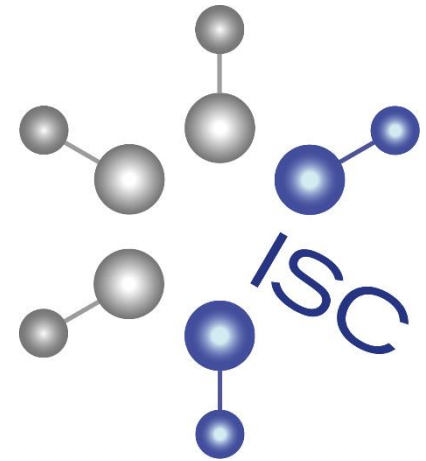




INTERNATIONAL
ELECTROTECHNICAL
COMMISSION



Graphene Standardization: Key Success Factor for Graphene Industrialization

Graphene 2018 – Industrial Forum, June 28, 2018

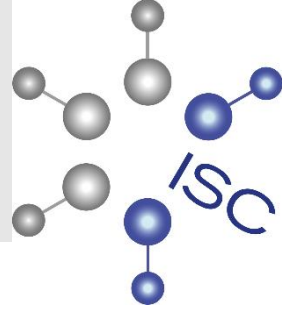


**Dr. Werner Bergholz &
Dr. Norbert Fabricius**

Ass. Secretary / Secretary: IEC/TC 113

ISC – International Standards Consulting
GmbH & Co. KG

