Національний технічний університет України
«КИЇВСЬКИЙ ПОЛІТЕХНІЧНИЙ ІНСТИТУТ
імені ІГОРЯ СІКОРСЬКОГО»

Department of Applied Radio Electronics

# [RE-37] TECHNOLOGY OF RADIOELECTRONIC EQUIPMENT MANUFACTURING

## Curriculum of the academic discipline (Syllabus)

### Course details

| | |
|---|---|
| Level of higher education | First (bachelor's) |
| Field of knowledge | G - Engineering, manufacturing, and construction |
| Specialty | G5 - Electronics, electronic communications, instrument engineering, and radio engineering |
| Educational program | All educational programs |
| Subject status | Elective (F-catalog) |
| Form of higher education | Full-time |
| Year of training, semester | Available for selection starting from the 3rd year, spring semester |
| Scope of the discipline | 4 credits (Lectures 16 hours, Practical classes 30 hours, Laboratory work 30 hours, Independent work 74 hours) |
| Semester Control/control measures | Credit |
| Class schedule | https://schedule.kpi.ua |
| Language of instruction | Ukrainian |
| Information about the course coordinator/teachers | Lectures: Golovnya V. M.,<br>Labs: Golovnya V. M.,<br>Independent work:<br>Golovnya V. M. |
| Course location | https://do.ipo.kpi.ua/course/view.php?id=7170 |

### Curriculum

**1. Description of the course, its purpose, subject matter, and learning outcomes**

Radio-electronic equipment manufacturing technology develops skills in designing technical documentation for a product; designing manufacturing processes; developing the necessary equipment; configuration and control; testing finished products at the stages of manufacturing and operation.

If the task of an REA designer is to design a set of technical documentation for a product, then the task

technologist – to design technological processes and ensure the production of finished products.

Knowledge and understanding of production technology allows for the manufacture of reliable and user-friendly high-tech devices for various purposes and degrees of complexity for a variety of operating conditions.

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**2. Prerequisites and post-requisites of the discipline (place in the structural-logical scheme of training under the relevant educational program)**

Students should be able to work in the SolidWorks environment (discipline "Three-dimensional modeling of REA").

Have an understanding and skills in REA design (discipline "REA Design").

**3. Course content**

Course content: 18 hours of lectures, 36 hours of lab work, test. Lecture material is additionally covered in lab classes.

Topic 1 Introduction

- Introduction. The place of radio-electronic equipment production technology in the process of designing, manufacturing, and operating radio-electronic equipment.
- Conceptual framework.
- Historical overview.
- Fundamentals of technological preparation for the production of radio-electronic equipment

Topic 2 Subtractive (machining) technologies for manufacturing parts.

- Classification. Mechanisms of influence on materials.
- Mechanical removal of material (cutting, drilling, turning, milling, planing, broaching).
- Chemical, electrochemical, radiation, ion, gas-flame removal of material.
- Physical and chemical processing methods

Topic 3 Additive manufacturing technologies

- Surface preparation
- Physical forming technologies (casting, pressing, powder metallurgy)
- Chemical, electrochemical, radiation, elion, gas-flame technologies
- 3-D technologies for manufacturing products

Topic 4. Technologies for changing properties (processing)

- Physical and chemical processes. Classification.
- Hardening, annealing, normalizing, tempering, work hardening.
- Alloying, diffusion saturation, carbonization, ion implantation

Topic 5 Coatings in the production of radio-electronic devices. Inorganic coatings

- General classification of coatings. Purpose
- Metallization. Technologies for forming other inorganic coatings (oxide, phosphate, nitride, etc.)
- Chemical deposition.
- Electrochemical coatings. Processes. Technology. Polarization

- Corrosion, its types and rate. Passivation. Galvanic corrosion couples. Corrosion protection

Topic 6 Coatings in the production of radio-electronic devices. Organic coatings

- Classification. Definition. Application methods, properties
- Paint and varnish coatings. Application technologies. Areas of application

Topic 7 Fundamentals of IC manufacturing technology

- Photolithography
- Equipment and apparatus

Laboratory classes

Main objectives of the laboratory class cycle:

a) to test acquired theoretical knowledge in practice;

b) acquiring skills in working with technological equipment;

c) mastering methods for measuring the parameters and characteristics of products and

processes; d) acquiring skills in evaluating experimental data and forming conclusions.

