FLOSFIA

Company Profile

FLOSFIA Inc.

1. Company Profile

FLOSFIA is a startup spun out from KYOTO University, to commercialize the MIST CVD technology

FLOSFIA's Corporate Profile

Founded in March 31, 2011

Head Quartered in Kyoto University, Katsura Capmus

Business areas include Power Oxide semiconductor devices and Mist EPITAXY solution

Founded by Toshimi HITORA（CEO）, Kentaro KANEKO, Ph.D.（CSO） Shizuo FUJITA

Co-developed with Kyoto University, Advanced Electronic Materials (Fujita Lab) , Ritsumeikan Univ., Electrical & Electronics Eng (Araki Lab)

Share holders include T Hitora, K Kaneko, S Fujita, UTEC, Nissay capital, Brother etc

2. Power Device Market Issue

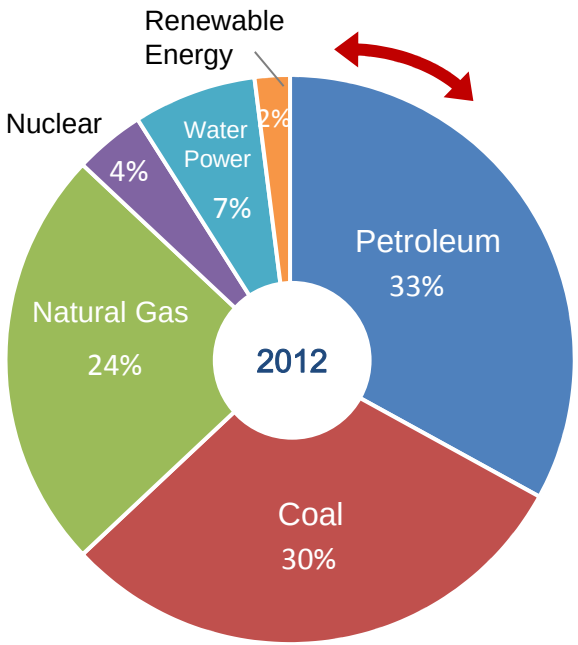
Enormous power conversion loss from generation to consumption: a major social concern
Low-loss and low-cost power devices being essential for the solution

The power device industry trying hard to achieve such a low-loss and low-cost power device
("Pain" in the current industry)

- Power conversion loss being a major social concern

- Proposals of SiC and GaN: limited in application due to Si ratio (5x to 10x) and high cost

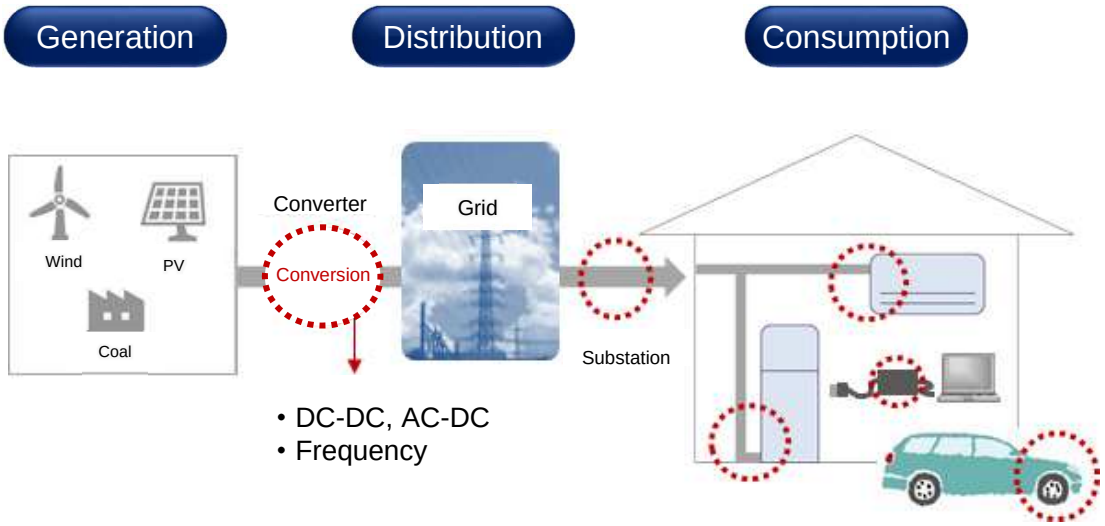
Power conversion loss
: 10% (to 50%)



Source: "FY 2012 Annual Report on Energy" by the Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry of Japan

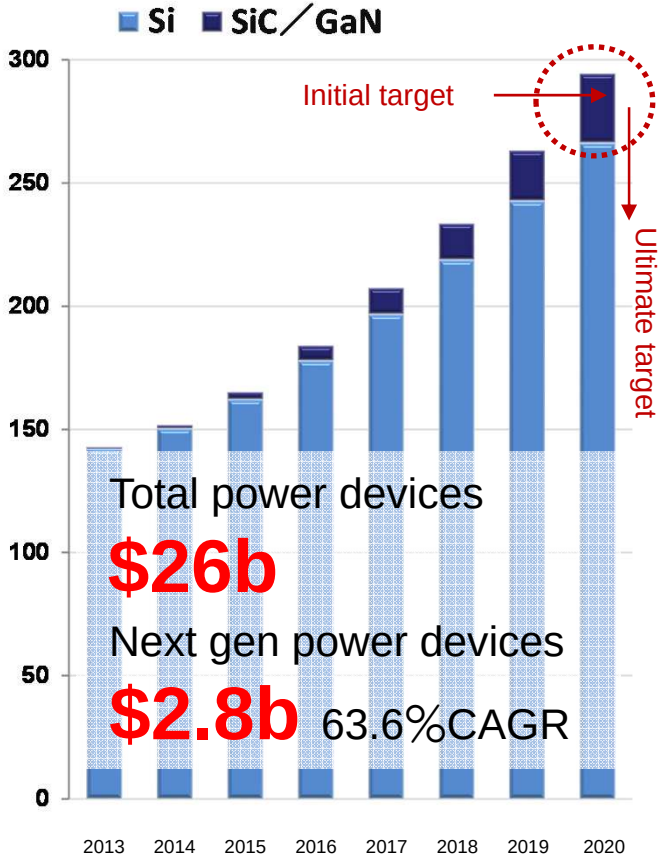
3. Our Goal

Market pain: More than 10% of all electricity is ultimately lost due to conversion inefficiencies of silicon power devices.