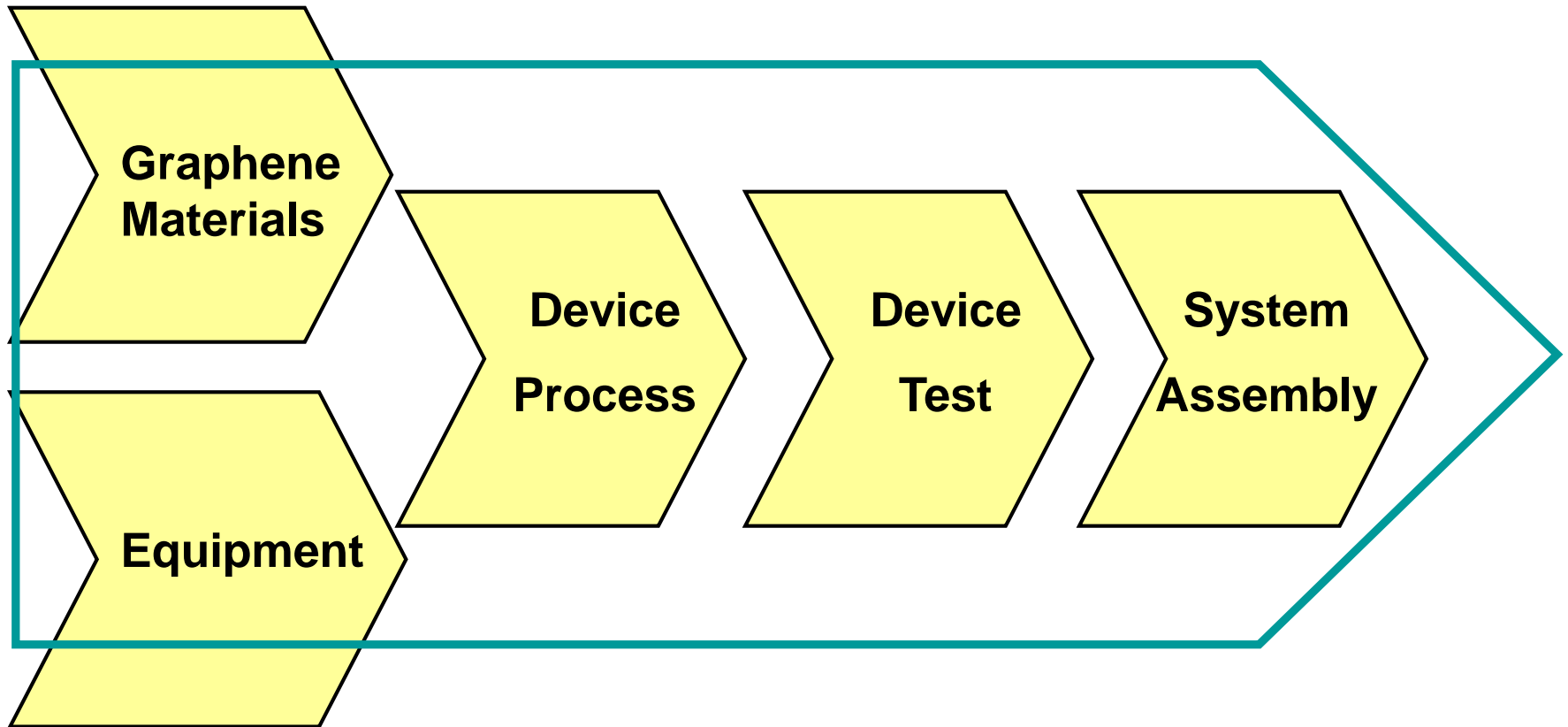
**IEC/TC 113:
NANOTECHNOLOGY FOR ELECTROTECHNICAL
PRODUCTS AND SYSTEMS**



- 1. The Need for & Benefits of Standardization**
- 2. The IEC Standardization Process**
- 3. Conclusions**

1. The Need & Benefits of Standardization

The generic value adding chain for graphene-based products:



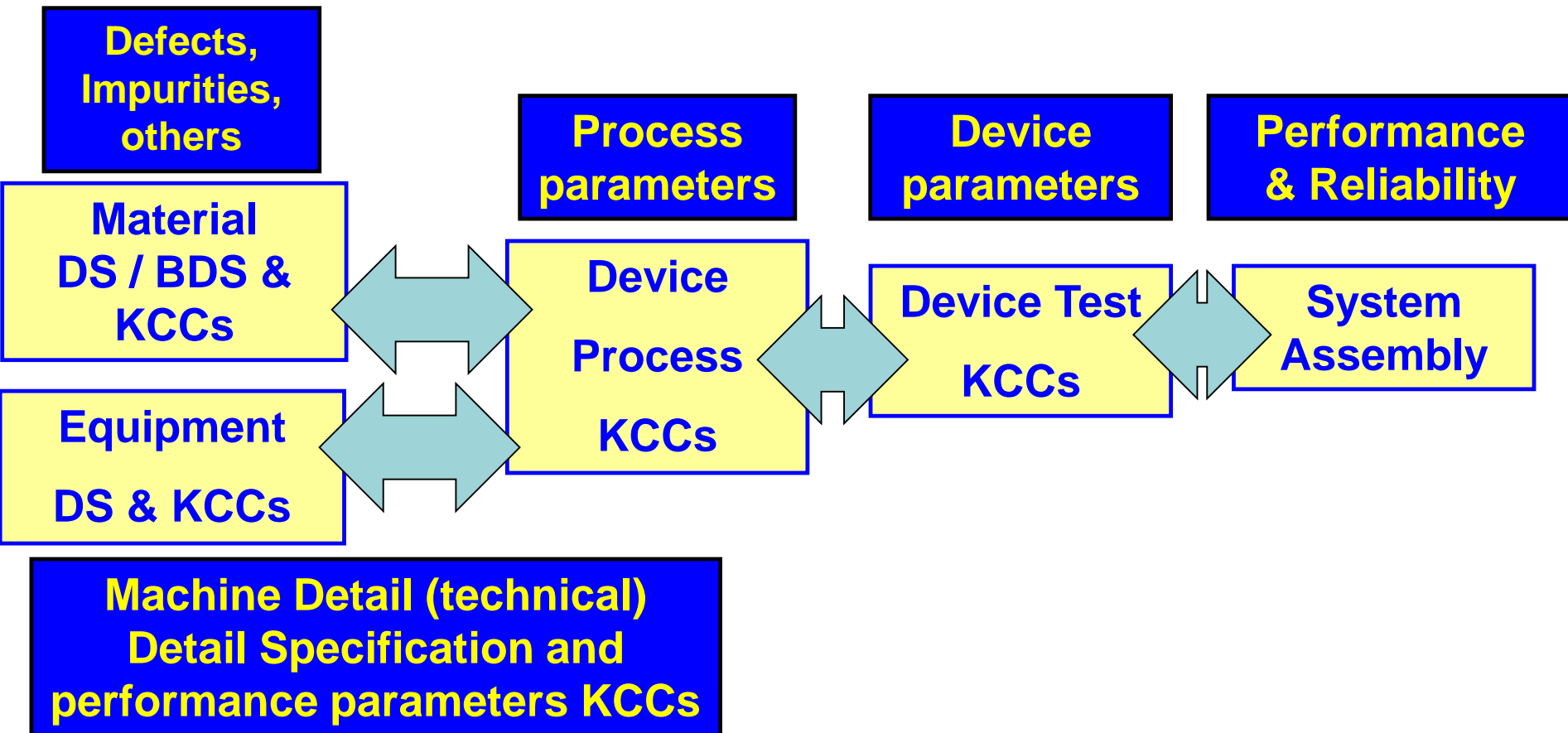
How to ensure **CONSISTENT QUALITY** ?



