous wavy methods. A simple method is used to fabricate fully stretchable LIBs based on a wavy shape at the battery device level, where all the components (include cathode, anode, separator and current collectors) and packaging were stretched equally for the first time. These stretchable LIBs showed a stretchability of 50%, and a high areal capacity of 3.6 m Ah cm^{-2}. The wavy structural stretchable device concept can be extended to new classes of flexible devices, representing promising directions for future research.

Another common and effective strategy for the manufacture of stretchable electronics is to develop island-interconnect configurations and mesh structures for enhancing the stretchability of functional devices. In this structural design, islands (fabricated from rigid materials) are interconnected by metal interconnections or other flexible bridges to achieve large and reversible deformation for strains applied on certain axes. These stretchable interconnects can be prepared by utilizing highly malleable/compliant electronic materials, such as low-temperature liquid metals, or by designing the interconnections to mitigate local strains through out-of-plane deformations (e.g. buckled devices, pop-up interconnections, and serpentine-shaped interconnection configurations). The shortcoming of out-of-plane structure is that it is difficult to implement in a rapid manufacturing process, such as roll-to-roll and printing. Therefore, an alternative method for the fabrication of stretchable interconnects is to use in-plane geometries for the conductors, e.g. stretchable line or zigzag, pulse, and horseshoe geometries. Recently, printed stretchable spiral interconnects have been fabricated by using reactive-ink chemistry; the printed 2D geometries could be changed as freestanding stretchable interconnects. Moreover, the stretchability could be effectively enhanced by the rational design of stretchable interconnects. For example, the stretchability of two serpentine-based and one spiral-based interconnects are comparative studied under the limitations of the same in-plane areas and contour lengths rooted from the same areal coverage and electrical resistance. The results revealed that the entanglement within a spiral helps to avoid elevation above the substrate; the spiral-based interconnects are much more stretchable than serpentine-based interconnects and can be stretchable up to 250% under elastic deformation and 325% without failure. The serpentine design of interconnects has been widely used for a variety of stretchable electronic systems, including epidermal electronics, skin-like temperature sensor and heater, stretchable battery, because serpentine structure design can enhance the capability to stretch interconnects in electronic systems. Further stretchability enhancement of the serpentine structures can be realized by allowing the structure to deform and buckle in the out-of-plane directions.

Based on the interconnect island mechanism, a good mesh structure can achieve a large and reversible level of stretchability, and the stretchability is often larger than 100%. For instance, materials and mechanical mesh design strategies offer extremely high stretchability for classes of electronic circuits, allowing accommodation of even demanding configurations such as corkscrew twists with tight pitch (e.g. 90° in ≈1 cm) and linear stretchingto ‘rubber-band’ levels of strain (e.g. up to ≈140%). In the future, progress will be made in mesh design, and materials using mesh and associated fabrication technologies will enable stretchable electronic devices with unconventional formats, with useful functions. [1]

2 Read and translate the following word combinations. Practice pronouncing them correctly.

Rigid materials, island-interconnect configurations, functional devices, electrochemical performances, areal capacity, arched structures.

3 Give the verbs corresponding to the following nouns:

Association, revelation, preparation, interconnection, exhibition, accommodation, extension, achievement, realization.

4 Work with a partner. Discuss the questions below.

- Why has the serpentine design of interconnects been widely used for a variety of stretchable electronic systems?
- What is the disadvantage of an out-of-plane structure?
- Which electrode can bear a 400% strain and exhibit stable electrochemical performances after 500 cycling tests?
- Why is the mechanical buckling method used?

5 Translate into Russian paying attention to the form of the verb-predicate in the Passive Voice.

1. Temperature and PAT data are displayed without reference data because these measurements are only periodically acquired with conventional devices. 2. The research protocol was approved by Northwestern University’s Institutional Review Board. 3. Sensors were placed on the skin without skin preparation for the neonate thereafter. 4. An additional example of skin-to-skin contact in a chest-to- chest position is shown in Fig. 7E, with the PPG EES on the upper limb to illustrate another option for placement. 5. In current clinical practice, measurements of skin temperature are typically limited to a single body location because of the need to minimize wired connections and adhesive interfaces to the skin 6. A primary antenna (32 cm × 34 cm; fig. S15) is connected to the host system, allowing for simultaneous transfer of RF power to the ECG EES and the PPG EES. 7. Calculated HR, SpO2, and RR from the experimental system are consistent with measurements obtained from gold-standard equipment operating concomitantly. [4]

TEXT 1.2 Stretchable conductors and electrodes

1 Translate the following word combinations.

Curvilinear surfaces, flocculation method, embedding fractal-structured, elastomer matrix, conductive polymers, carbon nanotubes, metal nanoparticles, stretchable conductors, integrated power sources, optical transparent properties.

2 Match the words to make collocations. Translate into Russian.

1 channel	**A** spectrum
2 millimeter	**B** waves
3 pilot	**C** system
4 signal	**D** estimation
5 spectral	**E** communication
6 terahertz	**F** scheduling
7 sensing	**G** contamination
8 user	**H** efficiency
9 terahertz	**I** detection

3 Scan the text to discover the right variant of mentioned above collocations.

There are a number of techniques for producing stretchable conductors. Existing stretchable conductors include electronic conductors, e.g. metal nanoparticles (NPs), Ag nanowires (NWs), Ag flakes, fractal Ag nanostructures, Cu NWs, carbon nanotubes (CNTs), graphene, serpentine-shaped metallic wires, conductive polymers and their composites. These conductive components are often used as fillers and arranged in the elastomer matrix while combining the structure design. For instance, we fabricated a flexible and stretchable conductor by embedding fractal-structured Ag particles into a PDMS substrate, which could stretch up to 100 %. Two stretchable conductors of polyurethane (PU) containing Au NPs are prepared by a layer-by-layer assembly method and a vacuum-assisted flocculation method, respectively. High conductivity and stretchability are observed in both composites. Liquid metal-based interconnects embedded into flexible polymer substrates are used as stretchable and highly conductive interconnects. The fabrication process is very simple and the as-prepared active devices showed a high fill factor. Ordered zigzag structures are used to prepare stretchable conductive tracks; their high stretchability comes from the synergistic effect of interpenetrating conductive networks of polymer gel and Ag NPs, and the zigzag structures.

