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Agreement number 2023-1-RO01-KA220-HED-000155412
European Network for Additive Manufacturing in Industrial Design for Ukrainian Context
Multiplier Event 4 - Poznań University of Technology, Poznań, Poland , 4 November 2024

AMAZE – Applied research methods for Additive Manufacturing in Industrial and Architectural Design – e-case study

Yuriy Fedkovych Chernivtsi National University, Ukraine

Prof. Igor Fodchuk, Prof. Mariana Borcha

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YURIY FEDKOVYCH CHERNIVTSI NATIONAL UNIVERSITY

The University was founded on 1875 by decree of Austro-Hungarian emperor Franz Joseph

The main building of the University – the previous Residence of the Orthodox Metropolitans of Bukovyna and Dalmatia – designed by the prominent Czech architect Josef Hlavka.

Since 2011 included to the UNESCO Heritage List

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HISTORY,

Outstanding milestones

1

04.10.1875

CHNU was founded by the Austro-Hungarian emperor Franz Joseph I

2

1918-1939

It was transformed into a Romanian University

3

1940

It was reorganized into Chernivtsi State University with Ukrainian language of studing

4

1989

CHNU was named after the outstanding Ukrainian writer from Bukovyna – Yuriy Fedkovych

5

2000

The University was conferred the status of National University

6

28.06.2011

The main University buildings – former Bukovynian and Dalmatian Metropolitans Residence was included to the UNESCO Heritage List

CHERNIVTSI UNIVERSITY TODAY

- ≈14 000 STUDENTS
- ≈700 PROFESSORS and ASSOCIATED PROFESSORS
- 10 FACULTIES
- 2 INSTITUTES
- 85 DEPARTMENTS
- 12 RESEARCH CENTERS

FACULTIES AND INSTITUTES

INSTITUTES OF:

- APPLIED PHYSICS AND COMPUTER SCIENCES
- BIOLOGY, CHEMISTRY AND BIORESOURCES

FACULTIES OF:

- FOREIGN LANGUAGES
- MATHEMATICS AND INFORMATICS
- LAW
- GEOGRAPHY
- ECONOMICS
- PHILOLOGY
- HISTORY, POLITICAL SCIENCE AND INTERNATIONAL RELATIONS
- PHYSICAL TRAINING AND HUMAN HEALTH
- ARCHITECTURE, CONSTRUCTION AND APPLIED ARTS
- PEDAGOGY, PSYCHOLOGY AND SOCIAL WORK

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BACHELOR AND MASTER STUDIES

FIELDS OF EDUCATION

SPECIALTIES

Education

- TEACHER TRAINING (BIOLOGY AND HUMAN HEALTH)
- TEACHER TRAINING (TECHNOLOGIES)
- TEACHER TRAINING (GEOGRAPHY)
- TEACHER TRAINING (ENGLISH)
- TEACHER TRAINING (GERMAN)
- TEACHER TRAINING (FRENCH)
- TEACHER TRAINING (HISTORY)
- TEACHER TRAINING (UKRAINIAN)
- TEACHER TRAINING (MATHEMATICS)
- ...

Arts and humanities

- PRINTING AND PUBLISHING
- FINE ARTS, DECORATIVE ARTS AND RESTORATION
- PHILOLOGY (GERMANIC LANGUAGES AND LITERATURES)
- PHILOLOGY (ROMANCE LANGUAGES AND LITERATURES)
- PHILOLOGY (UKRAINIAN LANGUAGE AND LITERATURE)
- HISTORY AND ARCHEOLOGY
- MUSIC ART

Social sciences, journalism and information

- ECONOMICS
- INTERNATIONAL ECONOMIC RELATIONS
- POLITICAL SCIENCE
- INTERNATIONAL RELATIONS
- PSYCHOLOGY
- CULTURAL STUDIES
- JOURNALISM

Business, administration and law

- SOCIAL WORK
- PHYSICAL THERAPY AND ERGOTHERAPY
- SOCIAL WELFARE

Natural sciences, mathematics and statistics

- BIOLOGY
- ECOLOGY
- CHEMISTRY
- BIOTECHNOLOGIES AND BIOENGINEERING
- GEODESY
- PHYSICS AND ASTRONOMY
- APPLIED PHYSICS AND NANOMATERIALS
- EARTH SCIENCES
- GEOGRAPHY
- MATHEMATICS
- APPLIED MATHEMATICS

BACHELOR AND MASTER STUDIES

FIELDS OF EDUCATION

SPECIALTIES

Information Technologies (IT)

- SOFTWARE DEVELOPMENT
- COMPUTER SCIENCES
- COMPUTER ENGINEERING
- CYBERSECURITY
- SYSTEM ANALYSIS
- INFORMATION SYSTEMS AND TECHNOLOGIES

Engineering, manufacturing and construction

- FOOD PROCESSING
- ELECTRICAL ENGINEERING AND ELECTROMECHANICS
- METROLOGY AND INFORMATION-MEASURING TECHNOLOGY
- MICRO- AND NANOSYSTEM ENGINEERING
- TELECOMMUNICATIONS AND RADIO ENGINEERING
- ARCHITECTURE AND URBAN PLANNING
- CONSTRUCTION AND CIVIL ENGINEERING

Agriculture, forestry, fisheries and veterinary

- AGRONOMY

Health and welfare

- MANAGEMENT
- ACCOUNTING AND TAXATION
- FINANCE, BANKING AND INSURANCE
- MANAGEMENT
- MARKETING
- ENTREPRENEURSHIP, TRADE AND EXCHANGE ACTIVITY
- PUBLIC MANAGEMENT AND ADMINISTRATION
- LAW
- INTERNATIONAL LAW

Services

- TOURISM
- PHYSICAL EDUCATION AND SPORT

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AMAZE team
from YURIY FEDKOVYCH CHERNIVTSI NATIONAL UNIVERSITY

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Dean of Faculty Architecture, Construction and Applied Arts

YURIY SOBKO

Associate prof.

Department of Construction

VOLODYMYR ROMANKEVYCH

Assistant of prof.

Department of Construction

MARIANA BORCHA

Head of Department Information Technologies and Computer Physics

TETIANA ANTOSHCHUK

Associate prof.

Department of Architecture

NATALIA VATAMANYUK

Associate prof.

Department of Architecture

edibon

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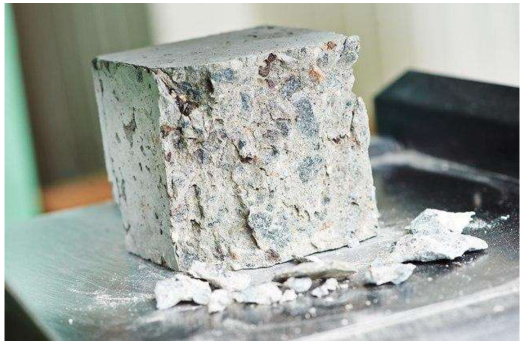
Project objectives
IO1 - AMAZE e-book for developing of complex design industrial
IO2 - AMAZE e-toolkit manual for digital learning in producing complex design industrial parts

module course 2 – Smart (Intelligent) Materials

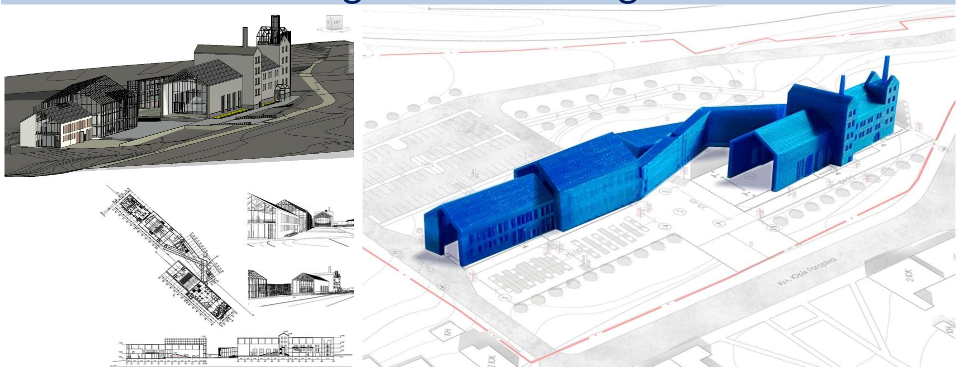
«Ultra-high strength composites»



Principles of structural strength and density, modified composites
with a complex of finely dispersed additives of microsilica and metakaolin

module course 3 – CAD/CAM/CAE design

Drawings in the Revit software package
using BIM technologies



Our team developed a project for the reconstruction of a brewery in
Chernivtsi using Revit software and printed it on a 3D printer.