1. The Need & Benefits of Standardization

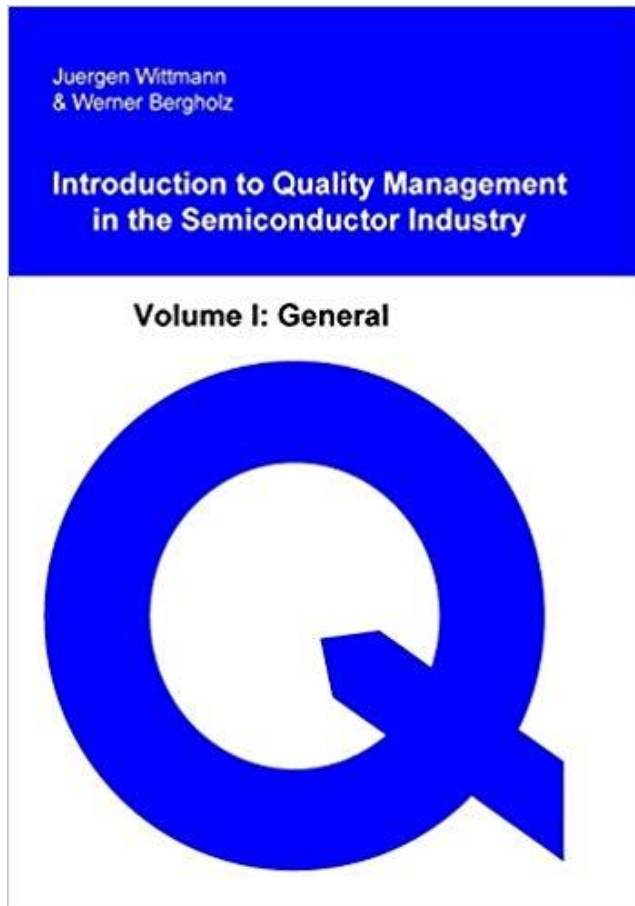
The Performance and reliability is “MADE”, not tested, via

- Key Control Characteristics KCCs
- Details Specification (DS) & Blank Detail Specification (BDS)



1. The Need & Benefits of Standardization

Detailed background information in 2 books, and in the Standard ISO 9001:2015 for Quality Management Systems