| No. | Title of laboratory work (computer workshop) | Number of lecture hours |
|---|---|---|
| 1 | Research on tools for subtractive material processing. Drills, reamers, broaches | 4 |
| 2 | Research on tools for subtractive material processing. Milling cutters. Grinders. Lathes. Honing machines | 4 |
| 3 | Research on the effect of generation frequency on the productivity of ultrasonic material processing | 4 |
| 4 | Study of the productivity and accuracy of metal processing by electrical erosion method | 4 |
| 5 | Research on precision photomasks | 4 |
| 6 | Research on contact photolithography processes | 4 |
| 7 | Research on cleaning processes and purity control of substrates for ICs | 4 |
| 8 | Research into the principles of constructing vacuum installations for applying thin films | 4 |
| 9 | Credit | 4 |

**4. Teaching materials and resources**

Laboratory work is carried out in the laboratories of the RTF department of the PRE on the available equipment in labs 306, 410, and 412, and in the microelectronics room, room 408.

Literature for mastering the course

**Basic**

1. Gotra Z.Y. Electronic Engineering Technology. Textbook in two volumes. Lviv: Lviv Polytechnic Publishing House, 2010. Vol. 1. 888 p.

2. Bilibin K.I. Design and technological engineering of electronic equipment: Kyiv, 2016. 568 p.

3. Technology of non-metallic coating application and production of printed circuit boards [Electronic resource]: textbook / L. A. Yatsyuk, O. V. Kosogin, D. Yu. Ushchapovsky, O. V. Linyucheva, Yu. F. Fateev; Electronic text data (1 file: 6.9 MB). – Kyiv: Igor Sikorsky Kyiv Polytechnic Institute, Polytechnika Publishing House, 2018. – 330 p.

**Textbooks.**


4. Bobalo, Yuriy Yaroslavovych. Quality and reliability of radio-electronic equipment. Elements of theory and methods of assurance: monograph / Y. Y. Bobalo, L. A. Nedostup, M. D. Kiselichnyk; edited by L. A. Nedostup; Ministry of Education and Science of Ukraine, Lviv Polytechnic National University. Lviv: Lviv Polytechnic Publishing House, 2013. – 196
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5. Bondarenko, Igor Mykolayovych. Design of Semiconductor Devices and Integrated Circuits: A Textbook for Students Majoring in Micro- and Nanosystem Engineering and Electronics / I.M. Bondarenko, O.V. Borodin, V.P. Karnauchenko; Ministry of Education and Science of Ukraine, Kharkiv National University of Radio Electronics. Kharkiv: KNURE, 2019. - 174 p. https://opac.kpi.ua/F/?func=direct&doc_number=000603218&local_base=KPI01

6. Vysochin, Viktor Oleksandrovych. Locksmith and assembly work in the production of radio-electronic equipment: A textbook for students of vocational and technical educational institutions /V.O. Vysotsk. K.: Higher School, 2006. - 279
https://opac.kpi.ua/F/?func=direct&doc_number=000201591&local_base=KPI01

7. Gotra, Zenon Yuriyovych. Electronic Engineering Technology: Textbook for Students of the Basic Direction "Electronics": in 2 volumes / Z. Yu. Gotra; Ministry of Education and Science of Ukraine, National University "Lviv Polytechnic". Lviv: Publishing House of Lviv Polytechnic National University,
2010. https://opac.kpi.ua/F/?func=direct&doc_number=000350523&local_base=KPI01

8. Zinkovsky, Yuriy Frantsevich. Computer circuit modeling of radio electronics elements: textbook for students of higher educational institutions /Y.F. Zinkovsky, A.V. Koval; Ministry of Education and Science, Youth and Sports of Ukraine, National Transport University.Kyiv: National Transport University, 2013 - Vol. 1, Part 1: Passive element base; Part 2: Filters. --2013. -- 348
p.https://opac.kpi.ua/F/?func=direct&doc_number=000350178&local_base=KPI01

9. Mirskikh, Georgy Alexandrovich. Control of parameters during the design, manufacture, and operation of radio-electronic equipment: textbook for students of higher educational institutions majoring in "Manufacture of Electronic Devices" and "Electronic Construction of Equipment" /G.O. Mirskikh, N.M. Rudenko; NTUU "KPI". K.: NTUU "KPI", 2009. - 140
https://opac.kpi.ua/F/?func=direct&doc_number=000241759&local_base=KPI01