- Great expectations for a low-loss and low-cost power device
- Difficult to achieve such device by extension of existing technology (SiC and GaN).

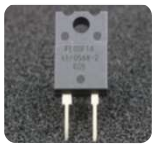
Global power device market



Source: "Power semiconductor global market research 2014" by Yano Research Institute Ltd.

FLOSFIA can target not just $2.8b next gen market but also $26b silicon market

FLOSFIA 's solution: Gallium oxide power devices



4. Property Comparison with Competing Materials

Ga_2O_3: excellent material compared with Si, SiC, GaN

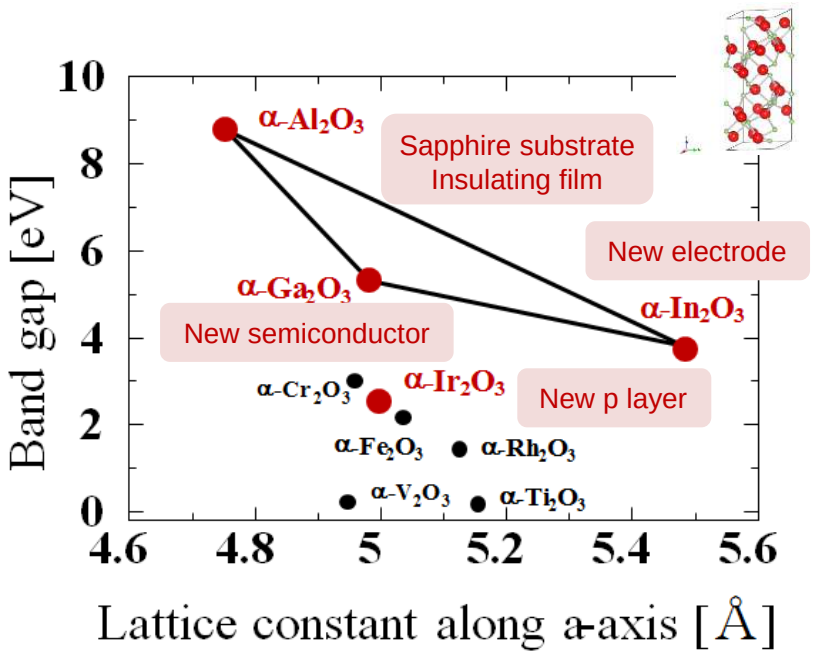
Ga_2O_3 including various crystal structures; α-Ga_2O_3 having advantageous physical properties

Name of material		Si	4H-SiC	GaN	β-Ga_2O_3	α-Ga_2O_3 (Corundum structure)
Bandgap Eg (eV)		1.1	3.3	3.4	4.5	5.3
Mobility μ (cm²/Vs)		1,400	8,000	1,200	200	300 (estimate)
Dielectric breakdown field Ec (MV/cm)		0.3	2.5	3.3	6.5	10 (estimate)
Relative dielectric constant		11.8	9.7	9.0	10	10 (estimate)
Baliga's figure of merit Si = 1	Low frequency ($\varepsilon\mu E_c^3$)	1	340	870	1,231	6,726 (estimate)
	High frequency (μE_c^2)	1	50	104	67	238 (estimate)

5. Benefits of Corundum Structured Gallium Oxide (α-Ga_2O_3)

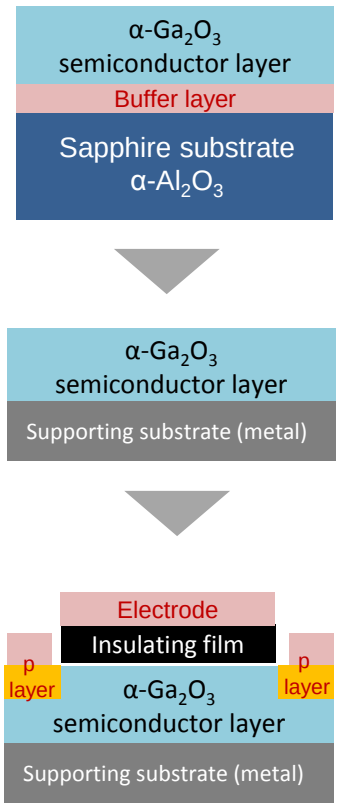
FLOSFIA : committed to corundum structured (α-) gallium oxide
Use of families allowing earlier commercial production, ensuring high reliability and reduction in resistance!

Corundum structured (α-) families



Fabrication of corundum families other than sapphire used to be difficult.
➡ A breakthrough made with "mist CVD" from Kyoto Univ. Achieving high quality crystals of various corundum families using sapphire!