and



With a chapter on nanomaterials

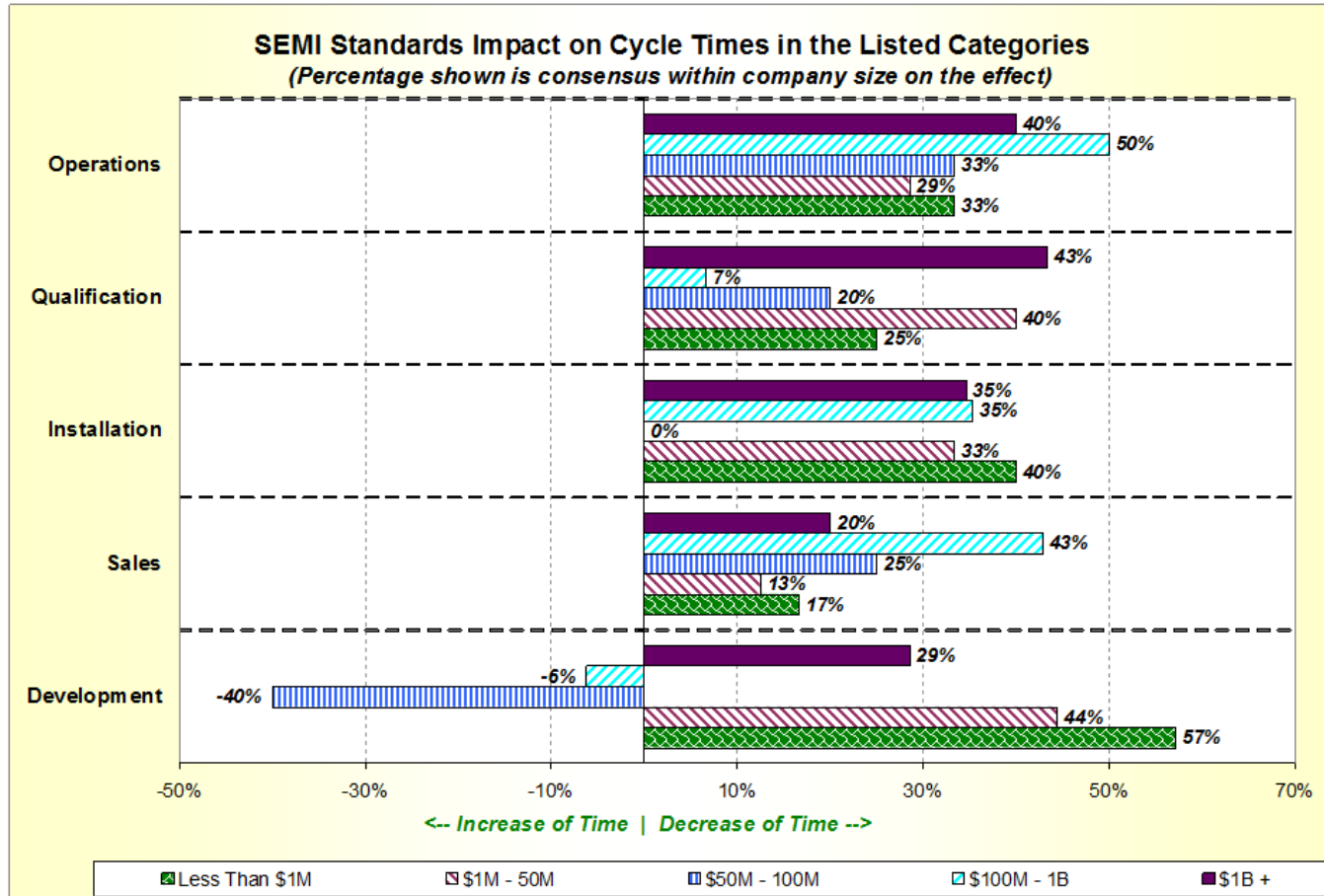
Case Study:

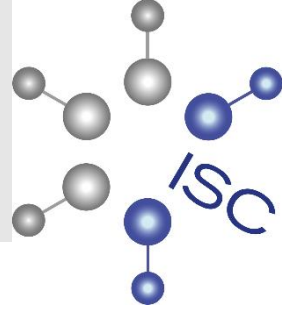
Transition 200mm → 300mm wafers Microelectronics

- Previous transitions (e.g. 150mm → 200mm): **Disastrous!**
- 200mm → 300mm:
 - Anticipiative standardization in I300I consortium
 - about 50 SEMI standards created BEFORE the transition was implemented
- Result:
 - Smooth transition
 - First production lot on 300mm had in 200mm a higher yield than the mature 200mm production
 - Cost savings estimated to be > 10 billion \$

1. The Need & Benefits of Standardization

Survey by B. Weiss from SEMI showed: Cycle time reduced





1. The Need for & Benefits of Standardization
2. The IEC Standardization Process
3. Conclusions



2. The IEC Standardization Process

Blank Detail Specification (BDS)

Concept of the “Blank Detail Specification” (BDS) and Key Control Characteristics (KCCs) developed in IEC TC 113 is core to the QUALITY MANAGEMENT BASED STRATEGY

- Standardized format for the specification for the **KCCs of the material / equipment / ...**
- **BDS:** No numbers for KCCs, **DS** with number, **Sectional Detail Specification** with some number
- Recommendation for standardized characterization methods to determine the KCCs



2. The IEC Standardization Process

Blank Detail Specification (BDS) – excerpt for Graphene

Table 4 – Format for electrical key control characteristics

KCC No	KCC	Specification	Measurement method	F	P	D
4.1	Sheet resistance	Nominal [] \pm Tolerance [] Ω/sq	IEC/TS 62607-06-04	✓		✓ ²
			IEC/TS 62607-06-08			
			IEC/TS 62607-06-09			
			IEC/TS 62607-06-10			
4.2	Sheet conductance	Nominal [] \pm Tolerance [] S/sq	IEC/TS 62607-06-04	✓		✓ ²
4.3	Conductivity	Nominal [] \pm Tolerance [] S/m	IEC/TS 62607-06-01		✓ ¹	
4.4	Field effect carrier mobility	Nominal [] \pm Tolerance [] cm^2/Vs		✓		
4.5	Hall carrier mobility	Nominal [] \pm Tolerance [] cm^2/Vs		✓		
4.6	Work function	Nominal [] \pm Tolerance [] meV		✓		