10. Technology of Electronic Equipment Production: Methodological Guidelines for Laboratory Work for Students of the Radio Engineering Faculty, Specialization "Electronic Devices" /Compiled by V. A. Bidenko, V. A. Kozhushnyi, V. A. Prus; NTUU "KPI". Kyiv: Polytechnika, 2007. - 52 p. https://opac.kpi.ua/F/?func=direct&doc_number=000195324&local_base=KPI01


**Monographs.**


11. Afanasyeva, Olga Valentinovna. Laser surface treatment of materials: monograph / O.V. Afanasyeva, N.O. Lalarova, E.P. Fedorenko; Ministry of Education and Science of Ukraine, Kharkiv National University of Radio Electronics, Kharkiv National Automobile and Highway University. Kharkiv: Panov A. M., 2020. - 100 p.https://opac.kpi.ua/F/?func=direct&doc_number=000634022&local_base=KPI01

12. Zinkovsky, Yuriy Frantsevich. Modeling of the element base of electronic devices in the Micro-Cap computer environment: monograph / Yu. F. Zinkovsky, A. V. Koval; Ministry of Education and Science of Ukraine, NTUU "KPI". Kyiv: NTUU "KPI", 2010. - 461
p.https://opac.kpi.ua/F/?func=direct&doc_number=000341214&local_base=KPI01

13. Metal oxide nanocomposites: electrochemical synthesis and properties: monograph /M. D. Sakhnenko, O. O. Ovcharenko, M. V. Ved; National Technical University "Kharkiv Polytechnic Institute." Kharkiv: Panov A.M., 2019. - 145
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14. Sakhnenko, Mykola Dmytrovych. Metal oxide nanocomposites: electrochemical synthesis and properties: monograph / M. D. Sakhnenko, O. O. Ovcharenko, M. V. Ved; National Technical University "Kharkiv Polytechnic Institute". Kharkiv: Panov A.M., 2019. -145

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**Articles.**

15. Volkov, E. V. Maximum stereo angle for forming X-ray volumetric stereo images / E. V. Volkov, S. I. Miroshnichenko. // Electronics and Communications: Scientific and Technical Journal 2013 No. 5(76). - P.
25-30 https://opac.kpi.ua/F/?func=direct&doc_number=000555906&local_base=KPI01

16. Tymchik, Grigory Semenovich. Limit characteristics of a coherent optical spectrum analyzer /Grigory Semenovich Tymchik, Quynh Anh Nguyen, Nikita Sergeyevich Kolobrodov //Scientific News of NTUU "KPI": scientific and technical journal. – 2014. - No. 5(97). - P. 119-123. https://opac.kpi.ua/F/?func=direct&doc_number=000584743&local_base=KPI01

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78-82. https://opac.kpi.ua/F/?func=direct&doc_number=000298573&local_base=KPI01

18. Tkachuk R. A. Fundamentals of Radioelectronic Devices Technology: Textbook / R. A. Tkachuk, V. G. Dozorsky, L. E. Dediv, I. Yu. Dediv. - Ternopil: Ivan Pul'uj Ternopil National Technical University, 2017. - 336 p.

19. Methodological guidelines for completing course projects and tests for students majoring in "Radio Electronic Devices" for all forms of education. Kyiv, NTUU "KPI", 2009 (Electronic educational publication).

20. Barishnikov V.N., Shobotenko N.S., Installation of Radio Electronic Equipment. - Kiev, Tekhnika, 1986.

**Textbooks.**

21. Design and production technologies for information recording equipment [Electronic resource]: textbook for students majoring in 171 "Electronics" / Igor Sikorsky KPI; compiled by: V.S. Lazebny, V.V. Pilinsky. – Electronic text data (1 file: 10.2 MB). – Kyiv: Igor Sikorsky Kyiv Polytechnic Institute, 2021. – 450 p. https://ela.kpi.ua/handle/123456789/41761

22. Pidgorny, A. V. Chemistry. Electrochemical Processes [Electronic resource]: textbook / A. V. Pidgorny, T. M. Nazarova. – Electronic text data (1 file: 2.85 MB). – Kyiv: NTUU
KPI, 2013. – 67 p. https://ela.kpi.ua/handle/123456789/3585