Corundum families used for high quality devices at competitive prices



Using sapphire (Al_2O_3) substrate

- Mass produced as LED material
- Priced comparably to Si
- Great advantage of using commercially available substrates
  Competing materials taking 20-30 yrs. for substrate development

Improving device quality

- Corundum families applied to electrodes, insulating films, p layers, the mixed crystal technique, etc. for construction of a plenty of device element processes

Successfully fabricating prototype diode (SBD) using α-Ga_2O_3 to achieve world top-level data

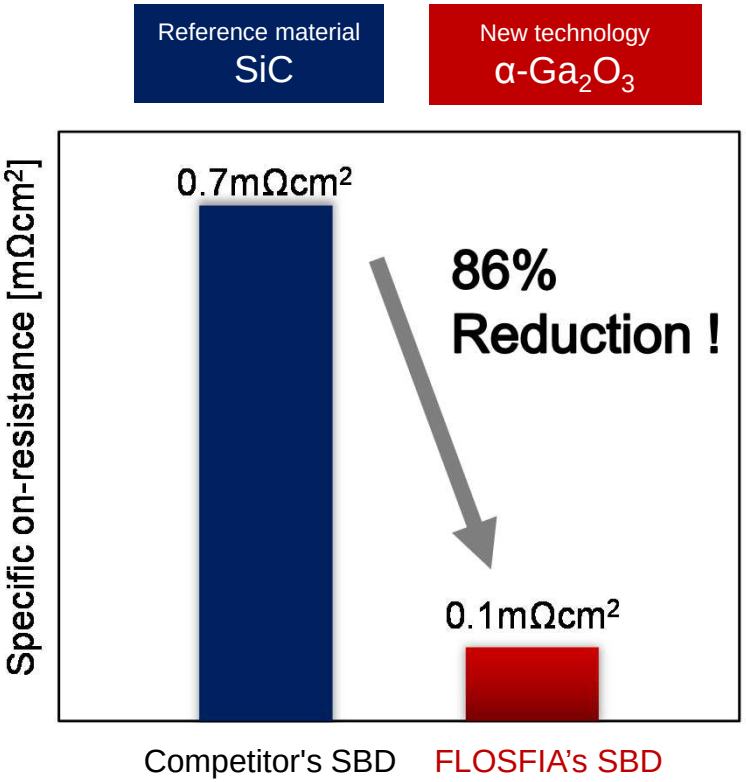
Ultra-low loss

Reduction in on-state loss

Demonstrated world top-level data (October, 2015)

(Experiment with 30 µm φ microchip: approx. 0.01 A)

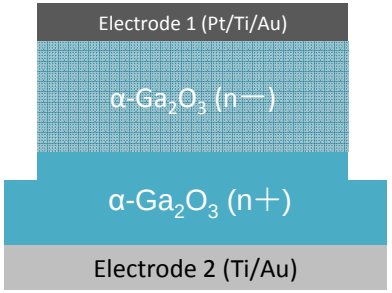
Power devices requiring 5+ A current



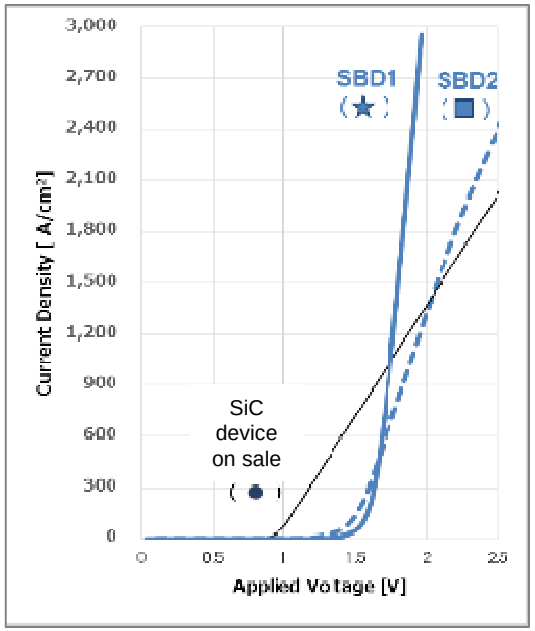
6. Our Achievements [Loss Reduction: Reduced On-State Loss]

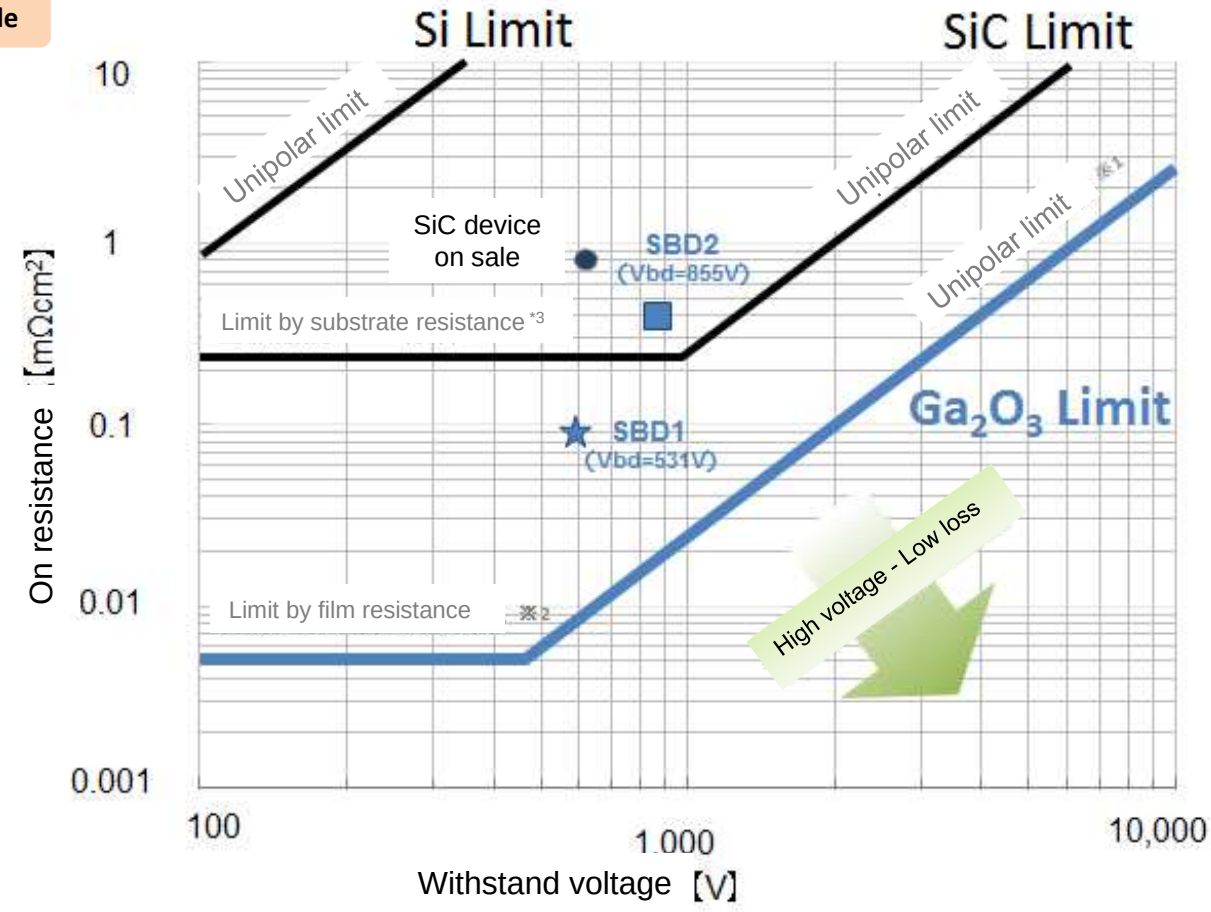
Succeeded in production of prototype diode (SBD) of α-Ga_2O_3!