As one of the most important conductive materials, Ag NWs have recently attracted a lot of attention for fabrication of stretchable conductors. Zhu's group carried out a pioneering work in this field. Ag NWs are drop-casted onto the surface of pre-cleaned substrates and then the liquid PDMS or other elastomers are casted on top of the Ag NWs film, and finally the PDMS or other elastomers are when it is cured. Moreover, Ag NWs are widely used as a thin film with percolation network embedded in elastic substrates. For instance, a photolithography process enables the fabrication of complex 3D interconnected patterns of Ag NWs networks embedded in PDMS, achieving stretchable microelectrodes with tailored electrical properties, low sheet resistances (down to 0.6 Ω/ sq), controllable gauge factors (ranging from 0.01 to 100), and good stretchability (above 50% uniaxial strain). The aspect ratios of Ag NWs play a critical role in the final electronic performance of flexible or stretchable electrodes. For instance, a highly stretchable metal electrode were fabricated by the solution-process method. The Ag NWs ware very long (> 100 μm), and hence the low-temperature sintering process ensured the formation of conductive networks. The resulting electrode simultaneously exhibited a high electrical conductivity (~9 Ω/sq) and mechanical compliance (strain > 460 %). Microscale structural design strategy is another effective method to improve the performance of Ag NWs-based stretchable electrodes, such as binary network structure design, constructing highly stretchable conductive fiber, etc.

CNT is another conventional nanomaterial tofabricate stretchable conductors by using tens of μm-to mm-long bundles and ropes of single-walled CNTs (SWCNTs) and multi-walled CNTs (MWCNTs). Similar to the Ag NWs, CNTs are often used as filler in the conductors; for example, SWCNTs were uniformly dispersed in a fluorinated rubber to construct elastic conductors, and MWCNTs were homogeneously dispersed in the poly [styrene-b-(ethylene-co-butylene)-b-styrene] triblock copolymers (SEBS) matrix to achieve superior stretchable conductors with a stretchability of more than 600 %.

However, with a few exceptions, CNT-based stretchable conductors provide modest conductive performance, require high concentrations of CNTs, are opaque, and their electrical conductivity declines significantly under stretching state. Multiple strategies are developed to realize CNTs-based stretchable conductors, such as wavy ribbons of CNTs, buckling of aligned CNTs, and well-aligned CNT ribbons embedded in PDMS.

Additionally, carbon materials and metal nanomaterials are also formed as hybrid composites to fabricate stretchable conductors. For instance, the resistance of hybrid Ag flakes/MWCNTs composite-based stretchable conductors is 5710 S cm^{-1} at the beginning and 20 S cm^{-1} at 140% strain. [1]

4 Translate the text above from English into Russian noticing the form of the verb-predicate in the Passive Voice.

5 Decide whether the statements are *TRUE* (T) or *FALSE* (F).

1. Zhu's group carried out a pioneering work in this field.
2. The resulting electrode simultaneously exhibited a low electrical conductivity (~9 Ω/sq) and mechanical compliance (strain > 460 %).
3. As one of the most important conductive materials, Fe NWs have recently attracted a lot of attention for fabrication of stretchable conductors.
4. Additionally, carbon materials and metal nanomaterials are also formed as hybrid composites to fabricate stretchable conductors.
5. Liquid metal-based interconnects embedded into flexible polymer substrates are used as rigid conductive interconnects.
6. Two stretchable conductors of polyurethane (PU) containing Au NPs are prepared by a layer-by-layer assembly method and a vacuum-assisted flocculation method, respectively.

6 Scan the text above and complete the sentences.

1) CNT is another conventional nanomaterial tofabricate …
2) The aspect ratios of Ag NWs play …
3) For instance, the resistanceof hybrid Ag flakes/MWCNTs …
4) Ag NWs are drop-casted onto the surface of pre-cleaned substrates …
5) Two stretchable conductors of polyurethane (PU) containing …
6) Microscale structural design strategy is …

UNIT 2 EDIBLE ELECTRONICS

TEXT 2.1 Conductors

1 Read and translate the following word-combinations. Practice pronouncing them correctly.

An incorporation of nanosized fillers, the sufficient robustness, the miniaturized fabrication, solid-state ionic conductors, biological doped polymers, the electrolyte-gating media, ion fluxes.

2 Read and translate the text.

There are many ionic conductors of natural origin that are of interest for edible electronics. Ionic conductivity represents a primary source of electrical conductivity in the natural world. To give an example, all types of biological systems use ion fluxes as an essential tool for signaling and communication. Ionic compounds represent an indispensable part of iontronic (bio) sensing and energy storage devices and can perform as the electrolyte-gating media for semiconductors or matrix for edible electrodes.

Ionic conductivity occurs due to the motion of anions and cations within the ion-solvating media. At the core of this phenomenon are electrolytic substances dissolved in a suitable solvent to give rise to mobile ions. Electrolytes come as acids, bases, salts, and even some biological doped polymers such as DNA or polypeptides.

Liquid and solid electrolytes can be distinguished. Despite the higher ionic mobility in liquid electrolytes with respect to solids, the implementation of the former in the operating device is limited by the unreliable liquid phase condition. In this case, solid-state ionic conductors potentially provide important advantages in terms of material stability and possibility of miniaturized fabrication down to the scale of thin films. Solid electrolytes are also appealing as they are solution processable, can be printed, and their sufficient robustness opens up opportunities for flexible and stretchable edible electronics. As an additional remark, in order to improve ionic conductivity of solid electrolytes, several approaches such as blending, plasticizing the electrolyte matrix, or incorporation of nanosized fillers in the structure, have been employed.