23. Technological Foundations of Electronics. Book 1. Microchip Production Technology [Electronic resource]: textbook for students majoring in 171 "Electronics," specializing in "Electronic Instruments and Devices" / A. I. Kuzmichev, L. D. Pysarenko, L. Yu. Tsybulsky; Igor Sikorsky Kyiv Polytechnic Institute. – Electronic text data (1 file: 3.74 MB). – Kyiv: Igor Sikorsky Kyiv Polytechnic Institute, 2019. – 127 p. https://ela.kpi.ua/handle/123456789/30141

24. Technology of applying non-metallic coatings and production of printed circuit boards [Electronic resource]: textbook / L. A. Yatsyuk, O. V. Kosogin, D. Yu. Ushchapovsky, O. V. Linyucheva, Yu. F. Fateev; Igor Sikorsky Kyiv Polytechnic Institute. – Electronic text data (1 file: 4.4 MB). – Kyiv: Igor Sikorsky KPI, Polytechnika Publishing House, 2018. - 330 p. https://ela.kpi.ua/handle/123456789/24954

**Articles.**

25. Zhovnir M. F. Assessment of the potential resolution and accuracy of linear and angular displacement measuring transducers based on the use of phase shifts of surface acoustic waves / M. F. Zhovnir, O. V. Shostak // Electronics and Communications: Scientific and Technical Journal. – 2015. – Vol. 20, No. 3(86). – Pp. 101-106https://ela.kpi.ua/handle/123456789/17587.

26. Chonka, E. Ya. Analysis of the accuracy of surface formation of parts manufactured on a 3D printer / E. Ya. Chonka, V. S. Antoniuk // XV All-Ukrainian Scientific and Practical Conference of Students, Postgraduates, and Young Scientists "Effectiveness of Engineering Solutions in Instrument Making," December 10-11, 2019, Kyiv, Ukraine: collection of conference proceedings / Igor Sikorsky KPI, PBF, FMM. – Kyiv: Igor Sikorsky Kyiv Polytechnic Institute; Center for Educational Literature, 2019. – P. 197-200. https://ela.kpi.ua/handle/123456789/31651

Supplementary

**textbooks.**

27. Bilyk I. I., Rudenkyi S. O. Technology of coating application and their properties: textbook. - 2023. - 120 p.https://ela.kpi.ua/bitstream/123456789/56927/1/Tekhnolohiia_nanesennia_pokryttiv_ta_yikh_vlastyvosti.pdf

28. Pupan L. I. Post-processes of additive technologies: textbook. - 2023. - 92 p. https://repository.kpi.kharkov.ua/server/api/core/bitstreams/0c4ef7cd-4ccf-4678-8cfa-d2988250ad81/content

29. Methodological guidelines for laboratory work "Research of printed circuit board manufacturing technologies" in the discipline "Technology of parts" for students majoring in 6.050902 "Radio-electronic devices" of all forms of training / Compiled by: Farafonov O. Yu., Furmanova N. I. - Zaporizhia: ZNTU, 2014. – 46 p. http://eir.zntu.edu.ua/handle/123456789/105

**Monographs.**

30. Ved, M. V. Catalytic and protective coatings with alloys and complex oxides: electrochemical synthesis, property prediction: monograph / M. V. Ved, M. D. Sakhnenko; National Technical University "Kharkiv Polytechnic Institute." - Kharkiv: NTU "KPI," 2010. - 272 https://repository.kpi.kharkov.ua/server/api/core/bitstreams/ad098cbe-5b14-42bb-b667-d2a837d4c817/content

31. Garashchenko, Y. M. Improving the technological preparation of additive manufacturing of complex products: monograph. – 2023. – 389 https://repository.kpi.kharkov.ua/server/api/core/bitstreams/bc9c882f-bc3a-45a1-a119-499fbdc0c6 4e/content

**Articles.**

32. Boklag D. K. Analysis of technological solutions for simultaneous 3D printing with multiple materials. – 2021. -5 p. https://openarchive.nure.ua/server/api/core/bitstreams/fee0a34e-080c-480f-a1de-2f765375b0d7/c ontent

33. Burburska S. V., Pasichnyk V. A. Possibilities of additive technologies in the manufacture of high-tech products for mechanical engineering and biomedical engineering //Technical Engineering. – 2022. – No. 1 (89). – P. 21-26. file:///D:/260532-%D0%A2%D0%B5%D0%BA%D1%81%D1%82%20%D1%81%D1%82%D0%B0%D1%82%D1%82%D1%96-600162-1-10-20220705.pdf