Note

1) Measured on pellets

2) Measured on films solidified according to suppliers specification



2. The IEC Standardization Process

BDS standards and KCC measurement standards

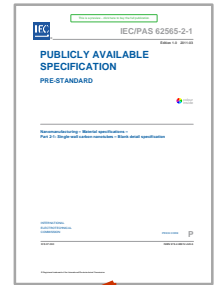
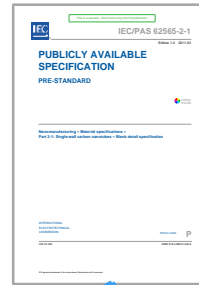
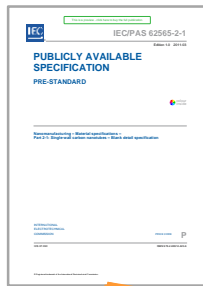
>> PT 62565-3-1

>> 625651

SBDS 1

SBDS 2

62565-3-X



>> Nanostandards-Wiki

KCC 01

KCC 02

KCC 03

KCC 04

KCC 05

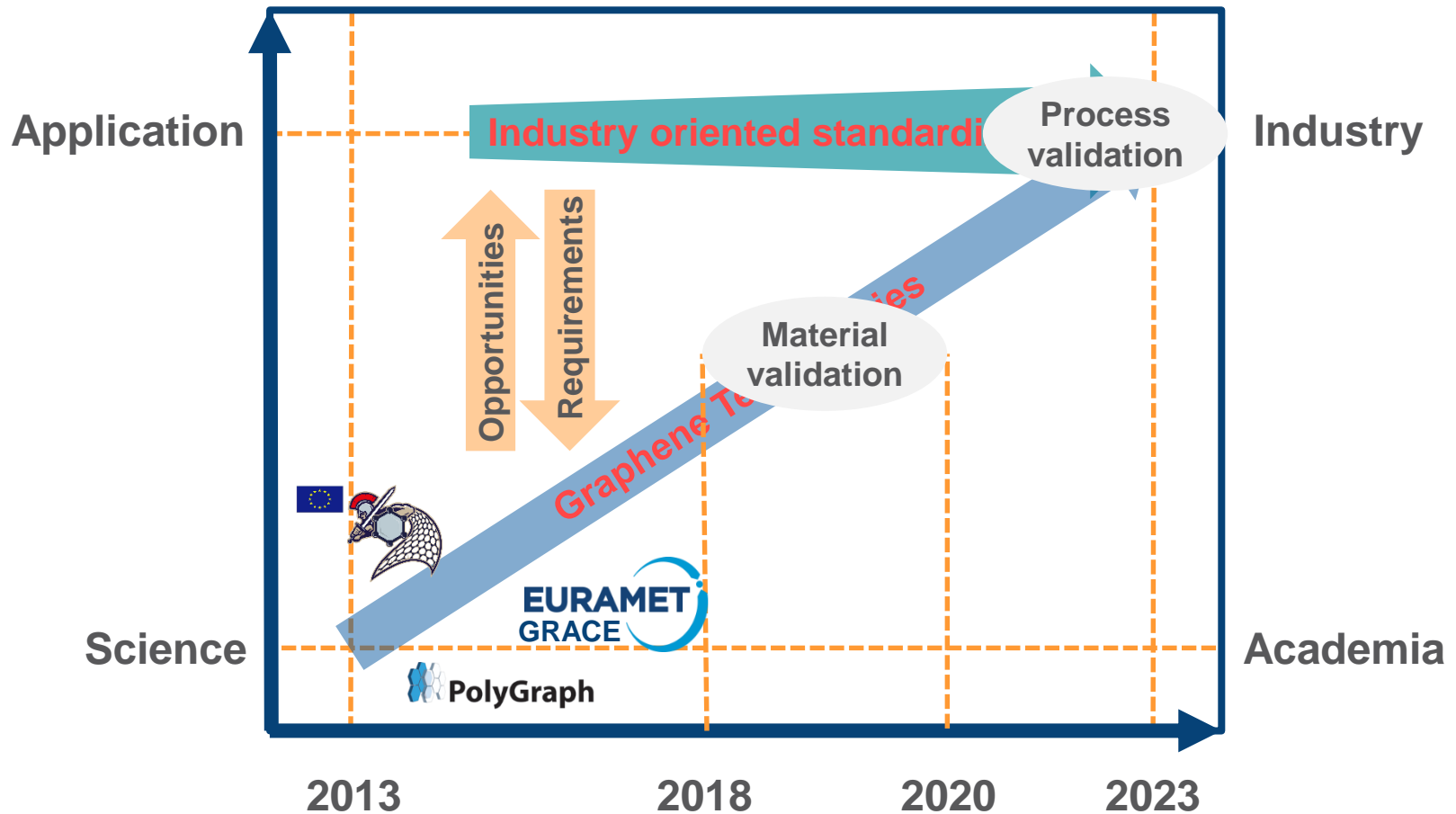