Electrolytic ionic conductors have been exploited in a number of edible electronics components and systems. Since mass flow in an electrolyte is subjected to complex frequency behavior, the frequency range of conductivity observation is an important parameter to be specified. Electrolytes in a form of hydrogels containing common NaCl salt have been introduced by Panhuis and coworkers as a promising conducting material for edible electrodes (with conductivity of 200 ± 20 mS cm^{-1} characterized at frequencies between 1 and 10^5 Hz). Hydrogels are considered appealing building blocks for ingestible and implantable devices, as their compliant, biocompatible, and mechanical properties closely match the characteristics of biological systems. The use of electrolytes has been also demonstrated in the domain of edible energy storage devices such as batteries, supercapacitors, and fuel cells. [2]

3 Work with a partner. Discuss the questions below.

- What represents ionic conductivity?
- What causes ionic conductivity?

4 Give the Russian equivalents of the following word combinations.

Charge screening effects; transfer-printing process; crystallinity; semiconducting and unsorted metallic; laminated and adhered; encapsulating; neutral mechanical plane; silicon nanoribbon.

5 Insert the appropriate form of the Participle.

1. In 2018, Nokia (to produce) a lightweight and power-efficient chipset for a massive MIMO antenna design, and it (to be) called ReefShark chipset. 2. To accommodate this massive user demand, various new MIMO technology like single-user MIMO (SU-MIMO), multi-user MIMO (MU-MIMO) and network MIMO (to be) developed. 3. Smartphones (to become) popular in the mid-2000s. 4. These types of networks (to be) referred to as 3.5G networks and they (to provide) data rates up to 2 Mbps. 5. Before the introduction of MIMO, single-input-single-output systems (to be) mostly used, which (to have) very low throughput and could not support a large number of users with high reliability. 6. Since the Massive MIMO concept (to be) introduced a few years ago, it has gained new heights every year. [5]

6 Fill in the gaps using the words in the box. Translate the text.

modules	neural	wireless	feasibility	algorithm	tools

CNN combined with a projected gradient descent algorithm that demonstrates the **1** _____ of using machine learning methods in channel estimation. Deep neural network (DNN) architecture to modify the **2** ______ at the base station and UE's. Deep learning-based channel estimation for various scenarios have been presented in Reference, and the results were like those of the optimal MMSE **3** _____. The recurrent **4** _____ network (RNN) is a powerful tool to solve this time series learning problem. Since CSI estimation has distant data, simple RNN tools are less efficient in predicting the distant data in **5** _______ communication. During channel estimation, channel data can be considered as big data, and several machine learning **6** ______ can be used to predict massive MIMO channels. [5]

7 Translate into English using the appropriate form of the Participle.

1. По своей природе тонкие, мягкие механические свойства датчиков, учитывали адгезию только за счет сил Ван-дер-Ваальса. 2. Эффективные модули в диапазоне от 200 до 300 кПа приводили к минимальным нормальным напряжениям и напряжениям сдвига на границе раздела кожи. 3. Механическая развязка, обеспечиваемая микрожидкостным каналом, снижала эти напряжения в 2,5 раза. 4. Экспериментальные и теоретические исследования раскрыли дополнительные фундаментальные аспекты мягкой механики и адгезии в этих системах. 5. Микрожидкостный канал снизил эффективный модуль EES и, как следствие, увеличил способность устройства деформироваться под действием приложенной силы. 6. Эти датчики удовлетворили потребности отделения интенсивной терапии из-за их высокой механической податливости и неинвазивного контакта с кожей. 7. В дополнение к расширенным возможностям мониторинга кожные профили и полностью беспроводные режимы работы предложили прямую терапевтическую ценность, уменьшив барьеры для контакта кожи с кожей между родителем и ребенком. [4]

TEXT 2.2 Systems Approbation

1 Read and translate the following text. Make up plan of the text.

Edible electronics stands in between two distant fields. It imposes, from one side, to examine the device components as food (or drug) suitable for the human administration, with the previously mentioned constraints, while on the other hand, as an electronic device that necessitates all the certifications imposed by competent organs. Therefore, edibility is not a sufficient condition that allows automatically a faster path through market certifications, and if designed for diagnosis and treatment tools the directive for medical devices operation must be followed.

Two of the most important organs dealing with the medical devices safety regulations are Food and Drugs Administration (FDA) and the European Union with the "Regulation (EU) 2017/745 on medical devices" that act promulgating regulations and guidelines to be observed for commercialization of products. These organizations provide a precise device classification that allows identifying the risks at which the patient is subjected during the medical system operation, and consequently providing appropriate safety protocols. Both FDA and EU-entity take advantage from a similar three classes system, from I to III, which with some differences passes from harmless passive devices designed for wearable external use, to invasively implanted devices potentially dangerous for the patient life, with requirements in terms of approbation and handling protocols becoming the more stringent, the higher the class is.

It is worth mentioning that approbation of a system composed of edible components is not obvious. Definition of edible electronics implies the occurrence of device ingestion, transfer ring it inside the gastrointestinal (GI) tract. This event could force both FDA and EU regulation to consider edible electronics systems as semi-invasive medical devices operating inside the body (class II or higher), also the ones meant to operate out of the body, which in the standard electronics context are often defined as class I. Moreover, edible devices embedding animal tissues or their derivatives also represent another characteristic example: despite their edibility should guarantee against toxicity and retention problems, they could be classified by the rule 18 of the EU lex automatically as a class III device, the one with the highest risk. Therefore, edibility of used materials *per se* does not guarantee a simplified approbation process for the device. The authority organs are extremely precise and in constant optimization, but for obvious reasons have not yet regulated the field, because of its novelty and lack in benchmark. A model that has set a precedent is Abilify MyCite from Proteus, the first ingestible medication system approved by FDA. It represents, to the best of our knowledge, the first example of an ingestible sensor also approved as a drug, despite embedding components commonly not considered as edible.

An essential principle of building an edible electronic platform is to envision separate functional electronic elements enabling the targeted final system. Depending on the nature of the function to be fulfilled, fundamental electronic building blocks are classified into passive and active ones.