34. Karakurkchi G. et al. Functional electrochemical coatings in dual-use technologies //Bulletin of the National Technical University "KhPI". Series: New solutions in modern technologies. – 2021. – No. 2 (8). – P. 101-112. file:///D:/234253-%D0%A2%D0%B5%D0%BA%D1%81%D1%82%20%D1%81%D1%82%D0%B0%D1%82%D1%82%D1%96-535874-1-10-20210611.pdf

35. Masuchok O. P. et al. Additive technologies for polymer materials (Review) //Automatic welding. - 2020. - No. 5. - P. 53-60. https://patonpublishinghouse.com/as/pdf/2020/pdfarticles/05/10.pdf

36. Pasichnyk V. A., Burburskaya S. V., Kutuz V. V. Issues of measuring the accuracy parameters of endoprostheses manufactured using additive technologies //Materials of the scientific and technical conference "Progressive Technology, Technology and Engineering Education". - 2019. - No. XX. - 4 p. file:///D:/172544-%D0%A2%D0%B5%D0%BA%D1%81%D1%82%20%D1%81%D1%82%D0%B0%D1%82%D1%82%D1%96-398169-1-10-20191003.pdf

37. Tsybulenko V. O., Pasichnyk V. A., Vorontsov B. S. Prospects for the use of hybrid additive-subtractive manufacturing. – 2022. – 9 p. -
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38. Chen Bin. Blade Segment with a 3D Lattice of Diamond Grits Fabricated via an Additive Manufacturing Process / Chen Bin [et al] // Chinese Journal of Mechanical Engineering. - 2020. - 12 p.https://cjme.springeropen.com/counter/pdf/10.1186/s10033-020-00496-6.pdf

39. Fan Congze. Interfacial Bonding Mechanism and Mechanical Performance of Continuous Fiber Reinforced Composites in Additive Manufacturing. / Fan Congze [et al]// Chinese Journal of Mechanical Engineering. – 2021. – 11 p. https://cjme.springeropen.com/counter/pdf/10.1186/s10033-021-00538-7.pdf

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41. Guo Sai, Ren Guanhui, Zhang Bi. Subsurface Defect Evaluation of Selective-Laser-Melted Inconel 738LC Alloy Using Eddy Current Testing for Additive/ Subtractive Hybrid Manufacturing. // Chinese Journal of Mechanical Engineering – 2021. – 16 p. https://cjme.springeropen.com/counter/pdf/10.1186/s10033-021-00633-9.pdf

42. Hugo I. Medellin-Castillo and Jorge Zaragoza-Siqueiros. Design and Manufacturing Strategies for Fused Deposition Modelling in Additive Manufacturing: A Review // Chinese Journal of Mechanical Engineering. – 2019. – 16
https://cjme.springeropen.com/counter/pdf/10.1186/s10033-019-0368-0.pdf

43. Kim Sungil. Optimization of selective laser-induced etching (SLE) for fabrication of 3D glass microfluidic device with multi-layer micro channels. / Kim Sungil [et al] // Micro and Nano Syst Lett. - 2019. – 7 p. https://mnsl-journal.springeropen.com/counter/pdf/10.1186/s40486-019-0094-5.pdf

44. Li Neng. Laser Additive Manufacturing on Metal Matrix Composites: A Review / Li Neng [et al] // Chinese Journal of Mechanical Engineering. – 2021. – 16 p. https://cjme.springeropen.com/counter/pdf/10.1186/s10033-021-00554-7.pdf

45. Li Qingde. Towards additive manufacturing oriented geometric modeling using implicit functions. / Li Qingde [et al] // Visual Computing for Industry, Biomedicine, and Art. – 2018. – 16 p.https://vciba.springeropen.com/counter/pdf/10.1186/s42492-018-0009-y.pdf

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47. Kovtun I. I., Roizman V. P. Deformations of Electronic Equipment Structures under Operational Loads / I. I. Kovtun, V. P. Roizman. – Khmelnytskyi: Khmelnytskyi National University, 2019. – 230 p.https://elar.khmnu.edu.ua/server/api/core/bitstreams/3c2efa2a-78f6-409f-87f5-a9a4b900321d/content

48. Lecture notes from the course "Design and Production Technology of Telecommunications Systems" [Electronic resource]: for students majoring in 172 "Telecommunications and Radio Engineering" of all forms of education / compiled by: N. O. Yevsina, O. V. Dudnik; National Technical University "Kharkiv Polytechnic Institute." – Electronic text data. – Kharkiv, 2022. – 35 p. https://repository.kpi.kharkov.ua/server/api/core/bitstreams/22b81594-f793-4b2d-bae0-71da5f0f0c1b/content