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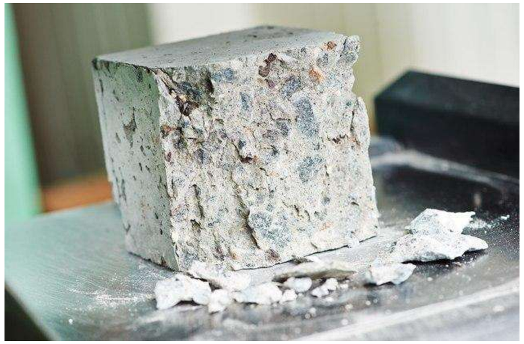
module course 2
Smart (Intelligent) Materials

«Ultra-high strength composites»

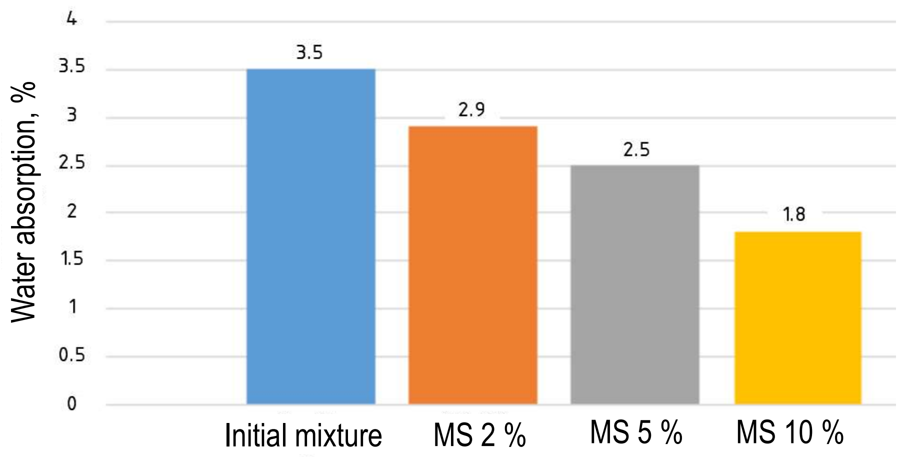


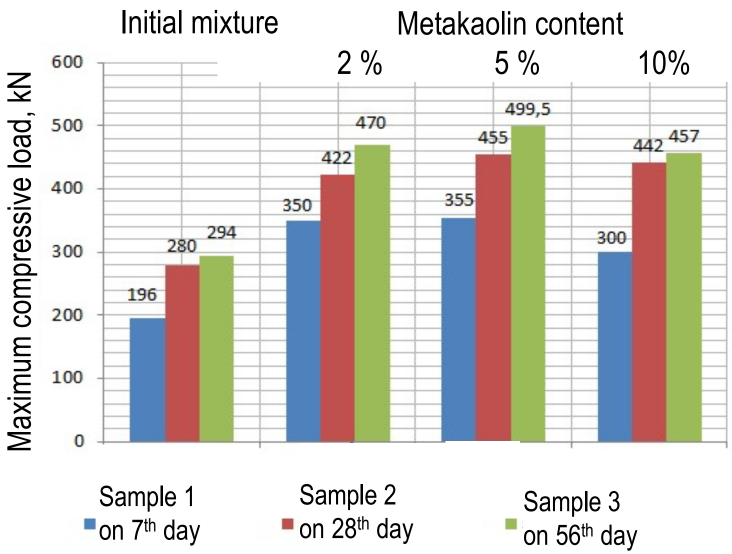
Principles of structural strength and density, modified composites
with a complex of finely dispersed additives of microsilica and metakaolin

Module course 2
in IO1 - AMAZE e-book
for developing of complex design industrial:

New materials and properties
used in architectural design
«Ultra-high strength composites»

Results of strength testing of concrete mixtures





Research methods:

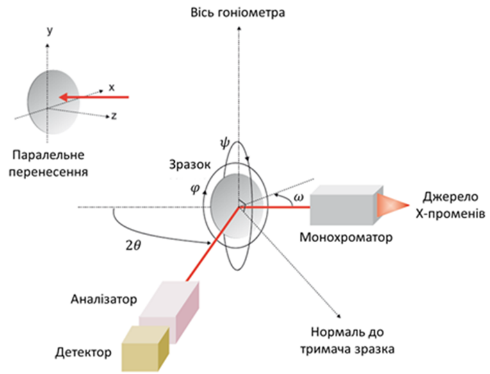
1.Scanning electron microscopy (SEM)

2. Energy dispersive X-ray spectroscopy, Hitach SU-70

3. High-resolution X-ray diffractometry

Zeiss EVO-50 scanning electron microscope with CCD detector

X'Pert PRO MRD diffractometer in a multicrystal diffraction scheme for CuKα1 radiation.



4. Determination of water resistance by the wet spot method in accordance with EN 12390-8

5. Determination of compressive strength on a hydraulic press in accordance with EN 12390-4

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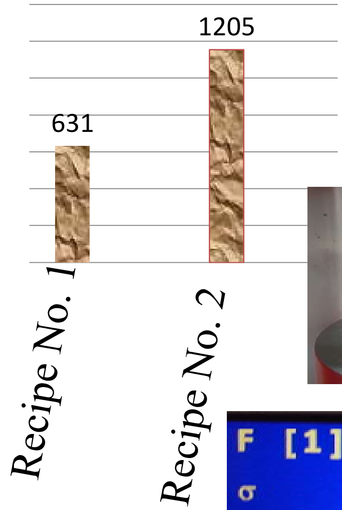
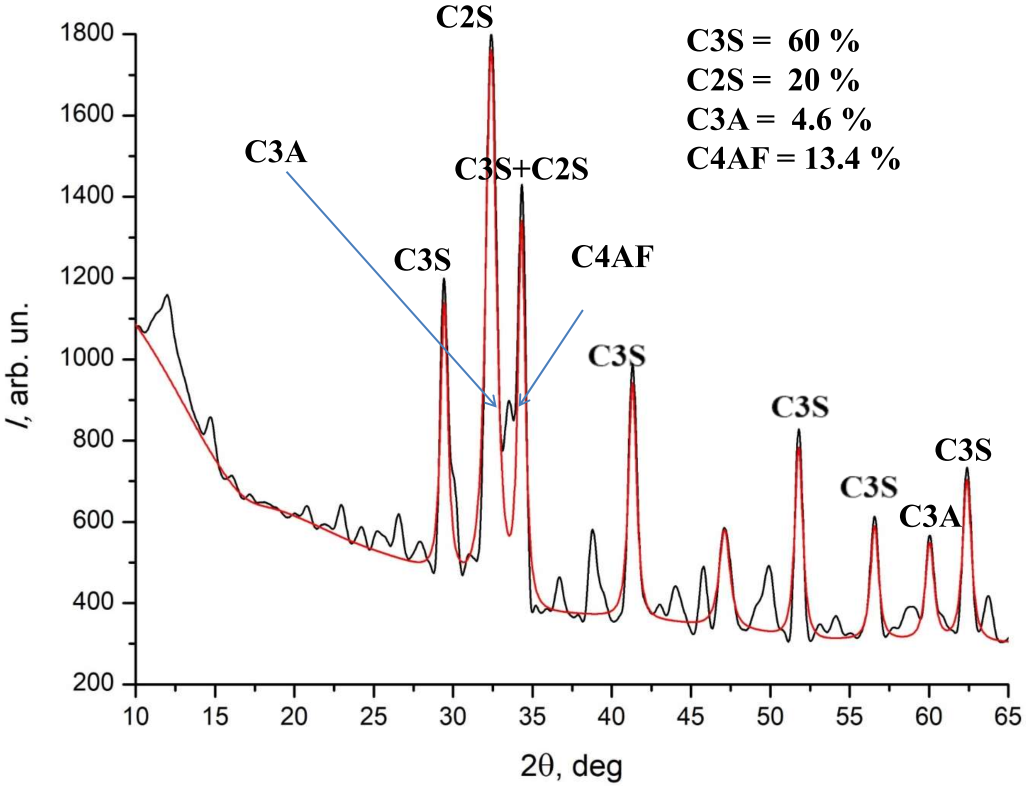
Development of cement composite formulation

	Recipe No. 1 kg/m3	Recipe No. 2 kg/m3
Cement PC-I 500 (EN 197-1:2011)	600	600
Quartz powder 50 microns.	-	30
Quartz sand, fraction 0.4-0.63 mm	584	520
Crushed stone diorite fraction 2/5 mm	315	315
Crushed stone diorite fraction 5/10 mm	315	315
Crushed stone diorite fraction 10/20 mm	660	660
Microsilica 0.1-0.3 microns.	-	60
Metakaolin 1-40 microns	-	30
Distilled water	160	**160**
Fiber	1%	1%
Plasticizer	5%	5%

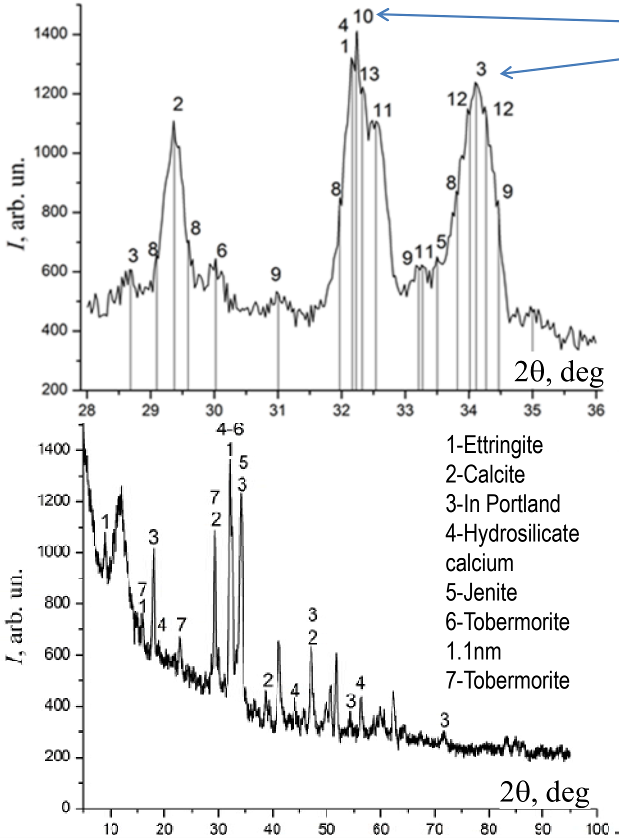
Compressive strength in kN





The phase composition of cement containing various clinker minerals

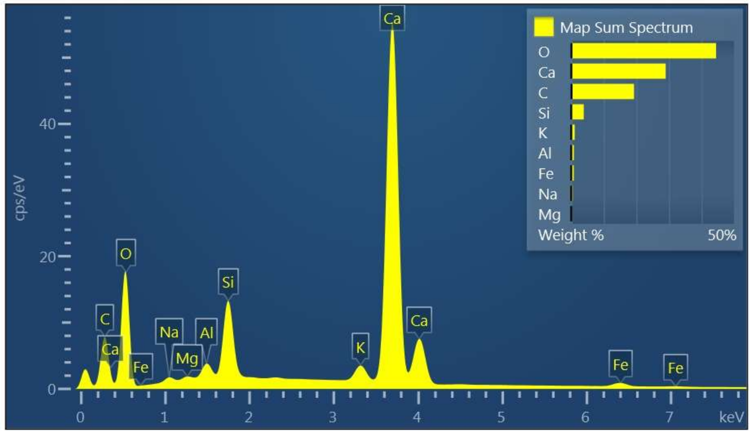
from analysis of experimental X-ray diffractograms (by the Rietveld method)



