Organic electronics

2005 2010 2015 2020 2025 2030 2035 2040

Market

R&D

Devices
Ultralow impact on ecology, new devices

Physics
Stricture control, organic/inorganic hybrid, device modeling

Spectroscopy
3D measurement, high resolution spectroscopy

E-paper
Organic LED lightening
3D electron microscopy
3D structural characterization
Flexible OLED displays
Photo-sensors
Nano-Rheology
Organic memory
Soft matter displays
Flexible modules
Mobile
Ubiquitous
Flexible processors
Power generations
Near-field spectroscopy
IR absorption, Raman
Chemical/Biochemical sensors
Large-area sensors
Large-area actuators
Sheet-type computers
Organic lasers
Organic RFIDs
Bio-displays

Ecology
Recycle
Ambient
High efficient
Electronics

M. Iwamoto (TIT), K. Kudo (Chiba), K. Nakajima (TIT), T. Sassa (Riken), H. Kaji, (Kyoto), A. Fujii (Osaka), Y. Yoshida (AIST), T. Yamada (NICT), M. Onoda (Hyogo), M. Ichikawa (Shinshu), Y. Noguchi (Chiba), S. Naka (Toyama), T. Someya (Tokyo)
Organic LEDs

Establishment of Fundamental Science of Amorphous Organic Materials
- Precise Analysis of Molecular & Aggregated Structures (AFM, IR, NMR, Quantum Chemical Calculation)
- High Luminance & High Mobility
- Long Life Time
- Design & Fabrication of New Materials

Establishment of Organic Device Engineering
- Elucidation of Carrier Injection, Carrier Transport, and Light Emission Properties at the Molecular Level (Science for Inorganic-Organic, Organic-Organic Interfaces)
- Reduction of Non-Radiative Process
- Fabrication of New Device Structures

Development of Fabrication Techniques of Organic Devices
- From Dry to Wet Process, Layer-by-Layer & Composition-Gradient Devices by Wet Process
- Control of Molecular Orientation, Realizing Interfaces with Molecular-Level Flatness,
- Control of Impurities, Improvement of Light-Output Efficiency
- Realizing Long Life Time by Materials & Device Degradation Analysis
- (Improvement of Sealing Technology, Device Fabrication Technology, Development of Atmospheric Stable Materials)

Soft Material Displays
Bio-Displays
Environmental-adapted, Super-high Performance, Low-cost, Super-low Power Consumption, Sealing-free Organic LEDs
Development for Organic Molecular Devices
Built-in into Organic Molecular IC

Organic LEDs for Large Screen Displays
Organic LEDs for Lighting
Bio-Displays

Market Deployment for Practical Use

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Polymeric Nano-Materials

nano-alloy
nano-composite
element technology
basic research
development

nano-material
functionality, dimensionality, nano-particle, control of spatial distribution

process technology
environmental friendly, recycle, mass-production

physics
structural control, hybrid interface control, model calculation

evaluation technology
three-dimensional analysis, high-resolution properties measurement, high-resolution spectroscopy

fabrication technology
micro-phase separation of block/graft copolymers thermo-plastic elastomer nano-template reactive processing dynamic vulcanization & devulcanization mass production, recycle

marketing
in situ & sol-gel methods high performance by nano-scale distribution organic & inorganic hybrid materials
dendrimer, nano-particle sensor, catalyst, drug delivery system

evaluation technology
high-resolution laser microscopy & spectroscopy IR adsorption Raman, etc.
dendrimer, nano-particle sensor, catalyst, drug delivery system

3D electron microscopy
3D structural analysis elemental analysis

atomic force microscopy
nano-rheology nano-tribology

NMR/X ray/NEXAFS microscopies

high-resolution near-field microscopy & spectroscopy IR adsorption Raman, etc.

high-resolution 3D microscopy with chemical analysis capability

2005 2010 2015 2020 2025 2030 2035
Organic Solar Cell

- Thin-Film-Type
- Dye-Sensitized-Type

**Efficiency**
- Functional Materials
- Purification Technique
- Tandem Structure
- Hybrid Material
- Photo-Sensor

**Lifetime**
- Stability
- Printing Mass Production
- All Plastic
- Charge Storage
- See-Through

**Mobile Ubiquitous**

**Flexible Module**

**Large Panel, Energy Industry**
- Low Cost
- Artificial Photosynthesis
- Energy Environment
- Design
- Saving Energy and Resources
- Building Material
- Agriculture
- Automobile
- Space
- Home • Industry