49. Lecture notes on the subject "Coatings and Their Properties" for bachelor's degree students majoring in 132 Materials Science [Electronic resource] / Department of Construction, Theoretical and Applied Mechanics. - Dnipro: National Technical University "Dnipro Polytechnic" - 2020 -61 p. https://btpm.nmu.org.ua/ua/download/lecture-course/%D0%9A%D0%BE%D0%BD%D1%81%D0%BF%D0%B5%D0%BA%D1%82%20%D0%9F%D0%9E%D0%9A%D0%A0%D0%98%D0%A2%D0%A2%D0%AF%20%D0%A2%D0%90%20%D0%87%D0%A5%20%D0%92%D0%9B%D0%90%D0%A1%D0%A2%D0%98%D0%92%D0%9E%D0%A1%D0%A2%D0%86.pdf

50. Methodological guidelines for practical work in the academic discipline "Design of Electronic Devices" for full-time students majoring in 171 – "Electronics" of the educational and professional program "Technology, Equipment, and Production of Electronic Equipment" of the educational degree "Bachelor" / Compiled by D. V. Mospan; Ministry of Education and Science of Ukraine; Mykhailo Ostrogradskyi Kremenchuk National University; Educational and Scientific Institute of Electrical Engineering and Information Technologies – Kremenchuk, 2022- 60 p. http://document.kdu.edu.ua/metod/2022_4104.pdf

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53. Tkachuk R. A. Fundamentals of Radioelectronic Devices Technology: Textbook / R. A.

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## Educational content

### 5. Methodology for mastering the academic discipline (educational component)

To complete each laboratory assignment, knowledge of the lecture material is required. The entire course is divided into 7 topics. Laboratory assignments do not cover all lecture topics, but complement them. The correspondence of laboratory assignments to lecture material is presented in the table.

| Laboratory<br>Lectures | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1 | X | X | | | | | | |
| 2 | | | X | | | | | |
| 3 | | | | X | | | | |
| 4 | | | | | | | | |
| 5 | | | | | X | | | |
| 6 | | | | | | X | | |
| 7 | | | | | | | | |
| 8 | | | | | | | | |
| 9 | | | | | | | X | X |

Topic 1 THE PLACE OF REA PRODUCTION TECHNOLOGY IN THE PROCESS OF DESIGNING, MANUFACTURING, AND OPERATING EQUIPMENT. THE PLACE AND ROLE OF THE TECHNOLOGIST IN THE PRODUCTION OF REA

Topic 1.1 REA technology. The place and role of the technologist in REA production. Basic principles of technological preparation for the production of radio-electronic devices. General issues of technological support for the production process [1, 2, 4, 5, 6, 7].

Topic 1.2 Basic terms and definitions. Regulatory documents on technological preparation of production.

Topic 1.3 Historical overview.

*Independent work assignment*: principles of organizing the production of radio-electronic equipment parts

[1, 2, 4, 5]. Topic 2 SUBTRACTIVE TECHNOLOGIES

Topic 2.1 Classification. Mechanisms of influence on materials. General classification of subtractive methods. Physical and chemical phenomena. Limits of use

*Independent work assignment:* review the lecture material

Topic 2.2 Mechanical removal of material (drilling, turning). Classification of lathes. Tools. Machining modes. Drilling machines. Types of drills. ZMR.

*Independent work assignment:* select drill bits for steel, brass, bronze, wood, polypropylene

Topic 2.3 Mechanical removal of material (cutting, milling, planing). Dragging. Broaching. Classification of milling machines. Tools. Machining modes. Types of milling cutters.

*Independent work assignment:* select end mills for steel, brass, bronze, wood, fiberglass

Topic 2.3.1 Chemical and electrochemical material removal. Solid, liquid, and gaseous etchants. Influencing factors. Equipment. Limits of application

*Independent work assignment:* technological process of etching printed circuit boards, chemical engraving

Topic 2.3.2 Beam, elion, gas-flame removal of material. Jet subtractive technologies. Equipment. Modes. Application

*Independent work assignment*: design an ion gun (drawing)

Topic 2.4 Physical and chemical methods of material removal. Anodic - mechanical, electroerosion - chemical, ultrasonic - electrochemical, and electric laser. Electro-hydraulic pulse and magnetic pulse processing of materials in the production of radio-electronic device components [33]. The Yutkin effect.