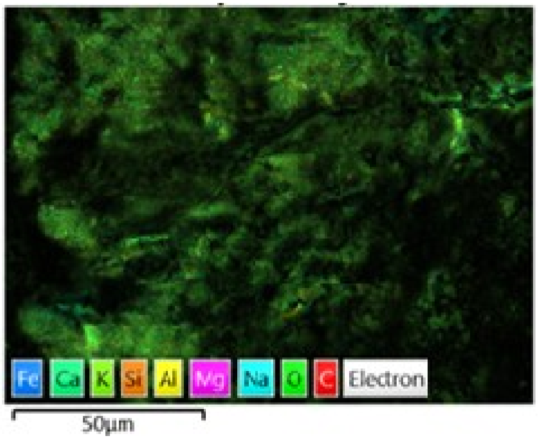
Peaks of intensity of of CHS, HAlC compounds

№	Chemical formula	*d*/*n*	Name of the compound
1	$Al_2Ca_6H_{66}O_{49.68}S_3$	0.974, 0.563, 0.388,	Ettringitis
2	$CaCO_3$	0.278, 0.303, 0.191	Calcite
3	$Ca(OH)_2$	0.491, 0.262, 0.192	Portlandite
4	$Ca_3H_2O_{7.5}Si_{1.5}$	0.278, 0.335, 0.181	Hydrosilicate calcium
5	$Ca_9H_{22}O_{32}Si_6$	1.049, 0.262, 0.278	Janite
6	$Ca_2H_3O_{11}Si_3$	0.308, 0.297, 0.351	Tobermoryt 1.1-nm
7	$Ca_{2.5}H_{11}O_{12.5}Si_3$	0.552, 0.310, 0.301	Tobermorite 1.4 nm
8	$Ca_5H_{10}O_{22}Si_6$	0.307, 0.301, 0.279	Wedge tobermorite
9	$Ca_2H_2O_5Si$	0.287, 0.269, 0.260	HSC
10	$Ca_5H_2O_{10}Si_2$	0.303, 0.277, 0.256	GSK
11	$Al_2CaH_{10}O_{21}Si_6$	0.305, 0.275, 0.268	CHS
12	$Al_2CaH_8O_{10}Si_{12}$	0.263, 0.262	CHAS
13	$Al_{3,5}Ca_3H_{9,7}O_{12}$	0.276, 0.309	CHA

X-ray diffractometry of cement containing ultradisperse modifiers



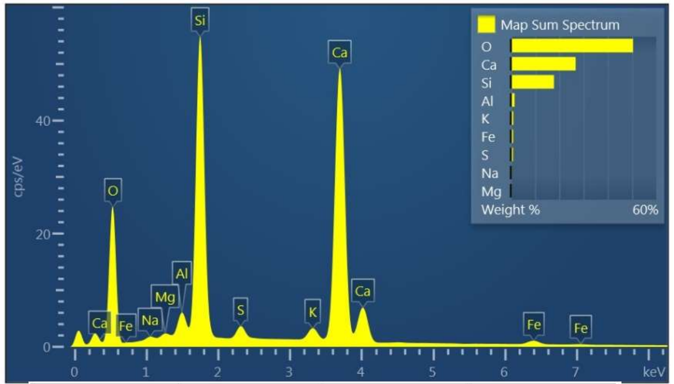
Elemental composition of concrete samples of the initial mixture according to the results of EDX analysis, and the results of energy dispersive X-wave analysis, respectively, on maps



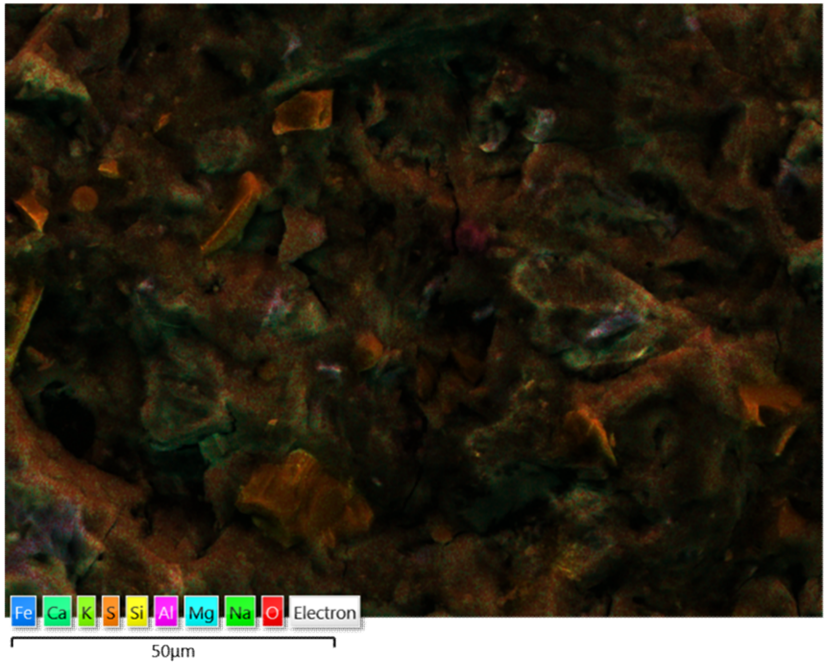
Element	Apparent Concentration	Wt%	Standard Label
C	108.28	**19.27**	C
O	285.15	**44.50**	SiO2
Na	5.13	0.45	Albite
Mg	2.27	0.21	MgO
Al	10.60	0.82	Al2O3
Si	55.79	3.86	SiO2
K	19.90	1.07	KBr
Ca	495.17	**29.03**	Wollastonite
Fe	10.54	0.79	Fe

The list of elements in the table and their percentage content indicate the presence of the vast majority of calcite $CaCO_3$ in concrete matrix No. 1. In the presence of moisture, as a result of the reaction of calcium oxide with atmospheric carbon dioxide, a layered structure with low adhesion and cohesion is usually formed. According to the EDX analysis, the fracture of concrete composite No. 1 mainly occurs in areas with high concentrations of calcite.

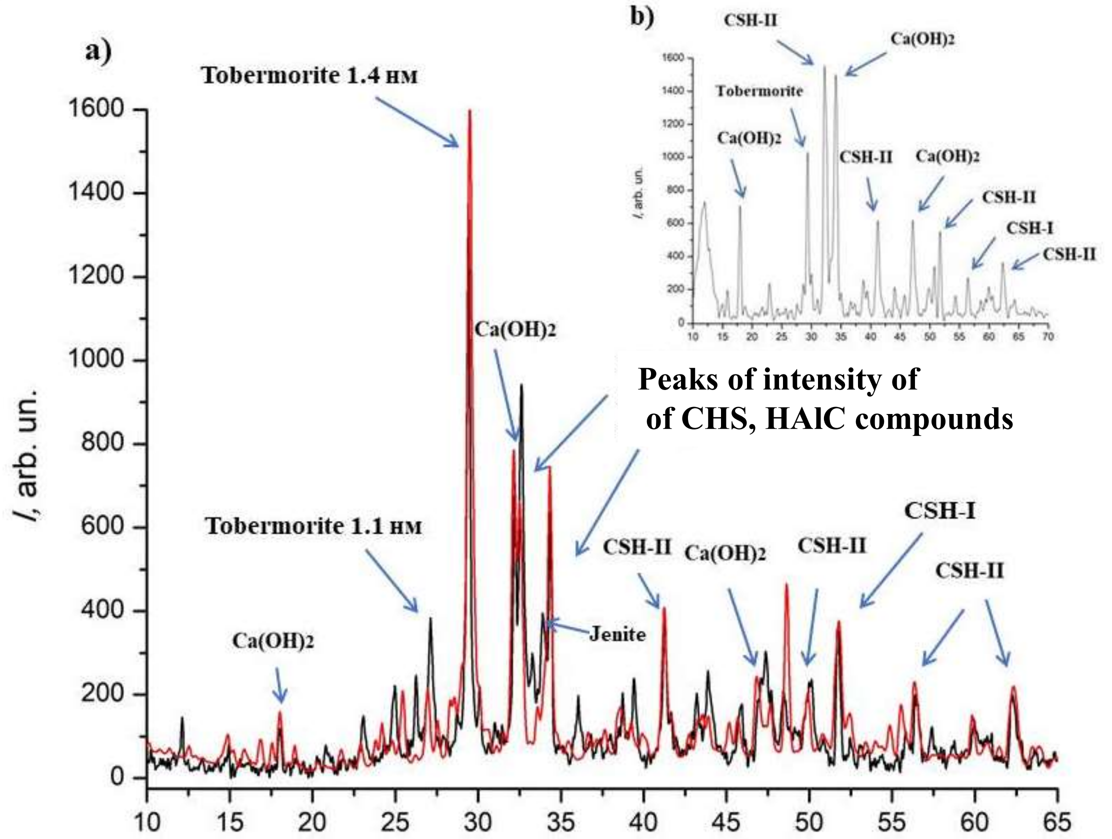
Elemental composition of concrete samples with the mixture modified by a complex based on microsilica and metakaolin EDX analysis and the results of energy dispersive X-ray analysis, respectively



Element	Apparent Concentration	Wt%	Standard Label
O	**393.92**	**50.40**	**SiO2**
Na	3.87	0.34	Albite
Mg	3.43	0.31	MgO
Al	19.98	1.52	Al2O3
Si	**257.48**	**17.81**	**SiO2**
S	12.53	0.90	FeS2
K	17.78	1.03	KBr
Ca	**439.97**	**26.75**	**Wollastonite**
Fe	12.70	0.94	Fe



The phase structure of the cement composite of formulation No. 2 is characterized by a large number of phases and their heterogeneity.The phase composition is dominated by compounds of low and high basicity HSCs, as well as unreacted microsilica particles. Probably, the significantly higher compressive strength of formulation No. 2 is associated with a more developed specific surface area of pozzolanic particles, which are able to react faster with Ca(OH)2, forming a dense microstructure.



a) - experimental (dark line) and calculated (red) diffractograms for more than a year of hydration of the compounds of the modified composite;

b) - on the 28th day of hydration of the composite.