Passive components such as resistors, inductors, and capacitors are ubiquitous in electronic design. Examples of edible passive components made out of food-based nutritive materials have been proposed by Jiang and coworkers. The authors realized edible resistors and inductors utilizing sweet potato starch and carbonized cotton candy, and capacitors from gelatin and edible gold. The characteristic values of resistance, inductance, and capacitance achieved are in the order of kΛ, mH, nF, respectively. Due to the variable flat to bent resistance (11.7 to 59 kΛ), such CB-based passive components may find application as strain sensors. Moving toward "Do-It-Yourself" electronics, the same group proposed to combine the inkjet printing of the carbon ink with the screen-printing of egg white (albumen) in order to fabricate edible capacitors. Transistors are key components in any circuit and are also a testbed for electronic properties of semiconductors, in particular, charge carrier transport.

Among these, thin film fieldeffect transistors are among the mostly studied architecture in large-area and flexible electronics, and are therefore one of the most obvious options also for edible transistors.

Significant contribution to the sector of edible field-effect transistors (FETs) has been made by Siegfried Bauer and collaborators, who reported the first potentially edible FET configurations exploiting various nature-derived and commodity materials, ranging from food to edible metals. The biodegradable, bioresorbable, and, in perspective, metabolizable transistors they demonstrated the possibility to achieve attractive electronic properties, such as an operational voltage as low as 4 V and a current on-off ratio up to five orders of magnitude. [2]

2 Answer the following questions.

- What are the two most important authorities responsible for the medical devices safety regulations?
- What is an essential principle of building an edible electronic platform?

3 Match the words to make collocations. Translate into Russian.

1 rigid	**A** platforms
2 measurement	**B** processing
3 radio-frequency	**C** system
4 signal	**D** imaging
5 baseline	**E** hardware
6 sensor	**F** interfaces
7 x-ray	**G** modules
8 binodal	**H** link
9 conventional	**I** modulation

4 Translate into Russian. Find the Participle II.

1. Calculated HR, SpO2, and RR from the experimental system were consistent with measurements obtained from gold-standard equipment operating concomitantly. 2. The other data presented here were collected from this same set of neonates. 3. The placement of the sensors was performed by research staff and/or NICU-trained nurses. 4. By eliminating wired connections, these platforms also facilitated therapeutic skin-to-skin contact between neonates and parents, which was known to stabilize vital signs, reduce morbidity, and promote parental bonding. 5. Data were transmitted, collected, and stored for further data analysis on a tablet PC. 6. Additional advances were needed to meet the challenging requirements of the NICU, where comprehensive, continuous sensing with wireless functionality, clinical-grade measurement fidelity, and mechanical form factors that eliminate risk of harm to exceptionally fragile neonatal skin were essential. [4]

UNIT 3 NANOMATERIALS IN SKIN-INSPIRED ELECTRONICS

TEXT 3.1 Skin-like Conductors

1 Read and translate the following word-combinations.

The fuorine rubber, the transmission electron microscopy, the vacuum-assisted flocculation, the layer-by-layer deposition, self-organized pathways, elastomeric fibers, the stretchable composite material, low-power multifunctional wearables, large-scale sensing circuits.

2 Read and translate the text.

Providing efficient power and data transfer for large-scale sensing circuits and displays depends on the conductivity and transparency of stretchable conductors, which are critical in low-power multifunctional wearables. Such requirements should be maintained under deformation. To address these issues, Park demonstrated the use of a stretchable composite material of silver (Ag) nanoparticles (NPs) and electrospun poly (styrene-block-butadiene-block-styrene) (SBS) elastomeric fibers. The $Ag+$ absorbed in SBS was reduced by a solution of hydrazine hydrate, resulting in AgNPs formation on the surface of an SBS substrate. The conducting composite could be stretched by up to 100% strain while maintaining a high conductivity of 2200 S/ cm. To achieve higher conductivities, Kim reported self-organized pathways in stretchable gold nanoparticle (AuNP) composites that were fabricated by two methods: (i) layer-by-layer (LBL) deposition and (ii) vacuum-assisted flocculation. Aligned AuNPs in a strained polyurethane (PU) polymer matrix were visualized by transmission electron microscopy (TEM) analysis. The aligned AuNPs enabled the composite films to be highly conductive ($5 \times$ LBL, 2400 S/cm; $5 \times$ VAF, $\sim$35 S/cm) at high strains ($5 \times$ LBL, $\sim$110% strain; $5 \times$ VAF, $\sim$480% strain). The results of Kim suggest that the dynamic behavior of the polymer may enable conducting nanomaterial-based composites to achieve higher stretchability and conductivity. Matsuhisa observed in situ formation of AgNPs from microscale Ag flakes in a fluorine rubber. The number of AgNPs was controlled by applying surfactant to the composite precursor. Interestingly, the AgNPs were aligned along the direction of the applied tensile strain, improving its conductivity (935 S/cm under 400% strain).

Despite the remarkable performance of such dynamic composites, the challenge in long-term wearability remains. Miyamoto developed gas permeable and stretchable conducting nanomesh. The stretchable nanomesh was fabricated by first electrospinning the nanomesh and then evaporating Au thin film (thickness of 70−100 nm) onto the nanomesh. The nanomesh was attached onto skin by laminating the nanomesh onto skin and then spraying water to dissolve the PVA layer. The nanomesh did not cause any inflammation owing to its mesh structure, which allows thorough transmission of sweat. This conducting nanomesh enabled a reliable recording of electromyograms (EMGs).

Development of high-performance transparent stretchable conductors is critical to realize skin-like optoelectronic devices. Work by Lipomi and Jin suggested that understanding morphological changes of strained one-dimensional (1D) nanostructure networks would be key for satisfying both stretchability and transparency simultaneously. Lipomi fabricated transparent (>79%) and stretchable (2200 S/cm under 150% strain) carbon nanotube (CNT) networks supported on elastomeric substrates. As a key process to enable electrically and mechanically durable electrodes, a buckled structure was induced through straining the CNT electrode. Stable resistance is maintained as long as the subsequent strain is less than the initial strain. Jin successfully devised a model to predict the change in resistance of CNT electrodes as a function of tensile strain during multiple cycles of stretching and releasing using coarse-grained molecular statics simulations, which matched well with those of the experimental results. According to their analysis, the resistance-strain hysteresis of the CNT network originated from both sliding between CNTs and buckling of CNTs during stretching and releasing processes. In addition to CNTs, Liang embedded Ag nanowire (NW) networks into a PUA polymer matrix to fabricate transparent (>90%) and conductive stretchable (15 Ω/sq under 20% strain) electrodes, which showed reliable stretching cyclic durability in the range of 20% strain. [3]

3 Discuss these questions with a partner.

- What are the requirements for deformation?
- Who developed gas permeable and stretchable conducting nanomesh?
- How is stable resistance maintained?