*Independent work assignment:* familiarize yourself with the technological capabilities of electroerosion processing [34].

Topic 3. ADDITIVE SHAPING TECHNOLOGIES

Topic 3.1 Surface preparation for coating [2, 25]. Types of ultrasonic cleaning technology for parts, intensification of technological processes [33].

*Independent work assignment:* develop a cleaning scheme for polycor for vacuum metallization.

Topic 3.2.1 Physical technologies. Metal and plastic casting. Classification. Features. Disadvantages. Advantages. Prospects [13].

*Independent work assignment:* develop a sketch *of* a mold [1].

Topic 3.2.2 Physical technologies. Metal and plastic pressing: technological methods [13].

Material requirements. Features of designing extruded products. Features of designing molds

*Independent work assignment:* review the lecture material, develop sketches of simple dies and

punch [1].

Topic 3.2.3 Physical technologies. Powder metallurgy. Classification. Forming technology. Features of the process. Advantages and disadvantages. Limits of application

*Independent work assignment*: drawing *of* powder materials.

Topic 3.3.1 Chemical and electrochemical technologies. Classification. Equipment. Limits of use. Advantages and disadvantages. Prospects for development. Growth modes.

*Independent work assignment:* review the lecture material.

Topic 3.3.2 Radiation, elion, gas-flame technologies. Classification. Equipment. Limits of use. Advantages and disadvantages, prospects for development. Deposition modes.

*Independent work assignment:* review the lecture material.

Topic 3.4 3-D technologies. Classification. Equipment. Limits of use. Advantages and disadvantages, prospects for development. Build-up modes.

*Independent work assignment:* review the lecture material Topic 4.

TECHNOLOGIES FOR CHANGING PROPERTIES

Topic 4.1 Physical and chemical processes. General classification. Features. Hardware.

*Independent work assignment:* analyze the limits of use of physical and chemical processes

Topic 4.2 Hardening, annealing, normalizing, tempering, carburizing. Metallization by annealing [2, 14]. Composition of pastes and technological processes for annealing silver and copper

*Independent work assignment:* familiarize yourself with the technology of preparing pastes for annealing silver [2].

Topic 4.3.1 Alloying, diffusion saturation. Physics of the process. Equipment. Advantages. Disadvantages

*Independent work assignment:* determine methods of doping and diffusion saturation for silicon.

Topic 4.3.2 Carbonization, ion implantation. Physics of processes. Limits of use. Advantages and disadvantages

*Independent work assignment:* determine methods of carbonization of steel parts

Topic 5 COATINGS IN THE MANUFACTURE OF RADIOELECTRONIC DEVICES. INORGANIC COATINGS

Topic 5.1 General classification of coatings. Purpose. Surface preparation for coating [2, 25].

*Independent work assignment:* features of surface preparation for coating in the production of printed circuit boards [1].

Topic 5.2.1 Metallization. Classification of metal coatings. Vacuum deposition and spraying. Metallization by annealing [2, 14]. Composition of pastes and technological processes of silver and copper annealing. Hot spraying of metals (sputtering, ultra-high-speed spraying). Gas and electric arc devices for sputtering.

*Independent work assignment:* familiarize yourself with the technology of preparing pastes for applying silver [2].

Topic 5.2.2 Technologies for forming other inorganic coatings (oxide, phosphate, nitride, etc.)

Formation methods. Characteristics. Modes. Advantages and disadvantages. Parylene.

*Independent work assignment:* determine the method of carbonization. Art. 3

Topic 5.3 Chemical deposition. Technological and functional coatings obtained by chemical deposition [2, 30]. Typical technological processes and equipment.

*Independent work assignment:* chemical metallization technology in the production of printed circuit boards [1].

Topic 5.4.1. Electrochemical coatings. Processes. Areas of application and classification of electrochemical coatings. Kinetics of electrochemical processes. Electrolysis. Laws of electrochemical deposition processes. Multilayer electrochemical coatings.

*Independent work assignment:* features of the design of parts subject to electroplating. [15,17]

Topic 5.4.2. Electrochemical coatings. Polarization and polarization curves. The effect of polarization potentials on the course of electrochemical deposition

Topic 5.5.1 Chemical corrosion, its types and rate. The role of moisture in the corrosion process. Corrosion protection [15].