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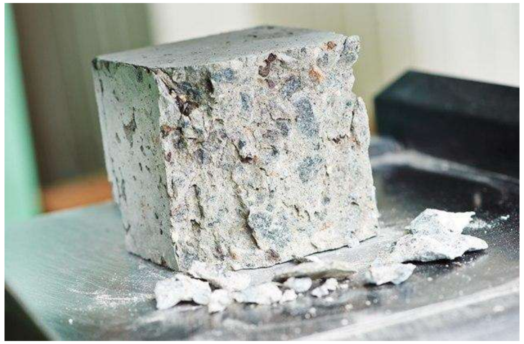
Module course 2 in IO2 - AMAZE e-toolkit manual for digital learning in producing complex design industrial parts. Ultra-high strength composites

module course 2
Smart (Intelligent) Materials

«Ultra-high strength composites»



Principles of structural strength and density, modified composites with a complex of finely dispersed additives of microsilica and metakaolin

Laboratory work #1
Production and storage of cement prisms

Laboratory work #2
Bending and compressive strength testing of cement prisms

Laboratory work #3
Preparation of a concrete sample

Laboratory work #4.
Class of concrete according to strength

Laboratory work #5
X-ray studies of cement

Laboratory work #6
Scanning electron microscopy of concrete

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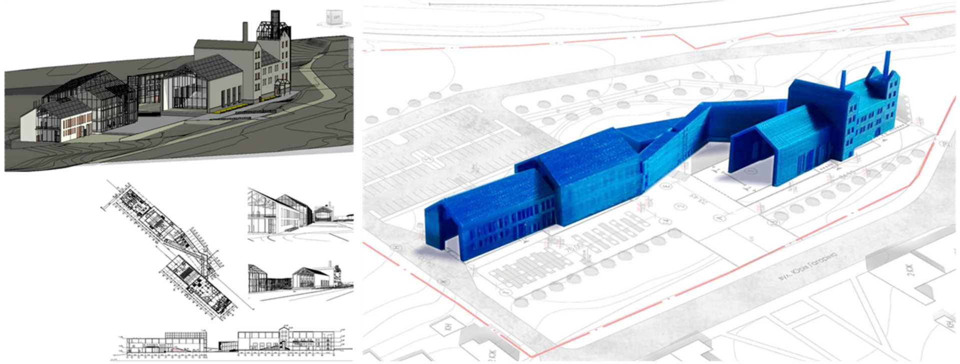
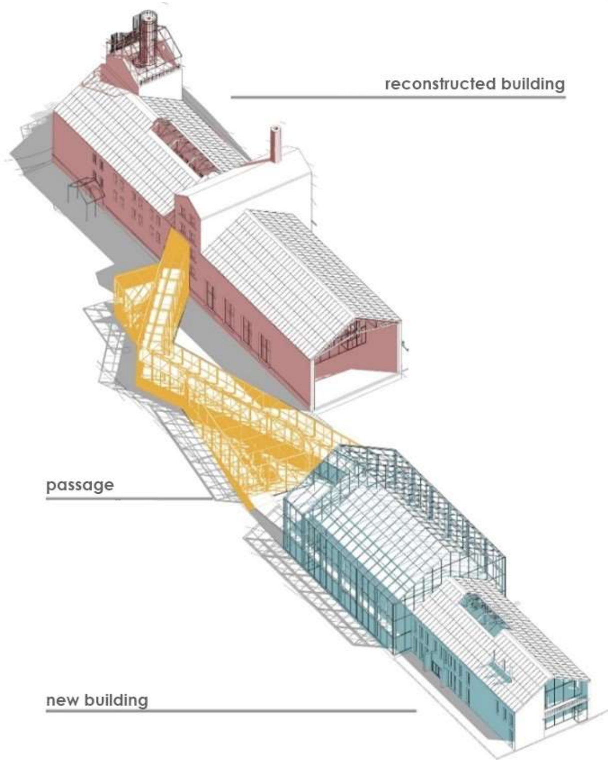
module course 3 – CAD/CAM/CAE design

Drawings in the Revit software package using BIM technologies



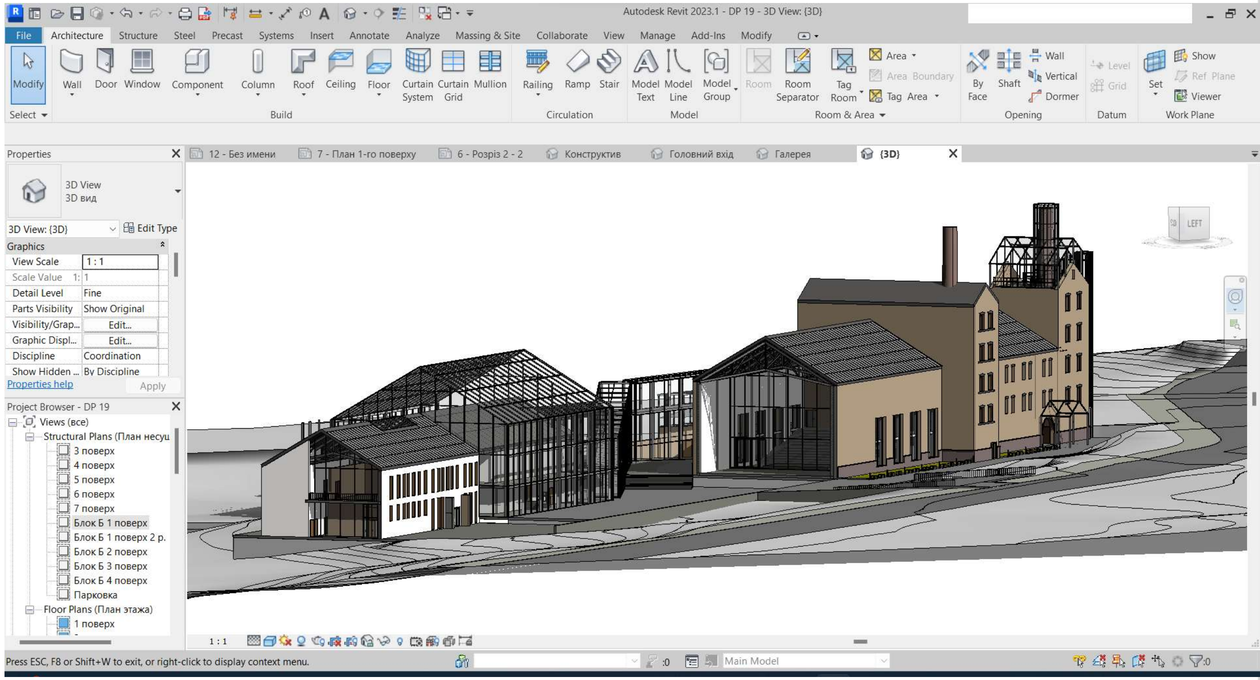
Our team developed a project for the reconstruction of a brewery in Chernivtsi using Revit software and printed it on a 3D printer.

