An overview on the presentations of the 21st International Conference for Crystal Growth and Epitaxy (ICCGE-21)

The 21st International Conference on Crystal Growth and Epitaxy (ICCGE-21), co-organized by the International Organization for Crystal Growth (IOCG), the Chinese Ceramic Society, and Northwestern Polytechnical University, and undertaken by the Chinese Association of Crystal Growth and Materials, was successfully held from August 3rd to 8th, 2025, at Xi'an, China. The ICCGE series, authorized by IOCG, is a prestigious academic event with significant international influence, held every three years, in Asia, the Americas, and Europe in turn. ICCGE-21 attracted over 150 overseas representatives from 30 countries, including Japan, Russia, the United States, Germany, France, Italy, and Switzerland, and approximately 350 Chinese scholars and graduate students in the field of crystal growth and crystal materials (see Tables 5 and 6)

Analyzing on the topics and contents of the presentations in the conference may provide insight into the research achievements, development trends, and hotspots in international crystal growth and epitaxial technology over the past three years.

I. Basic Data

ICCGE-21 featured 10 invited plenary talks, presented by renowned international scholars, including Professor Hiroshi Amano (2014 Nobel Laureate, Japan), Professor Chen Xiaolong, Professor Jochen Friedrich (Germany), Professor Geetha Balakrishnan (UK), Professor Joan M. Redwing (USA), Professor Talid Sinno (USA), Professor Jeffrey Derby (USA), Professor Koichi Kakimoto (Japan), Professor Michael Heuken (Germany) and Professor Zakaria Al Balushi (USA). The content covered the preparation and device applications of wide-bandgap semiconductors like AlGaN and SiC, epitaxial technologies such as MOCVD and thin-film materials, numerical

simulation of crystal growth, and low-dimensional and quantum materials. Plenary speakers and their report titles are listed in Table 1.

Table 1: Invited Plenary Reports

Number	Speakers	Affiliation and Background	Title
1	***Prof. Hiroshi Amano***	Professor at Nagoya University, Winner of Nobel Prize in Physics in 2014	Role of Crystal Growth and Epitaxy for Bright Applications of Wide-Band Gap GaN-Based and Ultra Wide-Bandgap AlGaN-Based Devices
2	***Prof. Michael Heuken***	Aixtron SE, Germany, 2025 Laudise Prize wunner	40 years of innovation in MOCVD technology
3	***Prof. Xiaolong Chen***	Institute of Physics, Chinese Academy of Sciences, China	Recent progresses on growing SiC crystals by high-temperature solution method
4	***Prof. Jeffrey Derby***	University of Minnesota University, USA, 2025 Frank Prize winner	“Seeing what is hidden by what we see” via crystal growth modeling
5	***Prof. Koichi Kakimoto***	Tohoku University, Japan, 2025 Frank Prize winner	Collaboration of numerical and experimental studies toward understanding and control of bulk crystal growth
6	***Dr. Jochen Friedrich***	Fraunhofer Institute for Integrated Systems and Device Technology IISB, Germany	Crystal Growth, Epitaxy and Characterization of WBG and UWBG Semiconductors – Status, Challenges, Solutions
7	***Prof. Joan M. Redwing***	Penn State University, USA	Advances in MOCVD for Epitaxial Growth of Wafer-Scale 2D Transition Metal Dichalcogenide Monolayers
8	***Prof. Talid Sinno***	University of Pennsylvania, USA（on-line）	Molecular simulations as computational experiments for understanding defect clustering phenomena in bulk crystalline semiconductors
9	***Prof. Geetha Balakrishnan***	University of Warwick, UK	Advances in the crystal growth of quantum materials
10	***Prof. Zakaria Al Balushi***	University of California-Berkeley, USA, 2025 Schieber Prize Lecture	Crystal Growth at Confined Heterointerfaces

The conference consisted of 17 parallel sessions. The arrangement of sessions continued the traditional setup of the ICCGE series with appropriate adjustments, notably adding a session on thermoelectric materials. Contributions were received through personal submissions and special invitations. The program included 140 invited talks, 256 oral presentations, and 144 posters, totaling 540 contributions. Following the convention of this conference series, the duration was four and a half days. The themes and number of presentations for each session are listed in Table 2.