*Independent work assignment:* review the lecture material

Topic 5.5.2 Passivation. Galvanic corrosion couples. Protection against electrochemical corrosion. Sacrificial material. Cathodic and anodic protection

*Independent work assignment:* corrosion couples in electrochemical corrosion [17].

Topic 6 COATINGS IN THE MANUFACTURE OF RADIOELECTRONIC DEVICES. ORGANIC COATINGS

Topic 6.1.1 Definitions. Application methods, properties. Factors of environmental impact on radio-electronic equipment. Classification of methods for protecting radio-electronic equipment from external influences with organic layers [1, 2, 29].

Topic 6.1.2 Influence of REA operating conditions on the choice of coating. Varnishing. Classification of varnishes. Characteristics. Advantages and disadvantages

*Independent work assignment:* select a varnish for normal operating conditions, for a tropical humid climate, and for a marine climate.

Topic 6.2 Paint coatings, technologies, areas of application. Sealing with polymer materials. The nature of adhesion. Moisture diffusion. Paint and varnish coatings and the physical basis for their application. Sealing with powder materials. Technologies for sealing parts and assemblies of radio-electronic devices with liquid sealants.

*Independent work assignment*: impregnation, production technology Topic 7

Fundamentals of IC manufacturing technology

Topic 7.1 Photomasks. Types. Features. Technology of production and application. Resolution.

Topic 7.2 Lithographic processes in IC manufacturing. Photoresists. Types. Application methods. Processing technology. Resolution. Causes of defects and rejects.

### 6. Independent work of students

Independent work by students includes mastering lecture and laboratory materials, submitting laboratory work to the instructor for review (within the deadlines specified by the instructor):

## Policy and control

### 7. Academic discipline (educational component) policy

- At the beginning of the semester, a Telegram chat for the discipline is created for quick student-teacher interaction. All students in the group must be present in the chat;
- Attendance at laboratory work and lectures is mandatory.
- All laboratory assignments must be submitted to the instructor for review within the specified time frame. Late submission of work results in the loss of the right to redo the work to improve the grade.
- If the teacher has questions about the authorship of the work submitted by the student for review, the teacher has the right to conduct an additional defense of the work.
- Incentive points are awarded for student participation in lectures and laboratory work.
- If they wish, students can prepare reports on a relevant topic, up to 3 pages in length, in A4 format.

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### 8. Types of assessment and the learning outcomes assessment rating system (LOAS)

The following maximum points can be obtained for each task (provided that it is completed correctly and submitted for review on time):

1. Lectures - 18 points in total (based on the results of a quick survey)
2. Laboratory work - 10 points for each

3. Presentation - 5 points for each

Calendar control

Students who have earned 30 and 60 points, respectively, on the date of the first and second calendar controls will receive certification.

*Note:* Provided that laboratory work is evenly distributed throughout the semester. If the latter condition is not met, students will be notified at the beginning of the semester about the change in the calculation of rating points.

Semester control: credit.

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***Table of correspondence between rating points and grades on the university scale***

| Number of points | Grade |
|---|---|
| 100-95 | Excellent |
| 94 | Very good |
| 84-75 | Good |
| 74-65 | Satisfactory |
| 64-60 | Sufficient |
| Less than 60 | Unsatisfactory |
| Admission requirements not met | Not admitted |

## 9. Additional information on the discipline (educational component)

- Certificates of completion of distance or online courses on relevant topics may be accepted (the relevance of the topics must be agreed with the lecturer).

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***Description of material, technical, and informational support for the discipline***

The laboratory work provided for in the course is equipped with the necessary measuring instruments (caliper, protractor, microscope, etc.), cutting tools, molds, and materials in full. Appropriate models have been developed and manufactured for performing work on electrical discharge and ultrasonic processing. Work on IC technology is carried out in the microelectronics laboratory on serial cleaning, photolithography, vacuum deposition of materials, and film thickness control equipment. Additional information is available on posters and tablets. Students also get to know the existing lathes, milling machines, engraving machines, and drilling machines in the department's workshop.

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Work program for the academic discipline (syllabus):
**Compiled by** V. M. Golovnya;
**Approved by** the PRE department (protocol No. 6/2025 dated 06/25/2025)
**Approved by** the methodological commission of the faculty/research institute (protocol No. 6/2025 dated 26.06.2025)