Success in prototyping low on-resistance diode



[Current Density - Voltage Characteristics]





*1 Premises: mobility of 300 cm²/Vs, dielectric breakdown field of 8 MV/cm, relative dielectric constant of 10
*2 Assumed with a thickness of 20 μm based on actual values on mobility and carrier temperature
*3 Assumed with 50% reduced resistance by thinning a SiC wafer on sale

←The threshold voltage can be reduced.

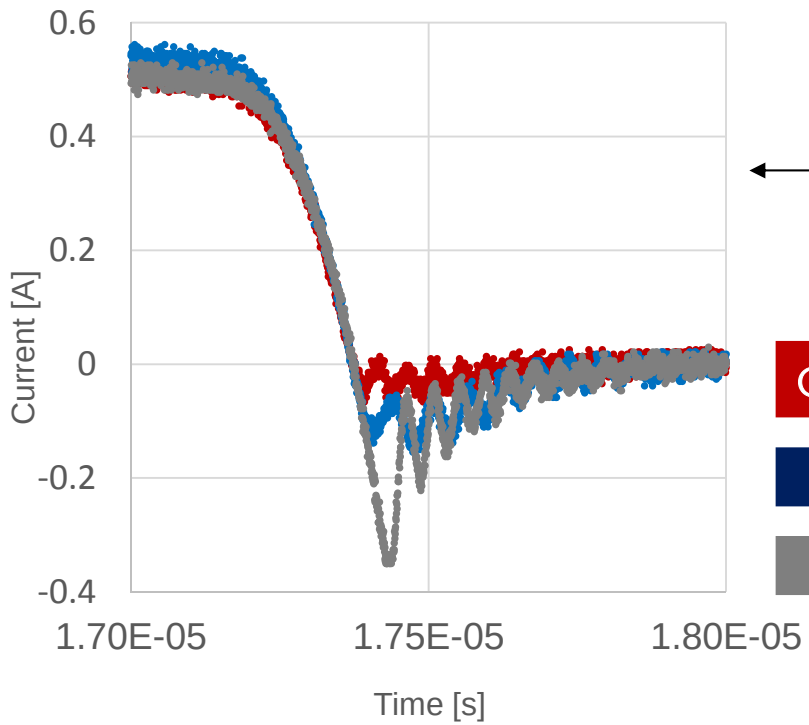
3-5. Our Achievements [Loss Reduction: Reduction in Switching Loss]

Prototyping, including implementation, and evaluation in progress. Much faster switching speed than Si, expected to reduce the switching loss in the circuit implementation.

Patent Pending

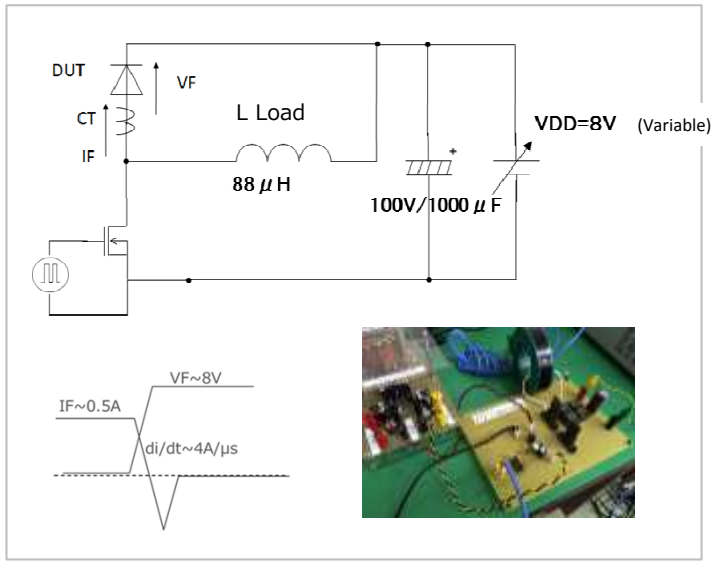
Ultra-low loss Reduction in switching loss

Fast switching verified in an implemented device (TO220)



Capacitance

Ga_2O_3	130pF
SiC	370pF
Si	200pF



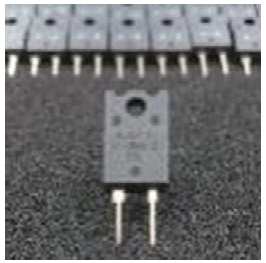
Thermal resistance same as commercial devices confirmed in Ga_2O_3 implemented SBD!