Table 2: Session Setup and Presented Papers

session	Topic	Invited talks	Oral	Poster
A	Fundamentals of Nucleation and Crystal Growth	10	28	9
B	Bulk Crystal Growth	10	27	27
C	Advances in Modelling Crystal Growth Processes Including AI	0	18	17
D	Thin Films and Epitaxial Growth	7	21	5
E	2D Materials and Technologies	16	8	3
F	Growth at the Nanoscale: Nanocrystals, Nanowires, Nanomaterials	12	11	1
G	Characterization of Crystal Structure, Defects, Impurities and Physical Properties	14	21	18
H	Semiconductors	9	16	15
I	Optical and Laser Crystals	8	22	13
J	Crystals of Piezoelectric, Dielectric, Ferroelectric Materials	5	9	3
K	Detector Materials	10	32	10
L	Industrial Crystallization	7	4	6
M	Crystallization of Organic and Biological Materials	0	9	3
N	Crystals for Photovoltaics and New Energy Applications	5	9	2
O	Thermoelectric Materials: Design, Synthesis, Growth and Properties	5	5	5
P	New Methods and Techniques for Crystal Growth	7	8	1
Q	Emerging Crystalline Materials	15	8	6
		140	256	144

II. Distribution of Conference Reports

The distribution of the 396 invited and oral presentations was analyzed from the perspectives of nucleation and crystallization principles, crystal growth methods, new technology applications, and crystal processing and property characterization, as detailed in Table 3.

From the perspective of crystal growth principles, 13 papers involved nucleation, with main progress including heterogeneous nucleation and nucleation specific to certain crystal materials (especially organic materials). 32 papers were on crystallization thermodynamics and kinetics, with only a few focusing on the microscopic mechanisms of crystallization.

Regarding crystal growth methods, there were 42, 7, and 31 reports on melt growth, solution (flux) growth, and vapor phase epitaxy/growth, respectively, mostly presenting research results on applying traditional methods to different and new crystals. Prominent research progress reflected in the reports included large-size Ga_2O_3 and SiC growth technologies. Additionally, the micro-pulling-down technique successfully grew 15μm ultra-fine single crystal fibers. Significant progress was also reported in microgravity crystal growth on the Chinese Space Station and crystal growth controlled by electromagnetic fields.

Numerical simulation of crystal growth processes has become a common method for process optimization. Except for coupling simulation of thermal fields, flow fields, and diffusion fields, numerical simulation is now also used to predict and optimize crystal composition segregation and crystalline defects. Computational models have evolved from 2D to 3D. Furthermore, technologies like artificial intelligence, neural networks, and machine learning are being applied to crystal growth research.

There were 38 papers on crystal structure and defect characterization, showing progress in characterizing dislocations, low-angle grain boundaries, and point defects. Over 20 papers addressed the property characterization of various crystal materials.

In the exploration of new crystal materials, the conference papers reflected abundant research achievements in recent years. Table 3 lists new crystals in fields like optics, lasers, and nonlinear optics.

Table 3: Distribution of Research Directions in Invited and Oral Presentations

Research Direction	Number of Papers	Keywords & Typical Examples
Crystal Nucleation Principles	13	Nucleation of nanocrystals on substrates; Heterogeneous vs. Homogeneous Nucleation; Heteroepitaxial Nucleation; Amorphous Aggregates as cradle of Crystal Nucleation; Protein Nucleation
Crystallization Principles (Thermodynamics & Kinetics)	32	chiral crystallization; Polymer-Induced Oriented Attachment; growth kinetics of elementary spiral steps; bunched steps on ice; Anisotropic interfacial energy and equilibrium morphology; configurational entropy in solid and liquid silicon
Melt Growth (CZ, VB, FZ, etc.)	42	
Solution (Flux) Growth	7	
Vapor Phase Growth & Epitaxy (MOCVD, MBE, Sputtering, etc.)	31	
New Crystal Growth & Process Observation Tech (EM fields, Microgravity, etc.)	17	High Temperature Material Racks and Microgravity Crystal Growth in China Space Station; metal single crystal assisted by high static magnetic field
Numerical Simulation & AI in Crystal Growth	28	Neural-Network surrogate for microstructure dynamics and crystal growth; Numerical Simulation of Impurities and Defects in n-Type 4H Silicon Carbide; Machine learning assisted design of SiC crystal growth; Artificial intelligence enhanced, sustainable growth of rare-earth materials-based laser crystals; Data-Driven Techniques; Machine Learning-Based Diameter Prediction and Critical Parameter