4 Translate into Russian noticing Modal Verbs.

1. Further reductions **can** be achieved by the addition of perforations through the open regions of the EES platform, as shown in fig. S20 for different patterns of holes. 2. Commonly used electrodes for this purpose **may** require additional adhesives that further increase the risk of skin injury. 3. The wireless users have increased exponentially in the last few years, and these users generate trillions of data that **must** be handled efficiently with more reliability. 4. Further clinical validation and testing **may** lead to broad adoption in both high-resource and low- resource settings. 5. These devices **can** gently and non-invasively interface onto the skin of neonates with gestational ages down to the edge of viability. 6. To improve overall system performance, a certain amount of fairness **must** be ensured among all the users. 7. Existing monitoring systems for the NICU require multiple electrode/sensor interfaces to the skin, with hardwired connections to separately located base units that **may** be stand-alone or wall-mounted, for heart rate, respiratory rate, temperature, blood oxygenation, and blood pressure. 8. We report the realization of this class of NICU monitoring technology, embodied as a pair of devices that, when used in a time-synchronized fashion, **can** reconstruct full vital signs information with clinical-grade precision. [4]

5 Match the following English terms with the Russian equivalents.

1	cellular frequencies	**a**	распределение ресурсов
2	wireless access technology	**b**	наноразмерные антенны
3	hardware impairments	**c**	конструкция приемопередатчика
4	energy efficiency	**d**	голографическое радио
5	machine learning	**e**	энергоэффективность
6	beamforming data	**f**	квантовая связь
7	resource allocation	**g**	неисправности оборудования
8	quantum communication	**h**	машинное обучение
9	transceiver design	**i**	сотовые частоты
10	holographic radio	**j**	данные формирования диаграммы направленности
11	nano-array antennas	**k**	технология беспроводного доступа

TEXT 3.2 Skin-like Sensors and Integrated Circuits

1 Read and translate the following words and word-combinations.

The fuorinated elastomer, composite nanofibers, the resistive pressure sensor, the polylactic acid polymer, the piezoelectric patch, the carbon nanotube, the elastomeric layer, the stretchable capacitive sensor, human-machine interfaces, conductive nanomaterials, wearable machines.

2 Read and translate the text.

Stretchable sensors have become essential modules in skin-inspired electronic systems as they enable interactive communication with wearable machines by sensing external stimuli and delivery of feedback information. Specifically, strain-tolerant conductive nanomaterials are key enablers of high-performance human-machine interfaces. Lipomi fabricated transparent and stretchable capacitive sensor arrays (64 pixels), in which a thin elastomeric layer was embedded in between top and bottom carbon nanotube (CNT) electrodes. Lipomi suggested an optimum nanomaterial strategy to keep a balance between transparency and sensitivity, even under high strains. Lim developed a transparent and stretchable piezoelectric patch by embedding CNTs in a polylactic acid (PLA) polymer sandwiched between top and bottom graphene layers. Strain/pressure sensitivity of the patch was improved by incorporating CNTs with high mechanical strengths, which resulted in significant increases in piezoelectricity of the PLA films when bent. In addition to capacitive and piezoelectric sensors, Lee fabricated a resistive pressure sensor based on electrospun conducting composite nanofibers, which consisted of CNTs, graphene, an ionic liquid, and a fluorinated elastomer. The ultrathin and nanoporous structure of the nanofiber network resulted in high pressure sensitivity ($>10^6$) and high transparency (>90%) with the ability to decouple from pressure-induced strains, and the nanofiber network was successfully integrated with an organic multiplexed array for large-area pressure-sensing capabilities. As another methodology for strain-insensitive strategies, Zhu devised a stretchable strain-suppression CNT circuit that is capable of sensing temperature accurately (∼1 °C under 60% strain). The realization of the strain suppression performances driven by static and dynamic differential circuits is noteworthy compared to those of other stretchable temperature sensors. However, compared with the production technology of and infrastructure for silicon electronics, current fabrication of intrinsically stretchable electronic devices requires significant improvement. Remarkably, Wang recently developed an intrinsically stretchable high-density transistor array (347 transistors per cm^2) with strain-insensitivity (0.99 $cm^2\ V^{-1}\ s^{-1}$ under 100% strain) and high yield/uniformity (average of $0.821 \pm 0.105\ cm^2\ V^{-1}\ s^{-1}$) performances by virtue of adopting intrinsically stretchable conjugated semiconducting polymer films (CONPHINE), photopatterned azide-cross-linked SEBS/PU dielectrics, and stretchable CNT electrodes. Future stretchable skin-like electronic systems would benefit from the development of intrinsically stretchable devices ranging from individual transistors to complex circuits. For practical applications of skin-like devices, individual electronic components have been integrated into multifunctional system platforms. Continuous efforts have resulted in the development of self-healable devices that can recover their performances even after incidental damages, paving the way toward the realization of robust skin-like electronic systems. Therefore, we include advances in self-healable skin-like electronic systems that are able to sense various stimuli and to deliver feedback information to the users, despite being subjected to repeated damage. Tee fabricated an autonomous, self-healable conductive composite composed of a supramolecular hydrogen-bonding network modified from a thermoplastic material. Cordier developed and nanostructured micronickel (μ-Ni) particles. Here, the key enablers for the mechanical and electrical self-healing performances were the hydrogen-bonding network in the self-healing polymer and the nanostructured surface of μ-Ni, respectively. Specifically, the low glass transition temperature (T_g) of the polymer enabled the conductive composite to self-heal under ambient temperatures. [3]

3 Decide whether the statements are *TRUE* (T) or *FALSE* (F).

1) For practical applications of skin-like devices, individual electronic components have been integrated into multifunctional system platforms.
2) Strain/pressure sensitivity of the patch was improved by incorporating SEBS with high mechanical strengths.
3) Specifically, strain-tolerant conductive nanomaterials are key enablers of high-performance human-machine interfaces.