Overcoming material problems

Successfully reduced thermal resistance

Patent Pending

- Original device structure achieving thermal resistance same as commercial SiC-SBD in packaged sample (TO220)
- Ga_2O_3 layer not being a bottleneck in thermal resistance



New technology
α-Ga_2O_3

13.9°C/W（TO220）

0.8°C/W (Ga_2O_3 layer)

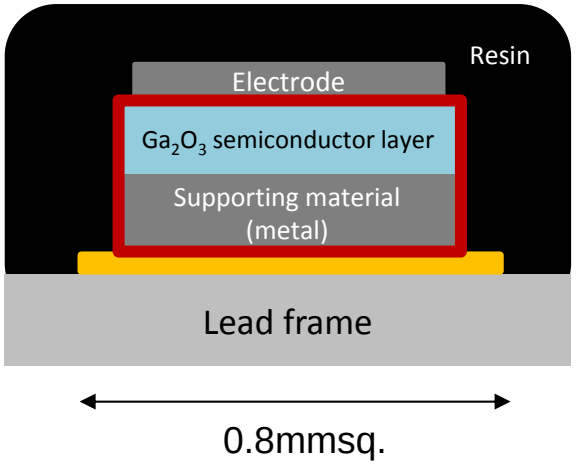
Assumption: thermal conductivity of 20 W/mK (estimated from β-Ga_2O_3 data),
chip size of 0.8 mm sq., thickness of 10 μm

Ref.

Reference material
SiC

12.5°C/W（TO220）
(Competitor's SBD)

Device structure



- Using Ga_2O_3 thin film (10- μm)
- Using supporting material(metal) (Good heat dissipation, low on- resistance, ease of handling)

6. Our Achievements [Overcoming Material Problems: New Approach for P Layer]

Discovery of p-type corundum structured material "α-Ir_2O_3" for device integration in combination with α-Ga_2O_3 ➡ Breakthrough to the world's first normally off FET (2nd device) !

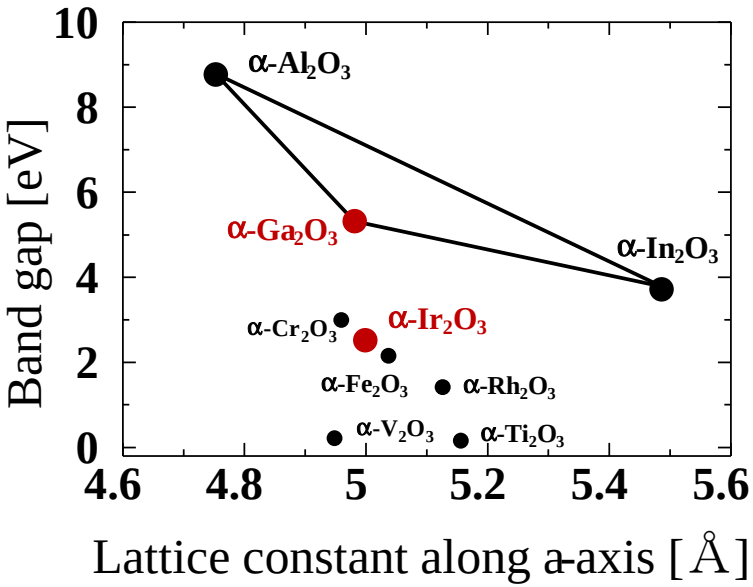
Overcoming material problems

Discovery of p-type corundum structured material "α-Ir_2O_3"

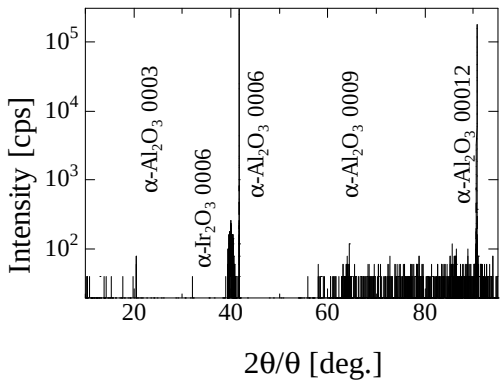
Patent Pending

- Lattice mismatch between Ga_2O_3 and Ir_2O_3 as small as 0.3%
- Confirmed high Hall mobility of 2.3 cm^2/Vs (carrier concentration of $1.0 \times 10^{21}/cm^3$) by measuring the Hall effect
- Mist CVD available for film deposition

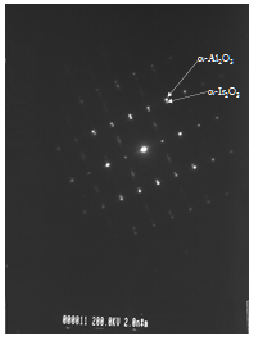
α-Ir_2O_3 and other corundum family materials