Crystal Processing & Surface Treatment	3	
Crystal Structure, Defects & Characterization	38	Magnetic spin textures in intercalated transition metal dichalcogenides; X-ray Topography for Dislocation; Interface diagnostics; Disordered structure; ferroelastic domains in $CsPbBr_3$; Polar Polymorph of $MAPbI_3$; Defect evolution and qnnihilation in 4H-SiC; Native Defects in GaN
Crystal Property Characterization & Application	23	
Industrial Crystallization	12	
Crystal Design & New Crystal Exploration	11	langasite Crystals; $Li_2B_4O_7$; Garnet and Perovskite; Li_2MoO_4; Electron-phonon coupling and laser wavelength extension in rare-earth crystals; BNA with high quality for broadband THz generation; laser gain single crystal fibers; Yb^{3+}-Doped Y2(Mg,Ca)$_3$(SiO_4)$_3$: A Novel Potential Ultrafast Laser Crystal; $La_2CaB_{10}O_{19}$ for Nonlinear Optical and Laser Applications; UV nonlinear optical crystal $NaSr_3Be_3B_3O_9F_4$; $Sm_xY_{1-x}Ca_4O(BO_3)_3$ for piezoelectric applications

III. Crystal Materials

The distribution of crystal materials covered in the 396 invited and oral presentations is shown in Table 4, distinguishing between papers on crystal growth and those on design, property characterization and device applications.

Overall, papers involving semiconductor materials were numerous, with significant progress particularly in the growth methods and preparation technologies of wide-bandgap semiconductors. There were also many papers on thin films and 2D crystals, and laser, nonlinear optical, and optical crystals, with several new crystals discovered.

In radiation detection crystals, progress in semiconductor detector crystals was significant, with the number of conference reports nearly matching those on scintillator crystals. There were also over 10 papers on infrared and

terahertz crystals, and about 20 papers on piezoelectric, dielectric, and ferroelectric crystals.

Thermoelectric materials were included as a session for the first time in an ICCGE conference, with 12 papers primarily focused on material design, property characterization, and application exploration.

There were 15 papers on photovoltaic materials, with 8 on silicon and 4 on perovskite materials. Additionally, there were several papers on superconducting and superhard materials. Over 20 papers covered the preparation technology and applications of nanomaterials.

Table 4: Crystal Materials

Crystal Material	Number of Papers		Typical Examples
	Crystal Growth	Design, Properties & Devices	
Elemental Semiconductors	16	3	Si, Ge, Diamond
Compound Semiconductors	14	4	GaSb, CZT, ZnMgTe, CdTe, a-GeO_2, ZnTe
Wide-Bandgap Semiconductors	36	15	GaN (8), SiC (18), Ga_2O_3 (13), AlN (4), AlGaN (2)
Thin Films & 2D Crystals	25	11	Fe_3GaTe_2, Bi_2O_2Se
Laser & Optical Crystals	15	18	BaF_2, $LiNbO_3$, Diamond, LGSB, CNGG, $Bi_4Si_3O_{12}$, $KBe_2BO_3F_2$, $Pb_2P_2O_7$
Nonlinear Optical Crystals	9	12	$LiNbO_3$, $Na_6Si_3F_{18}$, Rare Earth Iron Garnet and Perovskite, KDP, KBBF, $La_3Ga_{5.5}Nb_{0.5}O_{14}$, Electron- phonon coupling and laser wavelength extension in rare-earth crystals, Er:CaF_2 Single-Crystal Fibers for Mid-Infrared Laser, $(C_5H_5N_3O_2)_2$ $ZnCl_2$
Semiconductor	9	13	$CsPbBr_3$, PbO-base crystal, $CsPbX_3$,