4 Match the following English terms with the Russian equivalents.

1	dissimilar materials	**a**	металлические нанопроволоки
2	high-throughput manufacturing	**b**	плоские конструкции
3	stretchable conductors	**c**	эластомерная матрица
4	heterogeneous integration	**d**	криволинейные поверхности
5	planar structures	**e**	проводящие полимеры
6	metal nanowires	**f**	высокопроизводительное производство
7	conductive polymers	**g**	гетерогенная интеграция
8	elastomer matrix	**h**	фрактальный дизайн
9	fractal design	**i**	разнородные материалы
10	curvilinear surfaces	**j**	растягиваемые проводники

5 Translate into Russian noticing Modal Verbs.

1. These high-frequency bands are costly, and wireless carriers will **have to** pay millions to get this high-frequency spectrum. 2. Thus a base station centric architecture **might** evolve into a device-centric architecture in future networks to overcome challenges like network densification and increased frequency bands. 3. This chipset **could** reduce the massive MIMO antenna size to half, and it has been considered as one of the promising technology for Massive MIMO deployment. 4. Any bidirectional system thus **has to** separate the uplink and downlink channel using time or frequency domain to get orthogonal non-interfering signals. 5. Efficient wireless access technology that **can** increase throughput without increasing the bandwidth or densifying the cell is essential to achieve the ongoing demands faced by 5G. 6. Overall, the reliable connection and higher data are always good to have, but you **have to** pay some extra bucks to use massive MIMO technology. 7 The third factor, which **can** improve area throughput, that is, spectral efficiency, has remained mostly untouched and unchanged during this rapid development and growth of the wireless network. 8. Since there are a limited number of antennas in the massive MIMO base station, user scheduling **has to** be performed if the number of the users is more than the number of antenna terminals at the base station. 9. Samsung also demonstrated that massive MIMO **could** provide simultaneous high-speed video streaming without delay in a crowded place by experimenting at a crowded stadium in South Korea. [5]

UNIT 4 NANOELECTRONICS

TEXT 4.1 Semiconductors in Nanotechnology

For the past several decades, scientists have been experimenting with the potential benefits that nanomaterials, particularly carbon nanotubes, could offer semiconductors. As researchers develop methods to further reduce the size of semiconductor materials, dramatic improvements in the physical and chemical properties of these materials continue to arise. Minimizing the size of semiconductor materials has been shown to maximize the performance of semiconductors for their application in a wide range of material applications.

The quantum size effect (QSE) arises as a result of the increased quantum confinement of the electrons and holes following the increased reduction in size of small crystalline structures, such as that which occurs during the nanoscaling of semiconductor materials. Nanomaterials affected by QSE exhibit changes in their electronic structures, which results in an intermediate molecular size that falls between the size of a molecule and its bulk material. When present in this intermediate state, the individual energy density of states (DOS) of valence and conduction bands in metals and semiconductors undergo a unique transformation that leads to the spatial enclosure of charge carriers within these structures.

As a result of the electron structural changes that arise from QSE, dramatic modifications from the physical properties of bulk materials can be demonstrated by manufactured nanomaterial. By manipulating the size and shape of these intermediate atoms, researchers are able to adjust the energy and optical transitions of nanoengineered semiconductor materials. For example, by modifying the electronic energy state, researchers can adjust the light emission capable of passing through these nanoparticles to be within the ultraviolet, visible, near-infared and/or mid-infared spectral ranges, depending on the desired application of the material.

Bulk semiconductors are typically characterized by their different composition-dependent bad gap energy (E_g) values. E_g represents the minimum amount of energy required to excite a ground state electron to reach the vacant conduction energy band. Nanoscale semiconductors often exhibit a widened band gap that provides these materials with a unique chemical stability at high operating temperatures.

This thermal stability therefore provides a wide range of advantages to systems equipped with nanoscale semiconductors, especially when compared to similar silicon-based devices. For example, electronic systems can eliminate the need for excess wires, connectors or cooling systems that would previously have been needed to cool systems in the event that temperatures rise. Many systems, especially those involving fuel combustion, high-temperature manufacturing and drilling processes, can benefit by improving the reliability of their performance in the presence of these extremely high temperatures.

The elimination of these excess materials, which would otherwise increase the size, weight and overall complexity of the system, significantly improves thermal management. Within the aerospace industry, minimizing the weight of electronic systems plays a crucial role in determining the overall reliability of these systems during operation. By improving high-temperature capabilities of aircrafts, electronic control of engines, which can reach to temperatures of up to 600 °C, they can be better maintained to ensure passenger safety.

While this modification in the physical properties of nanomaterials has allowed for the development of increasingly strong materials, such as graphene, material chemistry researchers often struggle with the ability to determine the correlation between the physical properties that may arise with each newly created physical dimension. To this end, each component of a nanostructure must be carefully scaled in order to achieve the perfect combination of material compositions and length scales that will be appropriate for the final product of interest.

1 Study the text and find the English equivalents to the following words and word combinations:

значительные улучшения, сокращать размер полупроводников, химические свойства, производительность полупроводниковых устройств, применение / использование, материал подложки / основной материал, подвергаться изменению, носитель заряда, регулировать световое излучение, объемный полупроводник, энергетическая зона (в полупроводниках), играть важную роль, определять надежность.

2 Read the text and answer the following questions using the words and phrases from exercise 1:

1. How does the size reduction benefit semiconductors?
2. What is the main benefit of Quantum Size Effect (QSE)?
3. What are bulk semiconductors?
4. What are the key advantages of nanoscale semiconductors compared to other types of semiconductors?
5. What challenges do researchers face when working with nanoscale semiconductors?