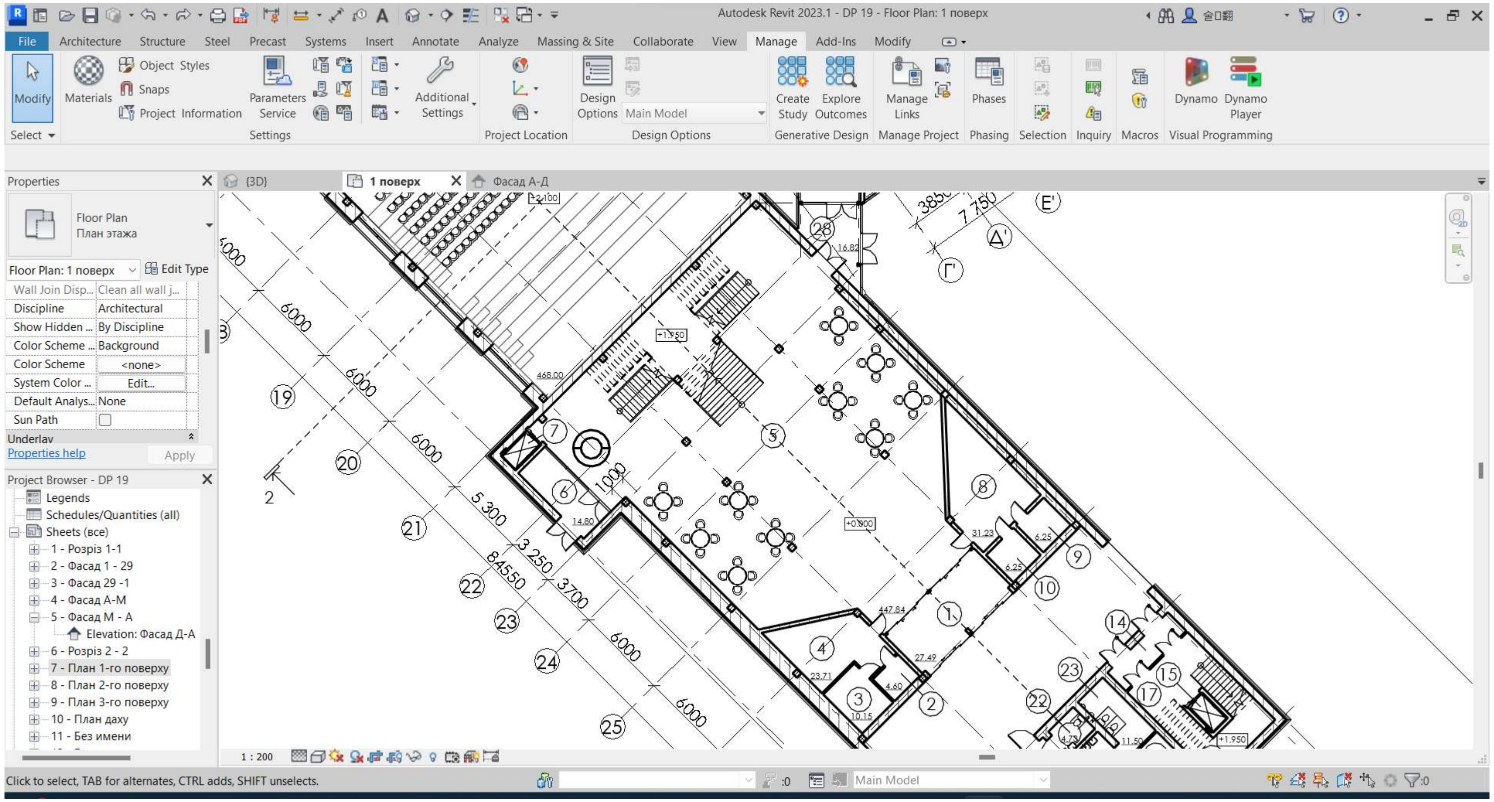
These guidelines are aimed at learning Autodesk Revit at the level that allows to build a 3D model of a building and create basic architectural and construction drawings – plans, facades, sections.

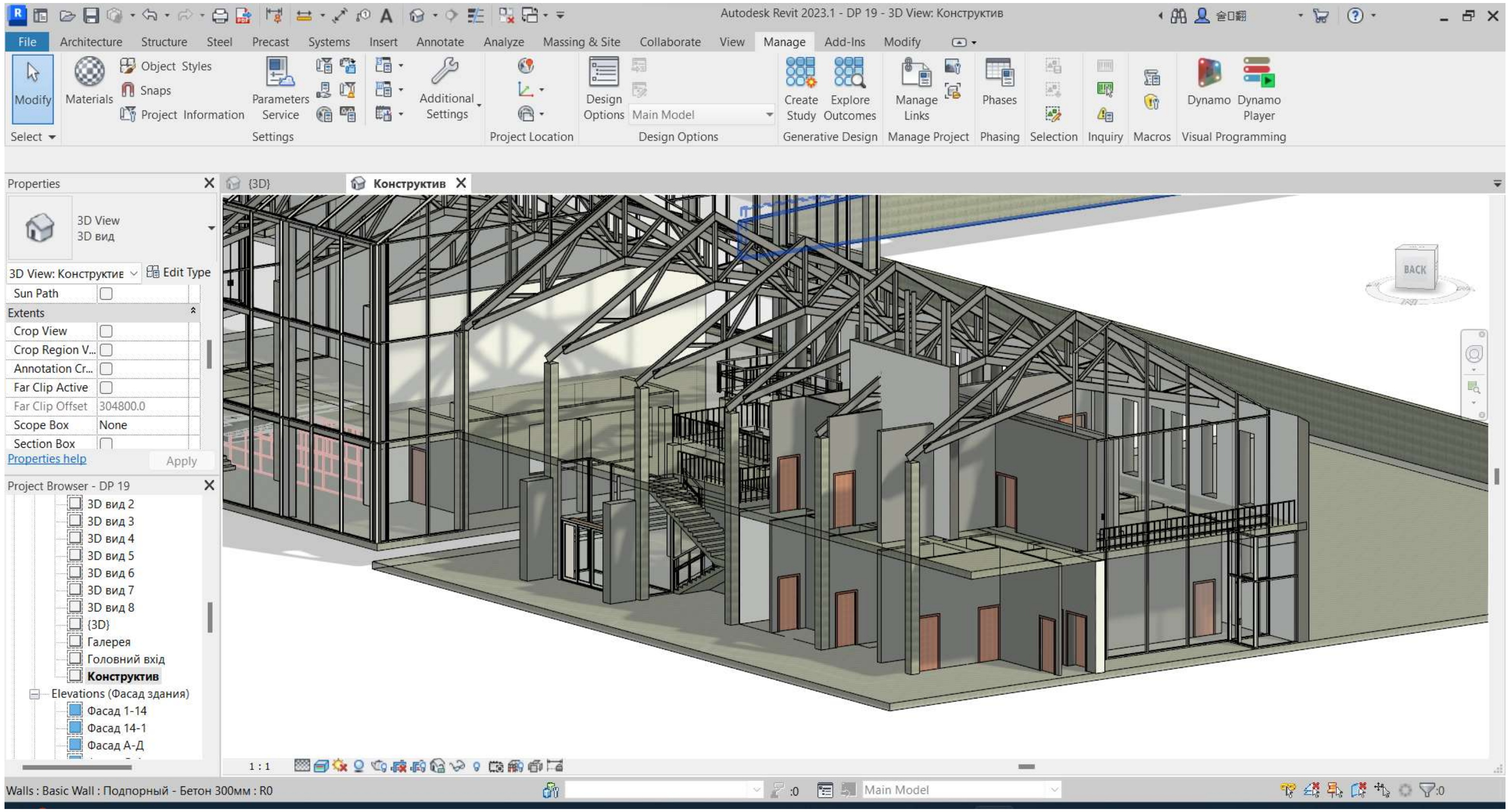


These guidelines can be used as supplementary documentation for practical training on following topics:

1. Description of the programme. Installation, interface, methods of work.
2. Setting up plan levels. Creating a grid of axes.
3. Description of walls, their characteristics.
4. Description of windows and doors, their properties. Create and configure types/styles.
5. Description of stairs and handrails, their properties. Custom shapes.
6. Description of floors and roofs. Building and editing.
7. Create a facade and section, flat and three-dimensional. Setting up the perspective view of the camera.
8. Visualisation – styles, materials and light sources.
9. Create and design Sheets. Transfer of Views (plans, facades, sections, 3D views) to sheets.
10. Create and configure text types and sizes.




Autodesk Revit 2023.1 - DP 19 - Floor Plan: 1 поверх
File Architecture Structure Steel Precast Systems Insert Annotate Analyze Massing & Site Collaborate View Manage Add-Ins Modify
Modify Materials Object Styles Snaps Project Information Parameters Service Additional Settings Design Options Main Model Create Study Explore Outcomes Manage Links Phases Dynamo Dynamo Player
Select Settings Project Location Design Options Generative Design Manage Project Phasing Selection Inquiry Macros Visual Programming
Properties
Floor Plan
План этажа
Floor Plan: 1 поверх
Edit Type
Discipline Architectural
Show Hidden ... By Discipline
Color Scheme ... Background
Color Scheme <none>
System Color ... Edit...
Default Analys... None
Sun Path
Underlay
Properties help
Apply
Project Browser - DP 19
Legends
Schedules/Quantities (all)
Sheets (все)
1 - Розріз 1-1
2 - Фасад 1 - 29
3 - Фасад 29 -1
4 - Фасад А-М
5 - Фасад М - А
Elevation: Фасад Д-А
6 - Розріз 2 - 2
7 - План 1-го поверху
8 - План 2-го поверху
9 - План 3-го поверху
10 - План даху
11 - Без имени
{3D}
1 поверх
Фасад А-Д
1 : 200
Click to select, TAB for alternates, CTRL adds, SHIFT unselects.
Main Model


Autodesk Revit 2023.1 - DP 19 - 3D View: Конструктив
File
Architecture
Structure
Steel
Precast
Systems
Insert
Annotate
Analyze
Massing & Site
Collaborate
View
Manage
Add-Ins
Modify
Modify
Materials
Object Styles
Snaps
Project Information
Parameters Service
Additional Settings
Design Options
Main Model
Create Study
Explore Outcomes
Manage Links
Phases
Dynamo
Dynamo Player
Select
Settings
Project Location
Design Options
Generative Design
Manage Project
Phasing
Selection
Inquiry
Macros
Visual Programming
Properties
{3D}
Конструктив
3D View
3D вид
3D View: Конструктив
Edit Type
Sun Path
Extents
Crop View
Crop Region V...
Annotation Cr...
Far Clip Active
Far Clip Offset
304800.0
Scope Box
None
Section Box
Properties help
Apply
Project Browser - DP 19
3D вид 2
3D вид 3
3D вид 4
3D вид 5
3D вид 6
3D вид 7
3D вид 8
{3D}
Галерея
Головний вхід
Конструктив
Elevations (Фасад здания)
Фасад 1-14
Фасад 14-1
Фасад А-Д
BACK
1 : 1
Walls : Basic Wall : Подпорный - Бетон 300мм : R0
:0
Main Model