XRD profiles



Diffraction spots



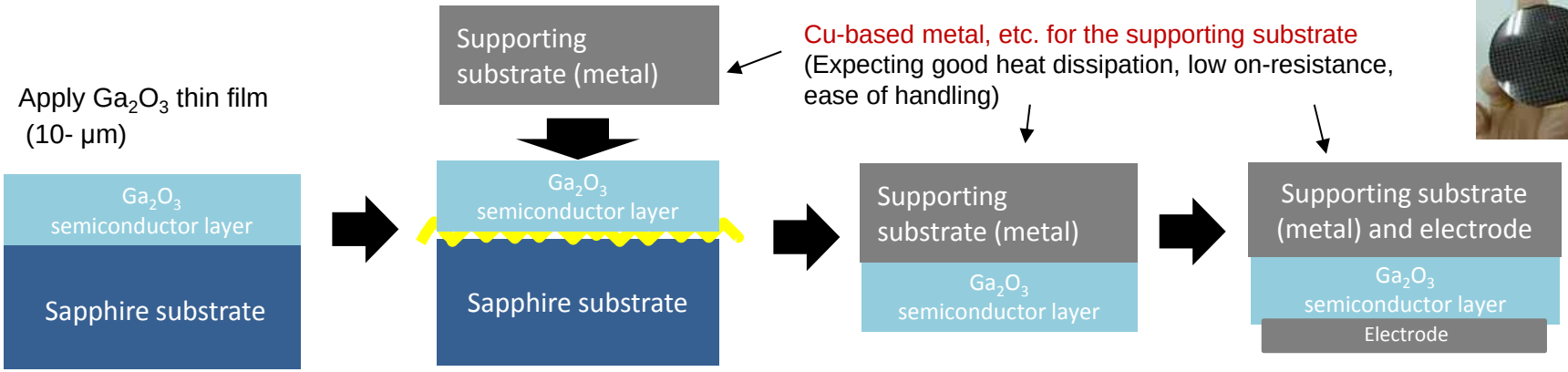
6. Our Achievements [Development of Production Process]

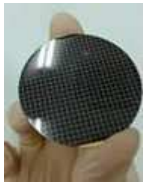
Successfully developed mass production basic technology using Ga_2O_3 thin film and supporting material (metal)!

Production process development

Successfully launched wafer process by developing a new production method applicable to mass production

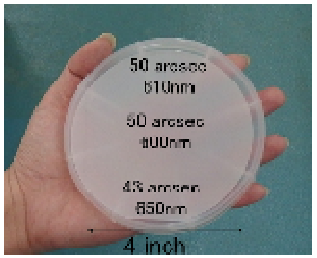
Patent Pending





1) High quality crystal **Inimitable**
The original technology, mist CVD, enables high quality Ga_2O_3 semiconductor

2) Enlarged diameter **Inimitable**
Succeeded in crystal growth to the mass production size of 4 in.



1) Minimizing R&D **Earlier commercial production**
Using mass produced sapphire substrates, no need for the long-term (10-20 yrs.) substrate development!

2) Achieving vertical devices* **Taking advantage**
Removing the sapphire substrate as an insulator

* Vertical device
A structure with electrodes on both sides of the chip to enable higher current

Thermal conductivity issue addressed

1) Good heat dissipation
Minimizing thermal resistance (less than SiC) by thinning the film
Turning low thermal conductivity into an advantage!

Taking advantage

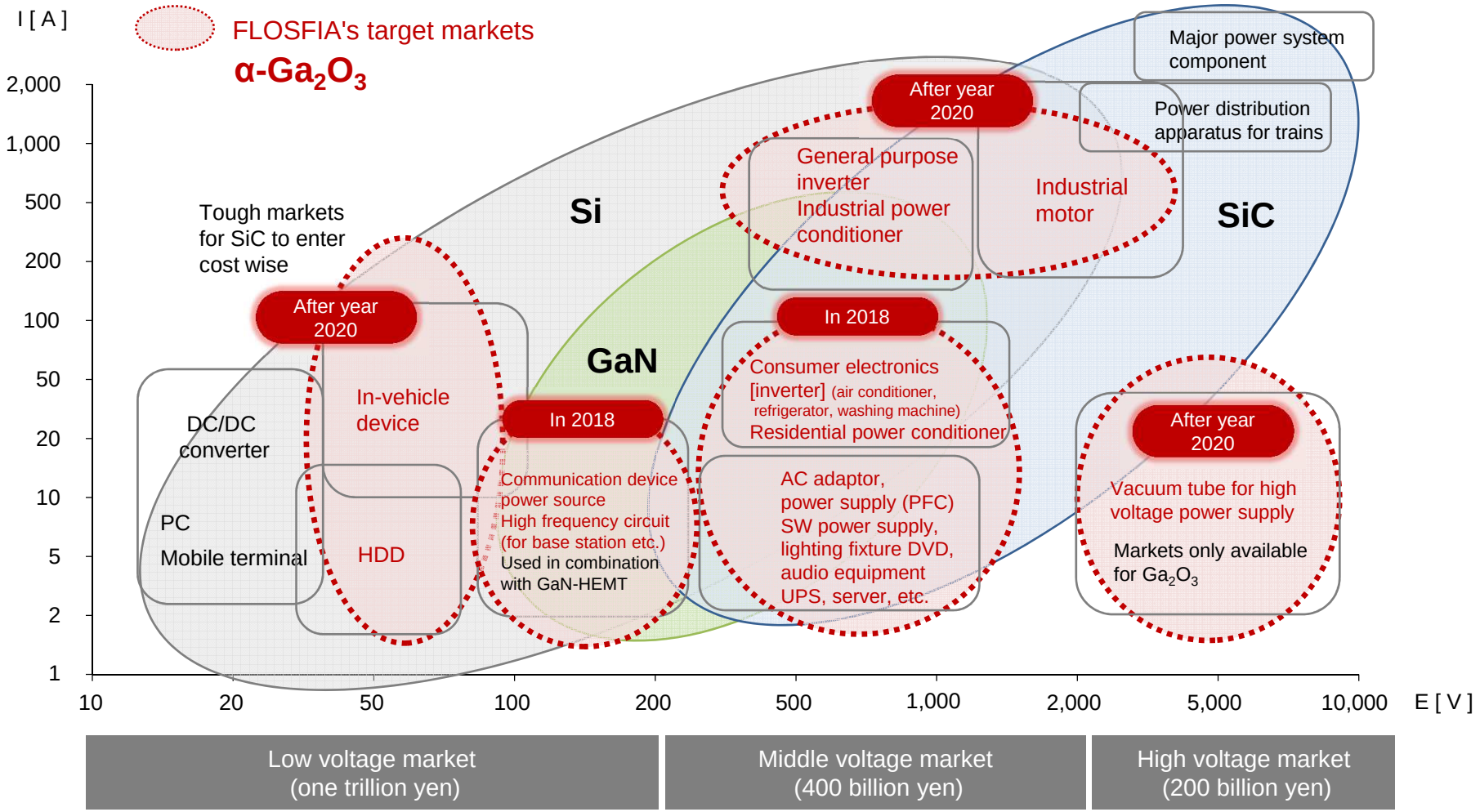
2) Low Substrate Resistance
Reducing the resistance to 1/50 - 1/100 of SiC substrate (commercial product)
Minimizing substrate resistance, as a bottleneck in the resistance of vertical devices