3 Translate the following sentences from the text into Russian commenting on the functions of –ing forms.

1. Minimizing the size of semiconductor materials has been shown to maximize the performance of semiconductors for their application in a wide range of material applications.
2. By manipulating the size and shape of these intermediate atoms, researchers are able to adjust the energy and optical transitions of nanoengineered semiconductor materials.
3. Within the aerospace industry, minimizing the weight of electronic systems plays a crucial role in determining the overall reliability of these systems during operation.
4. Many systems, especially those involving fuel combustion, high-temperature manufacturing and drilling processes, can benefit by improving the reliability of their performance in the presence of these extremely high temperatures.

4 Prepare a 3-minute talk covering different types of semiconductors and the domains of their application.

TEXT 4.2 Using Graphene to Increase the Bandwidth of Telecommunications

Following optical communication's pivotal role in the internet age, it is expected to be similarly central for the evolution of 5G networks. Contemporary communications are reliant on optical links, with the ability to transfer information at the speed of light, and circuitry, including photodetectors and modulators, which is capable of encoding vast quantities of data into these light beams.

Despite the popularity of silicon as a material for photonic waveguides on optical chips, due to its transparency at standard telecomm wavelengths, photodetectors are being made from alternative semiconductors such as GaAs, InP or GaN. Attempting to integrate these semiconductors with silicon is tricky, causing complications in fabrication processes and leading to increased costs. In addition to this, as photonic devices are simultaneously shrinking in size while growing in power usage, thermal management is now becoming an issue.

Graphene Photodetectors

As graphene is able to absorb light over a broad bandwidth, including at standard telecomm wavelengths, it demonstrates great potential for telecomm photodetectors. In addition to this, thanks to its compatibility with CMOS technology, graphene can be integrated with silicon photonics. Finally, as an excellent heat conductor, graphene can guarantee lower heat consumption in photonic devices. These factors have resulted in a high level of research into graphene for optical communications, which is now succeeding in developing full working prototypes.

The earliest graphene photodetectors were transistor-based and were developed at an IBM research lab in 2009. They had bandwidths higher than 25 GHz and consequently, were used to transfer data over a 10 Gbit s^{-1} optical data link. The use of an asymmetrical metal-graphene-metal transistor configuration helped to improve the efficiency of detection in those instruments. According to analysis, the bandwidth of graphene photodetectors of this type could eventually pass 500 GHz.

In 2013, a fruitful year for graphene photodetector results, a number of teams announced graphene photodetectors of a variety of geometries, making use of differing physical principles, and resulting in CMOS-compatible photodetectors that covered all communication bands up to 18 GHz. In each of these developments, graphene had been placed directly on top of silicon waveguides, allowing light to be absorbed as it disseminated down the waveguide. These were the first graphene photodetectors to be truly CMOS-compatible.

In 2016, using graphene/silicon pn junctions with potential bit rates of ~90 Gbit s^{-1}, the bandwidth of graphene photodetectors hit 65 GHz. Just a year later, in 2017, graphene photodetectors with a bandwidth exceeding 75 GHz were manufactured in a 6” wafer process line. Visitors were then able to experience the planet’s first all-graphene optical communication link, operating at a data rate of 25 Gbit s^{-1} per channel, as the record-breaking devices were demonstrated at the 2018 Mobile World Congress in Barcelona.

For this demonstration, the active electro-optic operations were carried out on graphene devices, with a graphene modulator processing the data on the transmitter side of the network and converting the electronic data stream to an optical signal. A graphene photodetector did the reverse on the receiver side, decoding the optical modulation into an electronic signal. These devices, displayed at the Graphene Pavilion, were formulated with Graphenea CD graphene.

Ericsson also used this show to exhibit the first graphene-based optical ultrafast interconnection in mobile access, with a graphene-based photonic switch. If in recent years, high costs have previously been a hurdle in the embrace of graphene technology, this is no longer the case.

With the ability to minimize costs while providing integration with existing technology, and the further potential for fast optical networks that are more energy-efficient than semiconductor photonic-based networks, it is easy to see why graphene-based integrated photonics are seen as a vital area for future growth.

1 Read and translate the text above. Summarise the major benefits of graphene photodetectors.

2 Skim the text and find the sentences containing the passive voice forms. Translate the sentences into Russian.

UNIT 5 TRANSMITTERS

TEXT 5.1 Overview of Radar Transmitter

The radar transmitter produces the short duration high-power rf pulses of energy that are radiated into space by the antenna. The radar transmitter is required to have the following technical and operating characteristics:

- The transmitter must have the ability to generate the required mean RF power and the required peak power.
- The transmitter must have a suitable RF bandwidth.
- The transmitter must have a high RF stability to meet signal processing requirements.
- The transmitter must be easily modulated to meet waveform design requirements.
- The transmitter must be efficient, reliable and easy to maintain and the life expectancy and cost of the output device must be acceptable.

One main type of transmitters is the keyed-oscillator type. In this transmitter one stage or tube, usually a magnetron produces the rf pulse. The oscillator tube is keyed by a high-power dc pulse of energy generated by a separate unit called the modulator. This transmitting system is called POT (Power Oscillator Transmitter). Radar units fitted with a POT are either non-coherent or pseudo-coherent.

Power-Amplifier-Transmitters (PAT) are used in many recently developed radar sets. In this system the transmitting pulse is caused with a small performance in a waveform generator. It is taken to the necessary power with an amplifier following (Amplitron, Klystron or Solid-State-Amplifier). Radar units fitted with a PAT are fully coherent in the majority of cases.

1 Read and translate the text above. Explain the meaning of the following terms and give their Russian equivalents:

a radar transmitter, RF bandwidth, a keyed-oscillator transmitter, a power oscillator transmitter, a power-amplifier-transmitter, a solid-state amplifier.

2 Translate the following sentences in English paying special attention to grammar

1. Передающим устройством (передатчиком) называется устройство, предназначенное для создания колебаний высокой частоты требуемой мощности и излучения в пространство этих колебаний в виде электромагнитных волн.
2. Передающее устройство радиолокатора генерирует короткие высокочастотные импульсы высокой мощности.
3. Передатчик должен иметь соответствующую высокочастотную полосу пропускания.
4. Передатчик должен быть легко модулируемым и соответствовать требованиям к форме импульса.
5. Передатчик должен генерировать радиочастотную энергию с достаточной стабильностью частоты для дальнейшей обработки сигнала.
6. Передатчик должен быть эффективным, надежным и простым в обслуживании, иметь длительный срок службы и быть рентабельным.
7. Передающие устройства строят по двум основным схемам: однокаскадные передающие устройства («мощный автогенератор») и многокаскадные передающие устройства («задающий генератор-усилитель мощности»).
8. Разработка многокаскадных радиопередающие устройства оказалась возможной благодаря созданию мощных усилительных приборов: пролётных клистронов, мощные лампы бегущей волны (ЛБВ), амплитронов и др.