Detector Crystals			Ag_3SbS_3, $Cs_3Cu_2I_5$:Tl, $NbOCl_2$, Unipolar Perovskite, CdMgTe, RE_2SiO_5
Scintillator Detector Crystals	6	18	Ce:$(Lu,Y)_2SiO_5$, $CsPbBr_3$, $Na_2Mo_2O_7$, $TlSr_2Br_5$: Eu^{2+}, Lu_2O_3, $CsPbBr_3$, $LaCl_5$: Ce^{3+}, LYSO, GAGG, $Mg_4Ta_2O_9$, Cs_2ZnCl_4, $Cs_2LiLa(Br,Cl)_6$:Ce
Infrared & Terahertz Crystals	6	7	Acentric Barium Chalcogenides, InAs-based type-II quantum wells
Piezoelectric, Ferroelectric, Dielectric Crystals	6	13	$LiNbO_3$, $LiTaO_3$, PMN-PT, KNN , PPKTP, $Sm_xY_{1-x}Ca_4O(BO_3)_3$
Thermoelectric Crystals	1	11	Bi-Sb-Te, $TlBiSe_2$, N-type PbSe, $Mg_{4.8}Ag_{1.4}Sb$, Ag_2Se, Pb(Se/Te) , SnSe
Photovoltaic Crystals	1	15	Si (8), Perovskites (4)
Superconducting Crystals	3	3	$La_3Ni_2O_7$, Re_3Ge_7
Superhard Crystals	4		Al_2O_3, BN(2)
Organic & Biological Crystals	6	7	
Nano & Low-Dimensional Crystals	21	9	Carbon Tube, nanoparticle, nano –wire, SnO_2 nanocrystals for gas sensor applications
Total	178	159	

IV. Conclusion remark

The 21st International Conference on Crystal Growth and Epitaxy (ICCGE-21), lasting four and a half days, concluded on August 8th, 2025, after completing all agenda items. The total number of officially registered participants was 496. The number of overseas attendees was lower than previous conferences. However, Chinese participation was enthusiastic, contributing approximately 70% of the presentations and attendees.

We compiled the content of the 396 invited and oral presentations across the 17 sessions and the involved crystal material distribution, presenting it to colleagues in the crystal growth field. It is hoped to evoke memories for the attendees and attract the attention of those who couldn't participate for various reasons, potentially helping their scientific research work.

Due to limited time and limited perspective, the focused points and content may not be appropriate, and there might be errors in the statistics and summary. Nevertheless, we venture to present the data, believing interested colleagues will discerningly identify its validity. If it holds any reference value, it would be our great satisfaction.

Table 5: Paper presented in ICCGE-21 by countries

Country	Paper presentd
China	244
Japan	39
Germany	11
Poland	11
France	9
Italy	9
South Korea	7
United Kindom	7
India	6
USA	6
Russia	5
Spain	5
Switzerland	5
Algeria	3
Austria	3
Chinese Taipei	3
Belarus	2
Canada	2
Romania	2
Serbia and Montenegro	2
Singapore	2
Belgium	1
Hong Kong, China	1
Kasakhstan	1
Kindom of Saudi Alabia	1

Qatar	1
Republic of Korea	1
Sweden	1
Total	390

Table 6: Participants registratered by Countries

Country	Paper presentd
China	347
Japan	46
USA	10
Poland	9
Germany	8
Italy	8
South Korea	8
France	7
Switzerland	6
Romania	6
Russia	5
Canada	5
Austria	5
Spain	3
Belarus	2
Netherland	2
Armenia	1
Qatar	1
India	1
Australia	1
United Kindom	1
Belgium	1
Israe	1
Singapore	1
Sweden	1
Total	486