**Printing Mass Production**

**See-Through**

**Charge Storage**

**Artificial Photosynthesis**

**Stability**

**Saving Energy and Resources**

**Printed Materials**

**See-Through**

**Large Panel**

**Energy Environment**

**Design**

**Low Cost**

**Functional Materials**

**Artificial Photosynthesis**

**All Plastic**

**Design**

**Space**

**Home • Industry**

**Agriculture**

**Automobile**

**Building Material**

**Artificial Photosynthesis**

**2005 2010 2015 2020 2025 2030 2035 2040**
Organic nonlinear optical materials

**KEY FEATURES**

- Synthetic design of molecules considering total environments
  - Control of inter / intra molecule interactions taking effect of an external electric field
  - Progress of computational chemistry, development of new organic synthetic approach

**MARKET**

- Progress of long distance optical communication technology
- Progress of short distance optical communication technology
- Progress of mobile electronic devices

**Launch of**

- Polymeric PR materials
  - High speed image correlators
  - Free space interconnected devices

- Organic wavelength converting materials
  - High efficiency wavelength convertors

- Organic Kerr materials
  - All optical ultra high speed switching devices

- Polymeric EO materials
  - Low voltage high speed optical modulators $\geq 100$ GHz

- Organic TPA materials
  - 3D-shaped high dense optical devices

**Application to**

- Satellite communication, THz optics, etc.
- Light diagnostics

**Novel optoelectronic devices with totally new concepts**

**Ubiquitous network society**
Organic transistors

Research & Development

Materials: Air stable, High mobility, Solution processable, Self-assembling

Processes: Ultralow impact on environment, from top down to bottom up

Devices: Organic/inorganic hybrid, device modeling, new structures

Circuits: New architecture, large-area circuit design

New application

- Organic memory
- Flexible OLED display
- Organic photovoltaic
- Large-area sensors
- E-paper
- Chemical/biochemical sensors
- Flexible processors
- Sheet computers
- Organic RFID
- Large-area actuators

Ambient electronics

Timeline:
- 2005
- 2010
- 2015
- 2020
- 2025
- 2030
- 2035
- 2040
Molecular Devices

Integration with calculation model (ex. Cellular automaton)
Integration with photonic structures

Self-organization

Development of fundamental devices
- Molecular single electron transistor
- Molecular spin devices (commutator, memory)
- Molecular single photon light source
- Molecular single photon detector

Integration and high-efficiency

Energy saving in systems utilizing the manifold of molecular devices
- Molecular computer
- Molecular memory with high density
- Molecular information- and communication- systems

Molecule- and biomolecule- sensing

Fabrication technique

Observation technique

2005 2010 2015 2020 2025 2030 2035 2040
Characterization

X-ray, Neutron
Electron, Ion

3rd Generation SR
μ-beam: 100μm
J-PARC

Spectroscopy
IR, NMR, ESR

Super resolution
spectroscopy
R=100 nm

Ultra-fast microscopy
R=10 nm

Ultrahigh Magnetic field NMR

Probe Microscopy

Multiple SPM
Microscopic electric measurements

High-speed AFM

Molecular manipulator

Rheology, Heat Dielectric

Micro thermal analysis

Micro rheometer (MEMS)

Molecular thermometer

Molecular rheometer

Structural analysis
of single molecule

Electronic state analysis
of single molecule

Molecular movie

Motion analysis
of single molecule

Ultimate characterization
(single molecule)

Process monitor
(from synthesis to devices)

Up-grade

In situ Multiple

Structural and electronic state analysis of buried nano-interface

Self-organized process

Ultra-fast reaction and relaxation process

Molecular movie

Molecular motion

Film processing control

Synthetic processing control

Combinatorial characterization

SPRING-8

4-probe electric measurement

Ultrahigh Magnetic field NMR

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Interfacial geometrical engineering for organic molecular electronics

Aim of construction of new engineering techniques for design of organic devices

Although the interfacial geometric engineering has been brought under cultivation as academic sciences in the future, it gives birth to essential engineering technologies for the development in a branch of new engineering in the 21 century will be expected.
Molecular electronics / Process

<table>
<thead>
<tr>
<th>Step</th>
<th>Dry</th>
<th>Wet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>Small</td>
<td>Large</td>
</tr>
<tr>
<td>Resolution</td>
<td>Low</td>
<td>High</td>
</tr>
</tbody>
</table>

- Spin-coat
- Evaporation
- Ink-jet process or other print process
- Self-assembly
- Nano-imprint lithograph
- Roll-to-Roll process

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