Meeting the market needs

3) Incomparably low cost
1/3 (for the same chip area) - 1/10 (for miniaturized chip) of SiC

7. Business Plans [Business Areas]

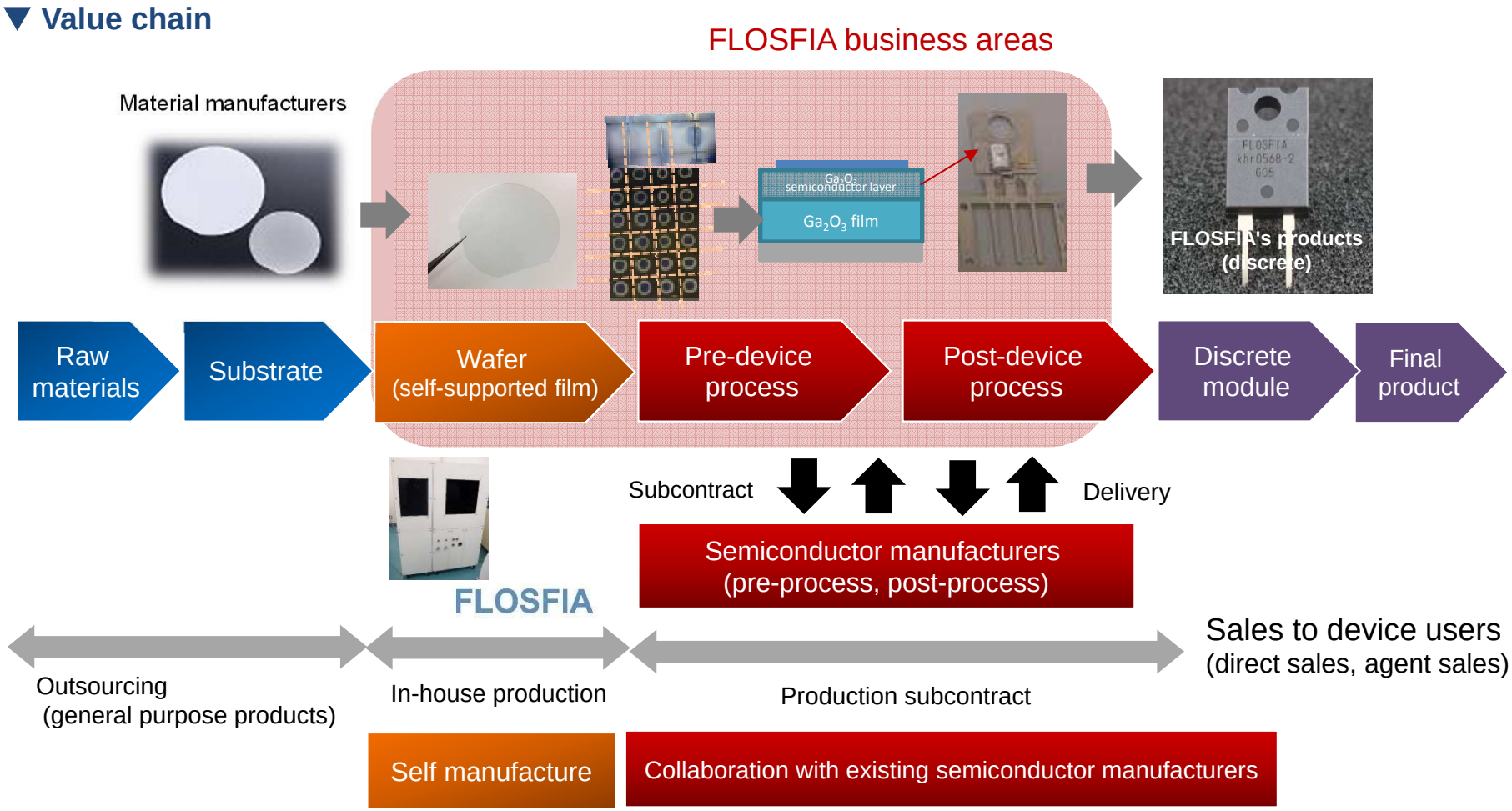
Aim to win a position in the commercial market. To be the most preferred material by taking advantage of low loss and low cost! Further aiming at the "high voltage market" by making use of the superior material properties, at the "low voltage market" by making use of cost competitiveness!



8. Business Model

Final product: semiconductor device including diode (SBD). Wafers to be produced in-house to establish key technology. The other processes in cooperation with external fabricators.