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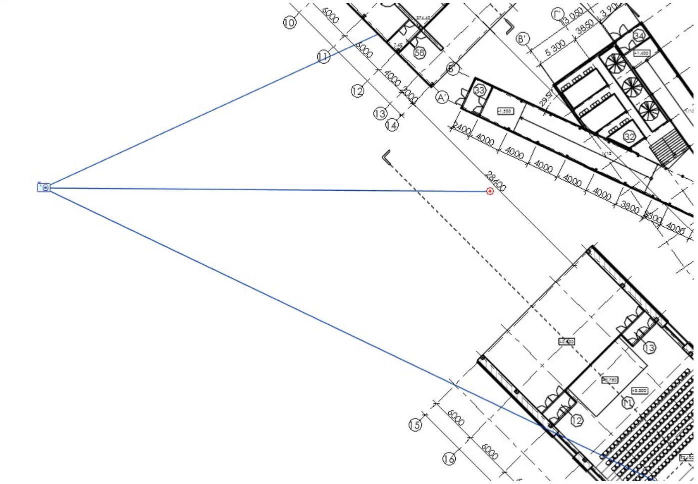

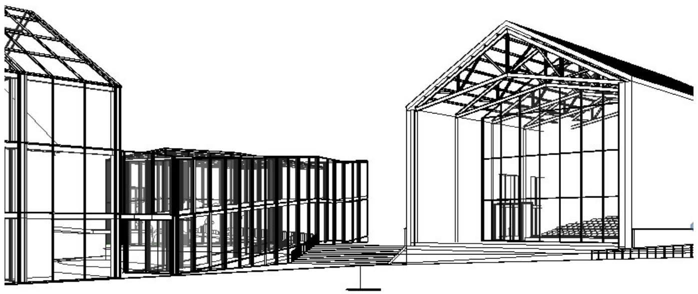

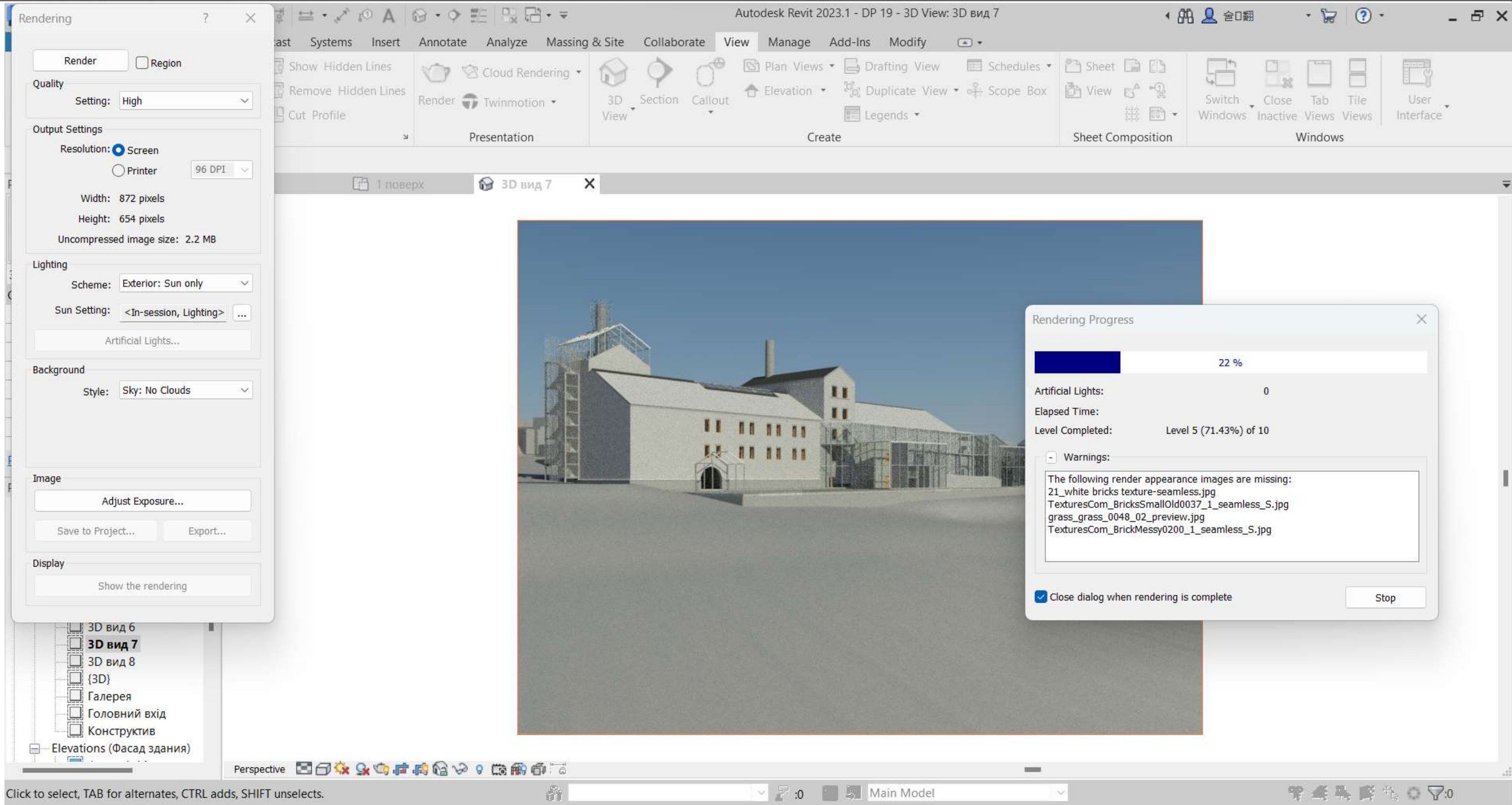

POLITEHNICA UNIVERSITY OF BUCHAREST 205 YEARS OF INNOVATION 1818

POLITECHNIKA POZNAŃSKA POZNAN UNIVERSITY OF TECHNOLOGY

ЧЕРНІВЕЦЬКИЙ НАЦІОНАЛЬНИЙ УНІВЕРСИТЕТ ІМЕНІ ЮРІЯ ФЕДЬКОВИЧА ЧНУ

edibon

IO2. Module course 3. Drawings in the Revit software package using BIM technologies

Task: Create an architectural design of a building.

It is possible to use ideas and sketches for designing a building from already finished student works.

1. Creating axes and walls:

Placement of windows, doors, openings in the walls;

Creating and editing rooms, defining areas, creating specifications.

2. Create a constructive scheme of the building:

Creating overlaps;

Placement of columns and beams;

Building a roof.

3. Creating a 3D visualization of the project:

Setting up materials and camera;

Rendering the image.

4. Creation of project documentation:

Generation of floor plans, facades, sections;

Creation of a master plan.

Co-funded by the European Union

Erasmus+ Programme Key Action 2 Cooperation Partnerships
for Higher Education (KA220-HED)
Agreement number 2023-1-RO01-KA220-HED-000155412
European Network for Additive Manufacturing in Industrial Design for Ukrainian Context
Multiplier Event 4 - Poznań University of Technology, Poznań, Poland , 4 November 2024

AMAZE Summer School

Students from Yuriy Fedkovych Chernivtsi National University

Specialities:

- ARCHITECTURE AND URBAN PLANNING
- CONSTRUCTION AND CIVIL ENGINEERING
- INFORMATION SYSTEMS AND TECHNOLOGIES

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AMAZE

ARCHITECTURE AND URBAN PLANNING

Anastasia Aurite

3th year of Bachelor program

Sofia Kolodrivska

3th year of Bachelor program

CONSTRUCTION AND CIVIL ENGINEERING

Vita Buzyniak

3th year of Bachelor program

Angelina Auziak

First year of Master program

INFORMATION SYSTEMS AND TECHNOLOGIES

Natalia Panivnyk

3th year of Bachelor program

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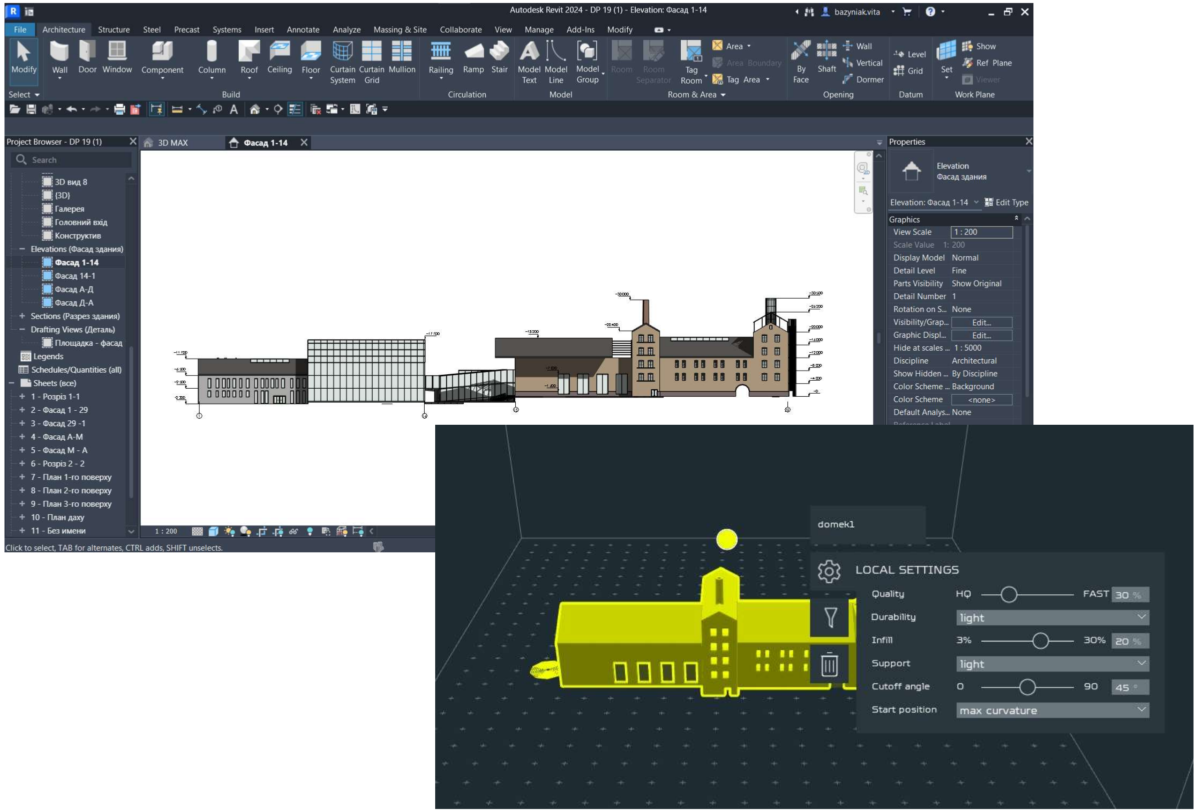
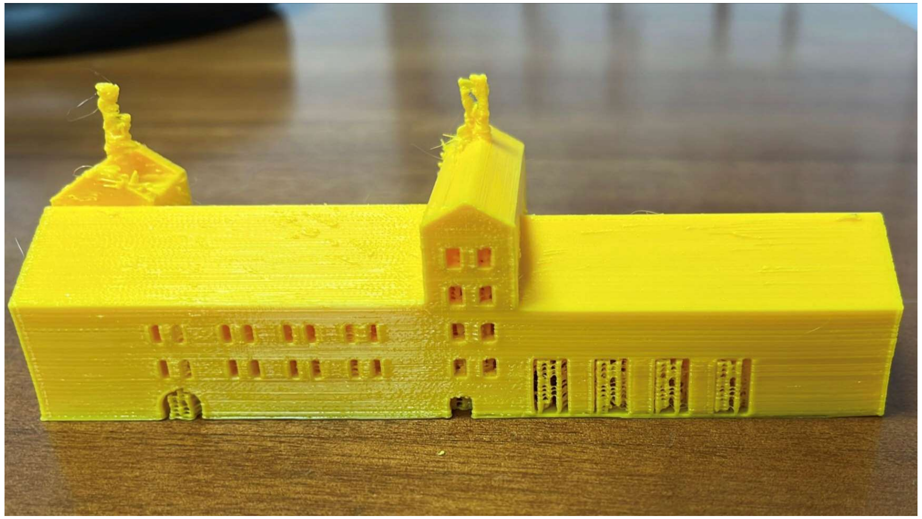


AMAZE Summer School



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AMAZE

Research of Ti-6Al-4V Alloy

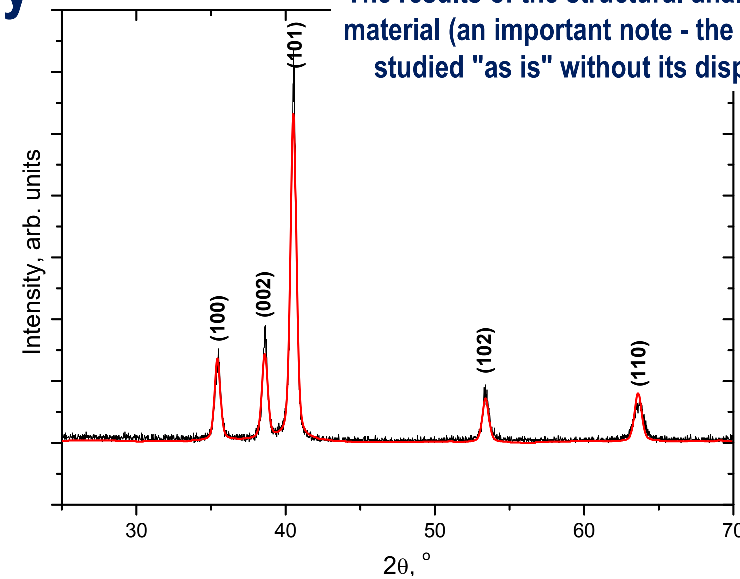
X-ray fluorescence method (an important note - the object was studied "as is" without its dispersion)

Fe	C	Si	V	N	Ti	Al	Zr	O	H	Домішок
< 0.6	< 0.1	< 0.1	3.5 - 5.3	< 0.05	86.45 - 90.9	5.3 - 6.8	< 0.3	< 0.2	< 0.015	0.3

content of industrial alloy Ti-6Al-4V

Element	Content (wt %)	
	Minimum	Maximum
Al	6.12	6.15
V	3.90	4.00
Fe	0.17	0.18
N	0.01	0.01
C	0.03	0.03
O	0.11	0.12
H	0.004	0.005
Y	0.0020	0.0021
Ti	Balance	

The results of the structural analysis of the material (an important note - the object was studied "as is" without its dispersion):

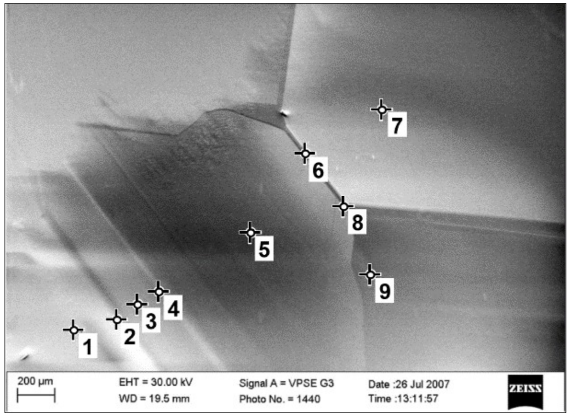


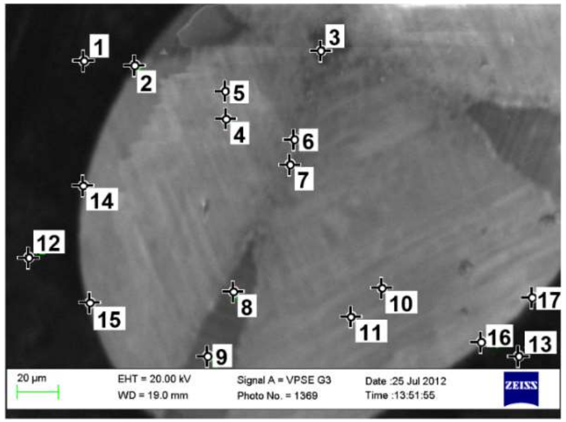
Alloy	*a*/nm	*c*/nm	*c*/*a*
Ti-6Al-4V-0.17O	0.2944	0.4677	1.58865
Ti-6Al-4V-0.20O	0.2945	0.4679	1.58879
Ti-6Al-4V-0.23O	0.2948	0.4685	1.58921

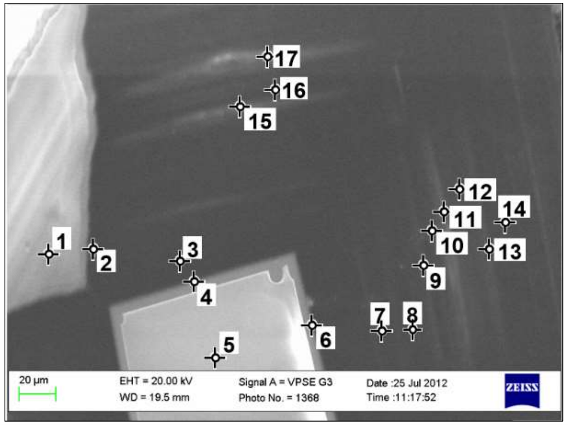
I.M. Fodchuk, S.V. Balovsyak, M.S. Solodkyi, M.D. Borcha,
Diana-Irinel Băilă, Remigiusz Labudzki, Mirian Bonilla

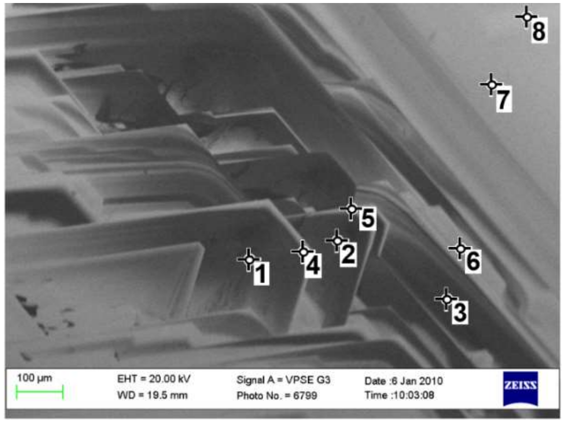
Spatial distributions of local strains in synthesized diamond crystals from the normalized parameters of Kikuchi patterns

Manuscript have been accepted for
Physics and Chemistry of Solid State
Vol. 25 No. 4 (2024)