KCC 06



62607-6-X

2. The IEC Standardization Process

Moving towards industry oriented standardization



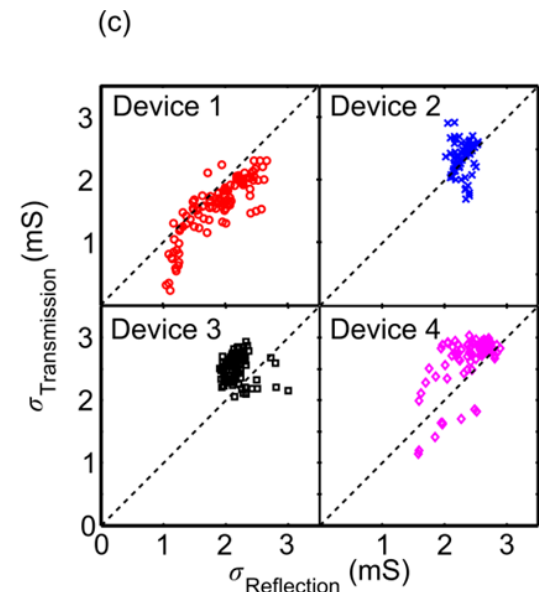
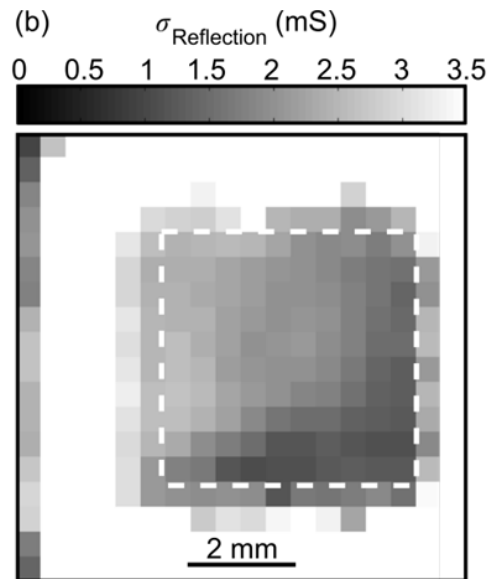
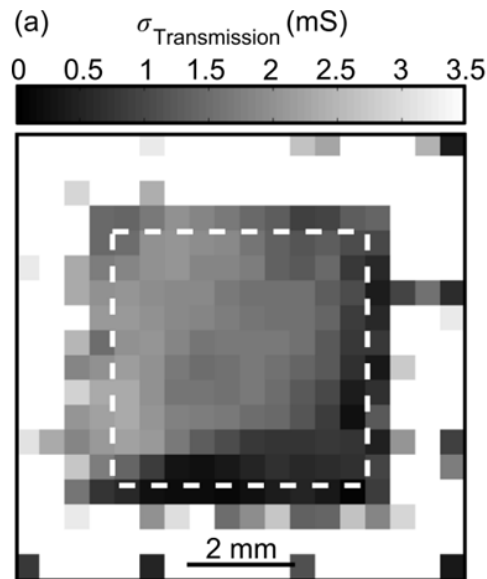
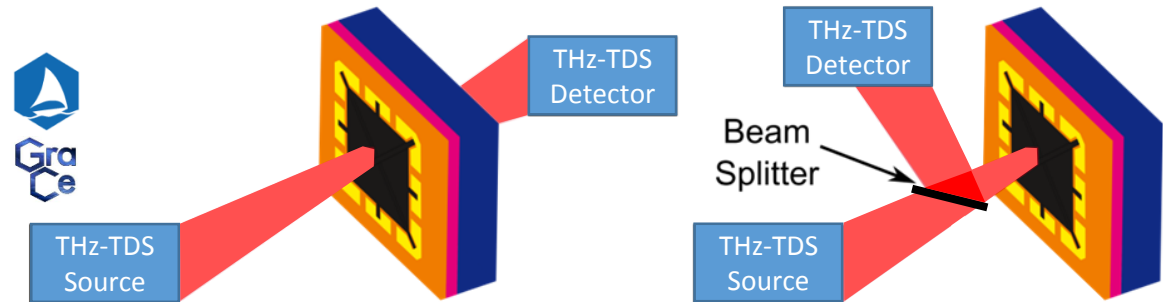
Standardization supports cooperation between the EU-Flagship and other EU projects like “Polygraph (FP7)”, “Gladiator (FP7)”, “GRACE” (Euramet EMPIR) as well as national funded projects.