▼ Value chain



9. Mist CVD

Employing mist CVD, enabling good-quality corundum family production

Conventional CVD

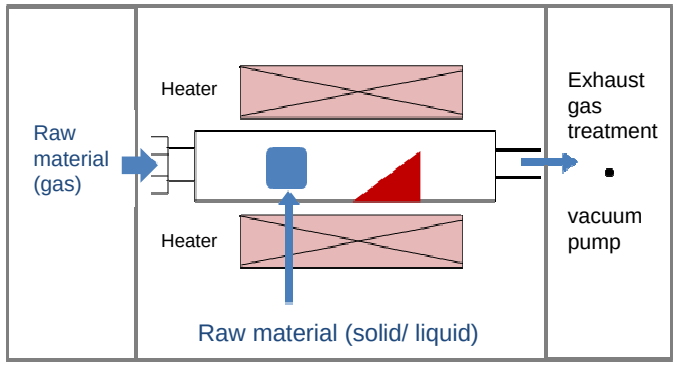
Our Core Technology — Mist CVD (MIST EPITAXY®)

Semiconductors made from gas (common practice)

Raw materials supplied to a deposition chamber as a gas
➡ Raw materials limited to those with a boiling point lower than the deposition temperature
Raw materials being hazardous

Semiconductors made in vacuum (common practice)

Vacuum pump needed
➡Limitation in area increase, high in costs, difficulty in miniaturization

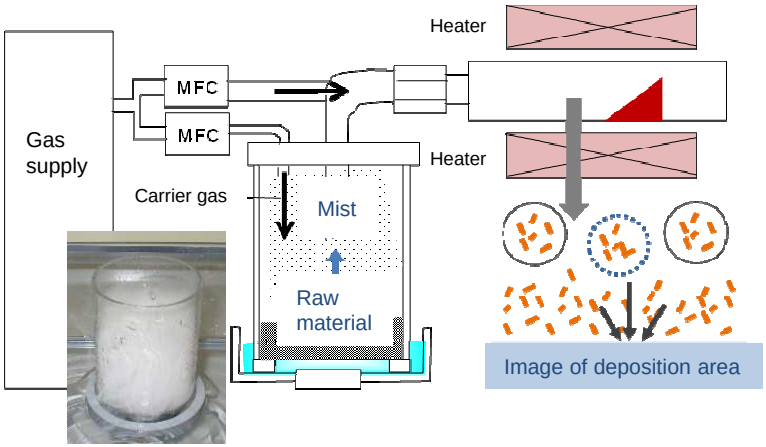


Made from liquid, particularly "water" (innovative!)

Raw materials supplied to a deposition chamber as a mist
➡ Successfully producing corundum families of good crystal quality for the first time. Widely developed in dopants and mixed crystals.

Made in non-vacuum (innovative!)

No vacuum pump required
➡ Achieving area increase, cost reduction, miniaturization, and high throughput



10. Film Deposition Solution Business I (Features of Mist CVD)

Mist CVD allowing fabrication of various metal oxide films ➡ to wide range of industries!

Metal oxide film fabricated on sapphire ➡

▼ State of film

Single crystal, polycrystalline, amorphous

▼ Type of film

Other metals are available for film deposition. Feel free to make an inquiry.

Metal oxide examples fabricated by mist CVD

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	lanthanoid	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Actinoid	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Uut	Uuq	Uup	Uuh	Uus	Uuo

Metal oxide film	Application examples
Gallium oxide	Power device
	LED substrate
Iron oxide	Semiconductor, magnetic material
Chromium oxide	Corrosion resistant film, protective film
Silicon oxide, aluminum	Insulating film

Metal oxide film	Application examples
Magnesium oxide	Insulating film
Copper oxide, nickel	P conductive layer of oxide PV
Titanium oxide	Photocatalyst
Indium oxide	Transparent conductive film for displays
Lithium oxide	Positive electrode, negative electrode, electrolyte of LIB
Zinc oxide, tin oxide	Electrically conductive transparent film for displays

11. Our Team [Representative Profile]

Leading the power device business since appointed representative of FLOSFIA with experience on product marketing in the previous career

Toshimi HITORA

Next generation semiconductor business frontier

[Academic Background]
March 2000: Completed molecular developmental biology course, Graduate School of Bioscience, Nara Institute of Science and Technology
March 1998: M.S. in Applied Biochemistry, Department of Industrial Chemistry, Graduate School of Engineering, Kyoto Univ.

June 2012 Representative director, President of ROCA Inc. (Currently, FLOSFIA Inc.)
Participating the business operations of ROCA Inc. (Currently, FLOSFIA Inc.) as one of the founders since its establishment in March 2011.
Joined the firm after resignation of the former representative due to the change in the business domain after challenging for the seawater desalination market.
Made a decision to target super energy saving power semiconductor device by applying our proven gallium oxide semiconductor deposition technology to the power semiconductor fields.

2005 - June 2012 Representative director, President of ALGAN Inc.
Founded the firm as the representative director and the president for application of aluminum gallium nitride semiconductor to UV sensors. After successfully developed a sensor device, applied products of the sensor also successfully developed. The applied products employed for, for example, production apparatuses by the world's leading company in the liquid crystal panel cleaning device field. Also offered commercial UV sensors to the market, resulting in adoption by NTT Docomo, a Japanese leading mobile telecommunication company, etc. Took part in the Intel Global Challenge (global business plan competition) on this topic, won the Asian district award (Intel-DST) and nominated as one of the finalist.
Left the position at the completion of the first prototype for smartphone cooperative system.

We wish to help innovation by green and clean technology and create products that contribute to society.

FLOSFIA

We would like to be an organization where diverse intelligence and wisdom (Sophia) flow to sophisticate the Sophia and flow it back to society for better daily life.
We named the company "FLOSFIA" from such thoughts. Our goal - intelligence and wisdom coming in to benefit everyone by creating new values - is just like a flow of river. We keep striving for creating superior value to society through each project as collected intelligence and wisdom.