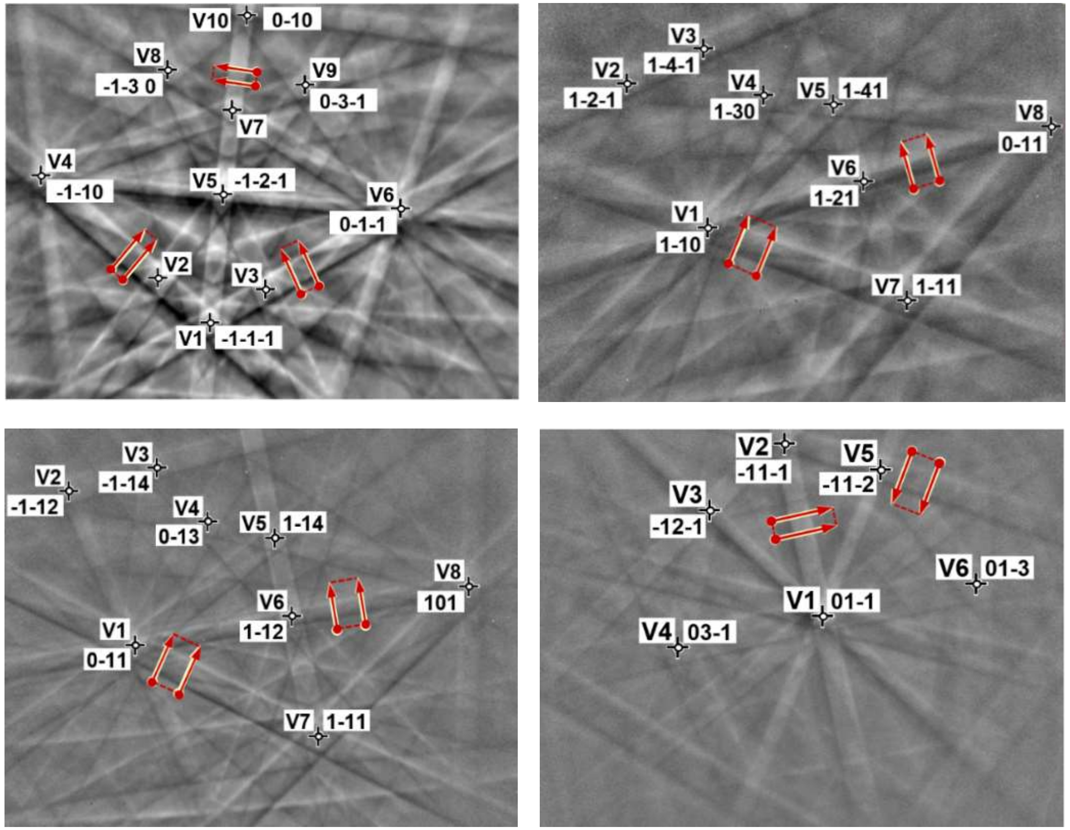


Fragments of cathodoluminescent images of artificial diamond crystal surfaces

a) sample D1(3.0×2.0 mm);
b) sample D2 (280×180 µm);
c) sample D3 (300×225 µm);
d) sample D4 (1.2×0.8 mm);

Synthesis conditions of the studied artificial diamond crystals

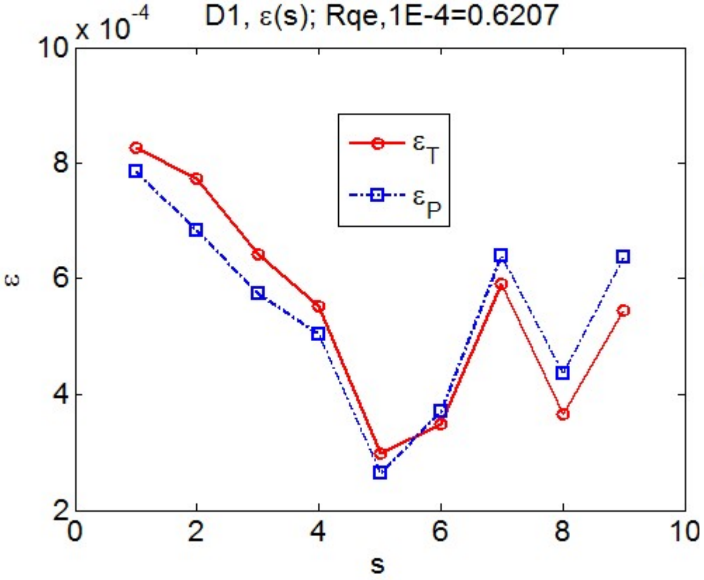
№	Sample	Temperature T, °K	Pressure P, GPa	System	Substrate
1	D1	1650	4.5-6	Fe-Co-C, Ni-Mn-C	
2	D2	1800	7	Mg-C + B	Ni-Mn-C
3	D3	1700	6	Fe-Al-C	Ni-Mn-C
4	D4	1650	4.5-6	Fe-Co-C, Ni-Mn-C	



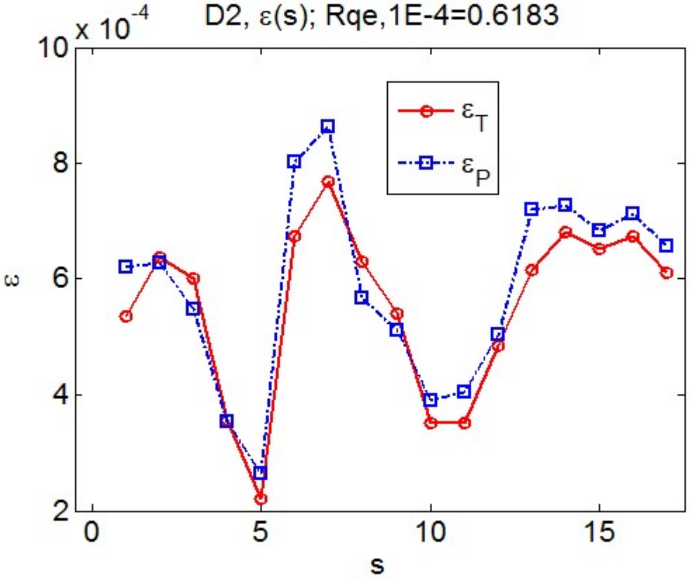
Experimental Kikuchi patterns obtained from :

a) section No. 1 of sample D1;
b) section No. 1 of sample D2;
c) section No. 1 of sample D3;
d) section No. 8 of sample D4;

The “+” markers indicate the nodes V of intersections of Kikuchi bands which correspond to direction indices (zone axes) [u v w]; the arrows show the fragments of the bands for which the profiles were calculated.



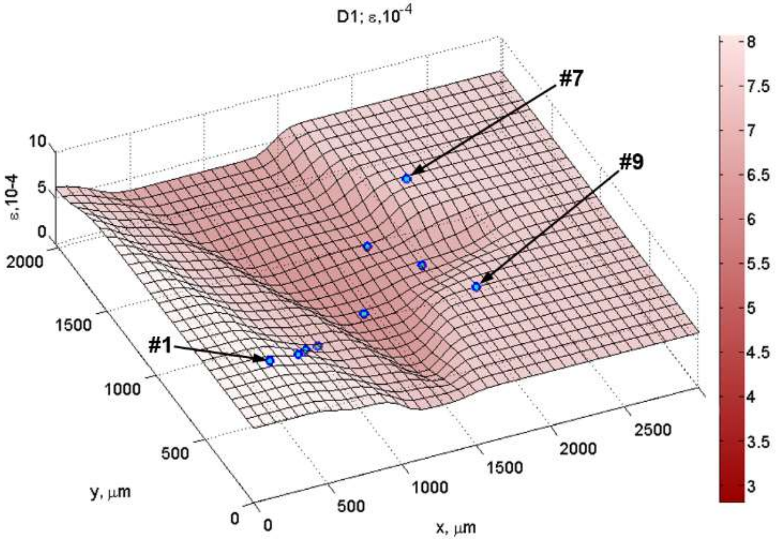
sample D1



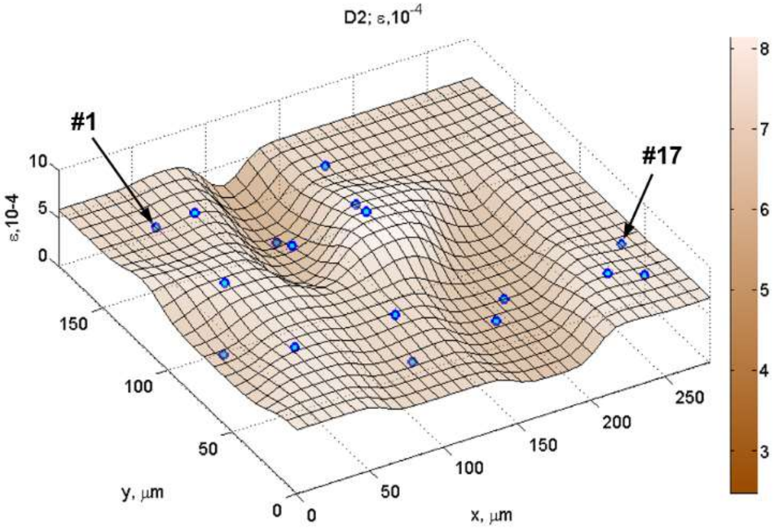
sample D2

Values of average strains ε_P calculated on the basis of the Kikuchi band profiles, and strains ε_T on the basis of the energy spectrum of the Kikuchi pattern for local sections s of crystals. Rqe is the root-mean-square difference between the values of ε_P and ε_T

Map of spatial strain distributions in the form of a three-dimensional surface for local areas of artificial diamond crystals



sample D1



sample D2

The position of areas for which the image of Kikuchi bands was obtained is shown by markers

Conclusions

1. The spatial distribution of deformations was determined for 6 samples of polycrystalline artificial diamond. Satisfactory agreement between the strain values obtained by proposed approach and by approaches of other authors indicates the correctness of the first of them for determining strains from the analysis of Kikuchi band profiles using energy spectra of Kikuchi patterns.

2. Approaches for characterization of the structure and study of the deformation state in artificial diamond crystals based on multi-beam diffraction of backscattered electrons are presented and can provide important information for controlling the technological process and predicting electrical and optical properties during the study of crystals.

THANK YOU !

MULŢUMESC !

DZIĘKUJĘ !

GRACIAS !

ДЯКУЮ !