2. The IEC Standardization Process

Example: sheet resistance, THz-TDS (IEC/TS 62607-6-10)

Measurement configurations:

- Transmission: DTU (DK)
- Reflection: das-Nano (ES)





2. The IEC Standardization Process

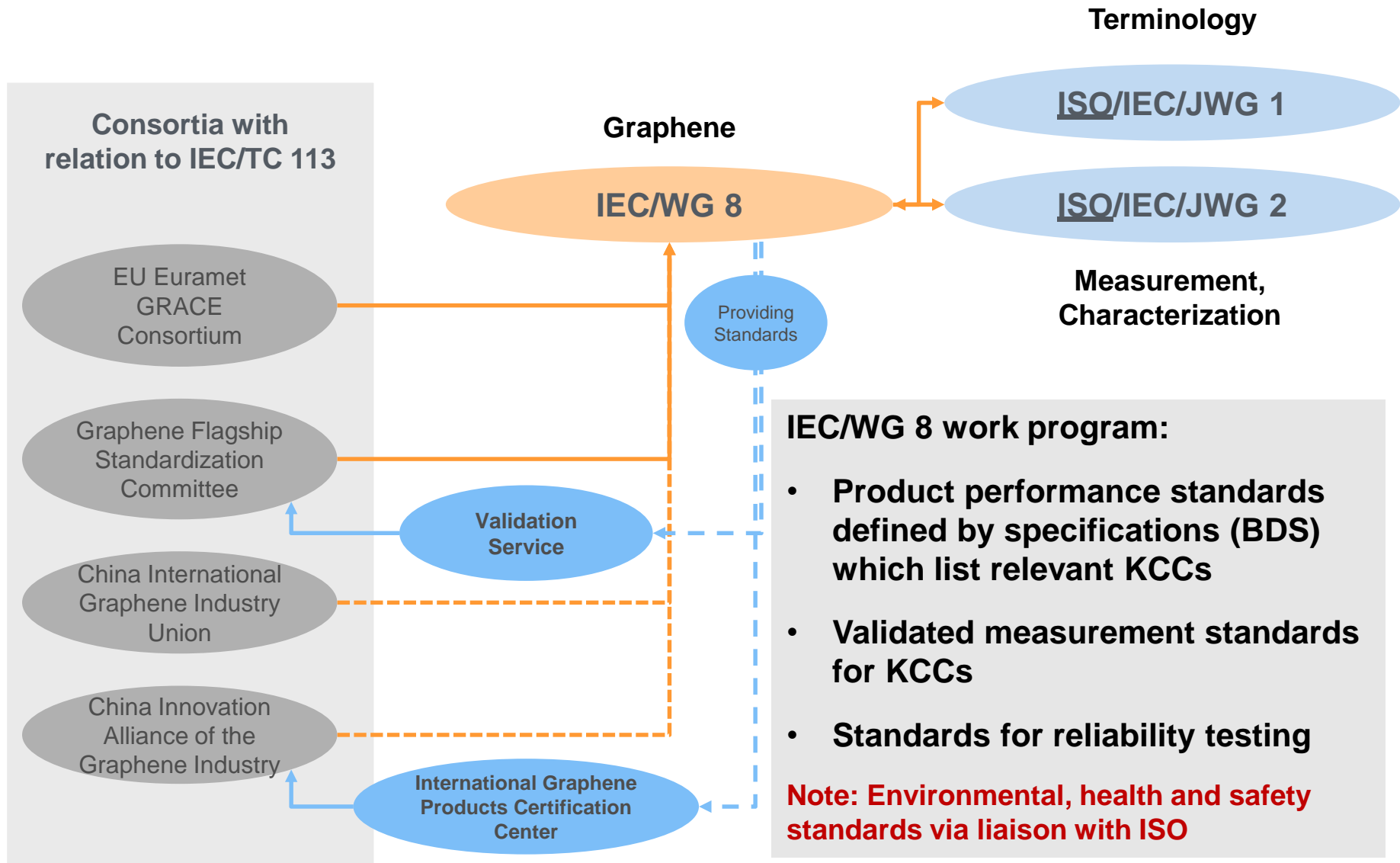
Current status of selected IEC graphene standardization projects