3 What types of transmitters do you know? Make a brief talk covering the major types of transmitters and their key features.

TEXT 5.2 Magnetron

The magnetron is a high-powered vacuum tube that works as a self-excited microwave oscillator. Crossed electron and magnetic fields are used in the magnetron to produce the high-power output required in radar equipment. These multi-cavity devices may be used in radar transmitters as either pulsed or CW oscillators at frequencies ranging from approximately 600 to 95,000 megahertz. The relatively simple construction has the disadvantage that the Magnetron usually can work only on a constructively fixed frequency.

The magnetron is classed as a diode because it has no grid. The anode of a magnetron is fabricated into a cylindrical solid copper block. The cathode and filament are at the centre of the tube and are supported by the filament leads. The filament leads are large and rigid enough to keep the cathode and filament structure fixed in position. The cathode is indirectly heated and is constructed of a high-emission material. The 8 up to 20 cylindrical holes around its circumference are resonant cavities. A narrow slot runs from each cavity into the central portion of the tube dividing the inner structure into as many segments as there are cavities. Each cavity works as a parallel resonant circuit. The rear wall of the structure of the anode block may be considered to as the inductive portion (a coil with a single turn). The vane tip region may be considered as the capacitor portion of the equivalent parallel resonant circuit. The resonant frequency of a microwave cavity is thereby determined by the physical dimension of the resonator. If a single resonant cavity oscillates, then it excites the next one to oscillate too. This one oscillates at a phase delay of 180 degrees and excites the next resonant cavity, and so on. From a resonant cavity to the next always occurs this delay of 180 degrees. The chain of resonators thus forms a slow-wave structure that is self-contained. Because of this slow-wave structure, this design is also-called "Multicavity Traveling Wave Magnetron" in some publications.

Transient oscillation

After switching the anode voltage, there is still no RF field. The single electron moves under the influence of the static electric field of the anode voltage and the effect of the magnetic field. Electrons are charge carriers: during the flyby at a gap, they give off a small part of the energy to the cavities. (Similar to a flute: A flute produces sound when a stream of air is flowing past an edge of a hole.) The cavity resonator begins to oscillate at its natural resonant frequency. Immediately the interaction between this RF field (with an initial low power) and the electron beam begins. The electrons are additionally influenced by the alternating field. It starts the process described in the sequence of phase 1 to 4 of the interaction between the RF field and the now velocity-modulated electrons.

Unfortunately, the transient oscillation doesn't begin with a predictable phase. Each transient oscillation occurs with a random phase. The transmitting pulses that are generated by a magnetron are therefore not coherent.

However, it is possible to get phase coherence, if the magnetron is fed with a continuous priming signal from a coherent oscillator.

Modes of Oscillation

The operation frequency depends on the sizes of the cavities and the interaction space between anode and cathode. But the single cavities are coupled over the interaction space with each other. Therefore, several resonant frequencies exist for the complete system. Several other modes of oscillation are possible ($\frac{3}{4}\pi$ mode, $\frac{1}{2}\pi$ mode, $\frac{1}{4}\pi$ mode) but a magnetron operating in the π mode has a higher output power and is most commonly used.

1 Read and translate the text above noticing technical terms and word collocations. Answer the questions.

1. What is a magnetron?
2. What disadvantages does it have?
3. How can the physical construction of a magnetron be explained?
4. What is oscillation? What modes of oscillation can be distinguished?

2 Choose a passage of 850 symbols from the text and translate it into Russian in written form.

3 Translate the sentences into English using the vocabulary from Text 5.2.

1. Магнитронами называют электронные приборы, в которых образуются колебания сверхвысокой частоты при помощи модуляции потока электронов.
2. В результате экспериментов появилось множество видов магнетронов, использующихся в радиоэлектронике.
3. Резонаторы создают кольцевую систему колебаний.
4. В магнетронах применяется движение электронов в перпендикулярных магнитных и электрических полях, созданных в зазоре кольца между катодом и анодом.
5. Простое устройство магнетрона, его невысокая стоимость, повышенная эффективность нагревания и разнообразное использование высокочастотных токов открывают большие возможности его использования в разных сферах жизни.

4 Make a short multimedia presentation on magnetron types and their application.

ANSWER KEY

Unit 1

TEXT 1.1: Manufacturing Methods and Mechanisms

Ex. 3: 1 to associate; 2 to discuss; 3 to implement; 4 to represent; 5 to attract; 6 to introduce; 7 to explain; 8 to transmit.

TEXT 1.2: Stretchable Conductors and Electrodes

Ex. 2: 1 D; 2 B; 3 G; 4 I; 5 H; 6 A;7 C; 8 F; 9 E.

Ex. 5: 1 T; 2 F; 3 F; 4 T; 5 F; 6 T.

Unit 2

TEXT 2.1: Conductors

Ex. 6: 1 feasibility; 2 modules; 3 algorithm; 4 neural; 5 wireless; 6 tools.

TEXT 2.2: Systems Approbation

Ex. 3: 1 F; 2 G; 3 H; 4 B; 5 I; 6 A;7 D; 8 C; 9 E.

Unit 3

TEXT 3.1: Skin-like Conductors

Ex. 5: 1 I; 2 k; 3 G; 4 E; 5 H; 6 J; 7 A; 8 F; 9 C; 10 D; 11 B.

TEXT 3.2: Skin-like Sensors and Integrated Circuits

Ex. 3: 1 T; 2 F; 3 T.

Ex. 4: 1 I; 2 F; 3 J; 4 G; 5 B; 6 A; 7 E; 8 C; 9 H; 10 D.

.

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