	62565-03-05	62607-06-06	62607-06-08	62607-06-09	62607-06-10	62607-06-11	62607-06-12	62876-03-01
Stage	BDS: Graphene powder	KCC: strain uniformity parameter	KCC: sheet resistance	KCC: sheet resistance	KCC: sheet resistance	KCC: defect density	KCC: number of layers	Reliability
		Raman	4 point probe	Eddy current	THz-TDS	Raman	Raman, optical reflection	T, ΔT, RH
PWI								
NP								
CD								
DTS								
TS								



2. The IEC Standardization Process

Standardization landscape „Graphene and other 2D-Materials“





2. The IEC Standardization Process

Standardization landscape „Graphene and other 2D-Materials“

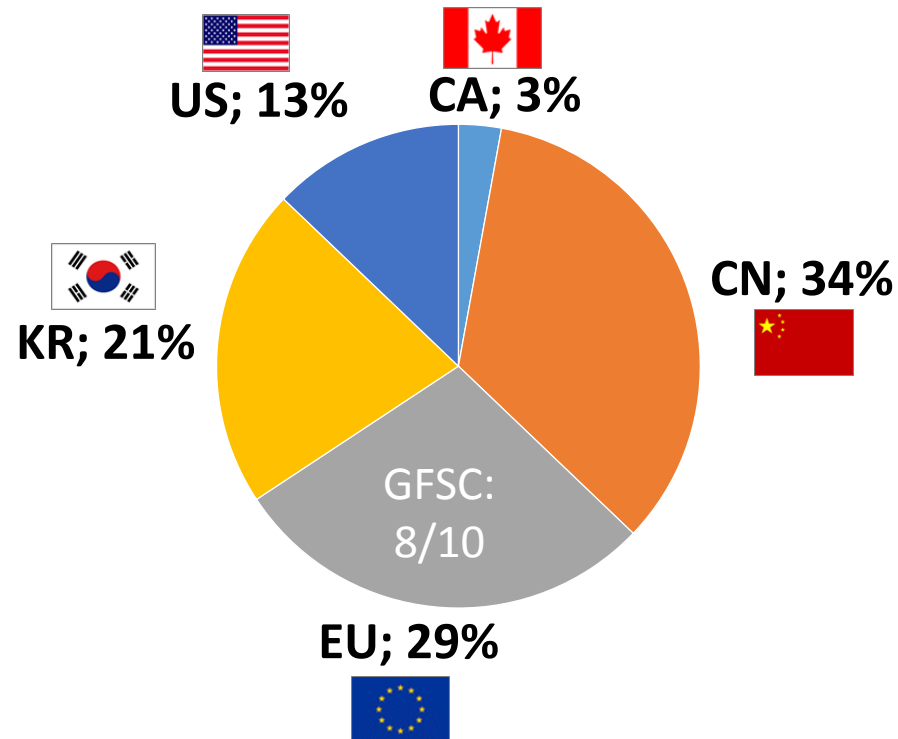
If you want to know more details about:

- **Standardization**
- **Certification** of Graphene Products and the manufacturing process

Standardization and certification seminar

- Co-organized by IGCC (International Graphene Products Certificate Center), Phantoms Foundation and ISC (International Standards Consulting GmbH & Co KG)
- **Date:** Thursday June 28, 2018 – 15:00 to 19:00
- **Location:** Conference room 2 (Conference level)

2. The IEC Standardization Process – Truly international Project Team Leadership by country (03/2018)

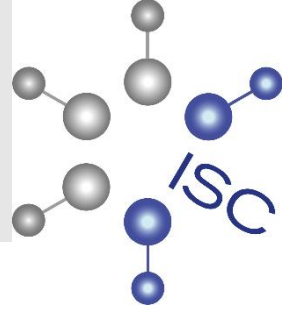




2. The IEC Standardization Process - Meetings

Update on ISO meeting(s), IEC/TC 113 & ISO/TC 229 work

- Meeting schedule:
 - Last: Ottawa, May 2018, joint with ISO/TC 229
 - Next: Busan, October 2018, co-located with IEC General Meeting
 - Next Meeting with ISO: Sidney, Australia, around May, exact date tbd



1. The Need for & Benefits of Standardization
2. The IEC Standardization Process
3. **Conclusions**