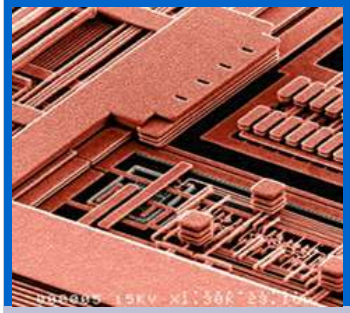


Science with a Conscience: Fostering Integrity in Innovation

V Ramgopal Rao

IIT Bombay/IIT Delhi/BITS Pilani

https://web.iitd.ac.in/~rrao/

Email: rrao@bits-pilani.ac.in

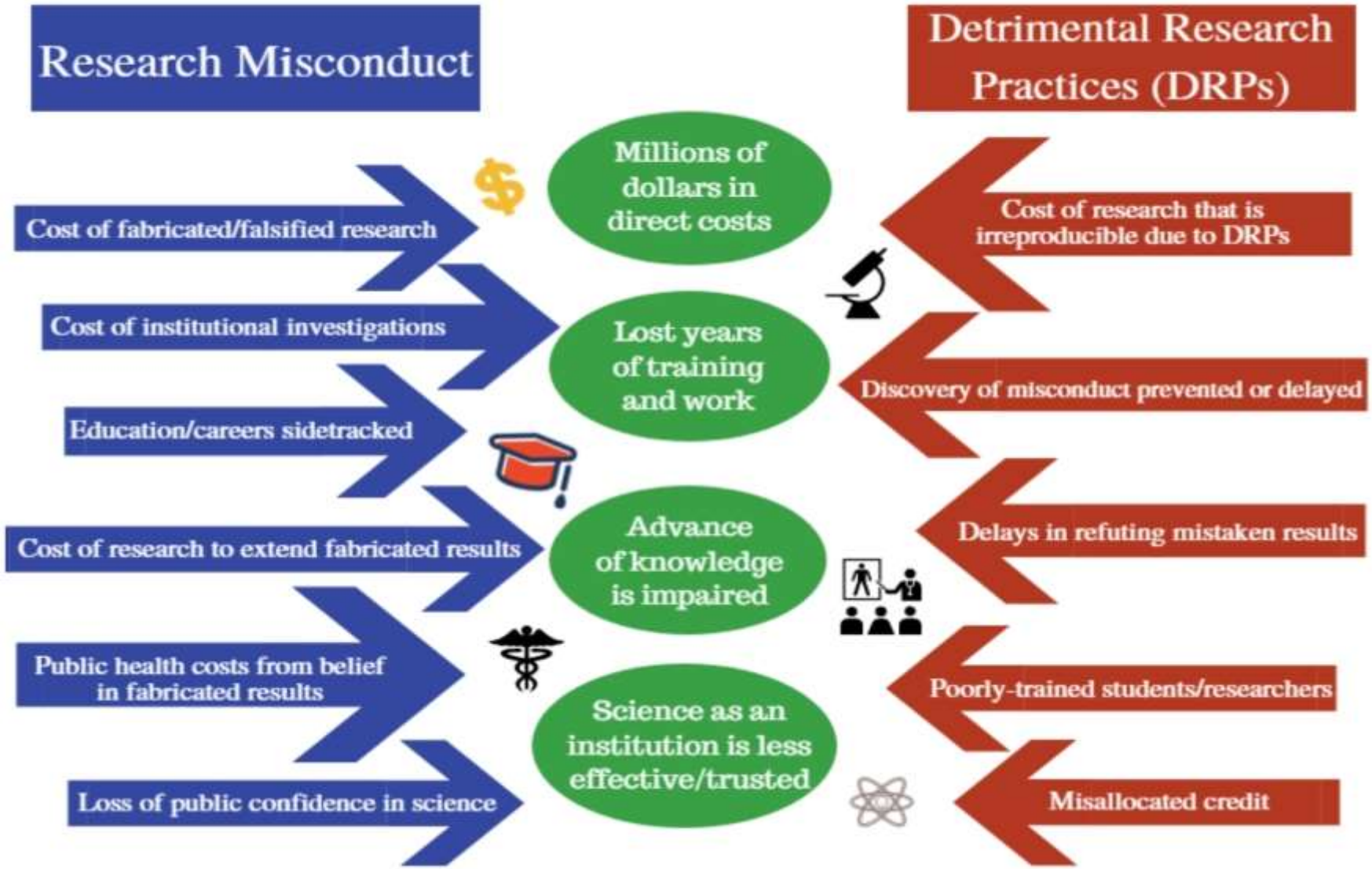
CSIR, New Delhi

June 18, 2025

Current status of Indian R&D

- India ranks
  - 1st in # of institutions
  - 2nd in # of enrolled students in HEIs
  - 3rd in the world in for research output
  - 6th for Patent filings
  - 9th for citations
  - 39th for Innovation
  - 54th for % GDP allocation for R&D,
  - 83th for # of researchers per million population.
  - 86th for academia-industry collaborations
- India's share of scientific publications is 5.31%. China's share is 20.67% and for US, it is 16.54%.
- R&D investment by Indian industry is still small at 0.2% of GDP. In comparison, US industry spends 2.7% of GDP, South Korea 3.9% and the United Kingdom 2.1%.
- Ranked #1 in terms of "papers written"/$ spent....

Costs and Consequences of Research Misconduct



Fostering integrity in Science, US National Academies of Science, Engineering, and Medicine, 2017

The Research Integrity Risk Index (RI^2): A Composite Metric for Detecting Risk Profiles

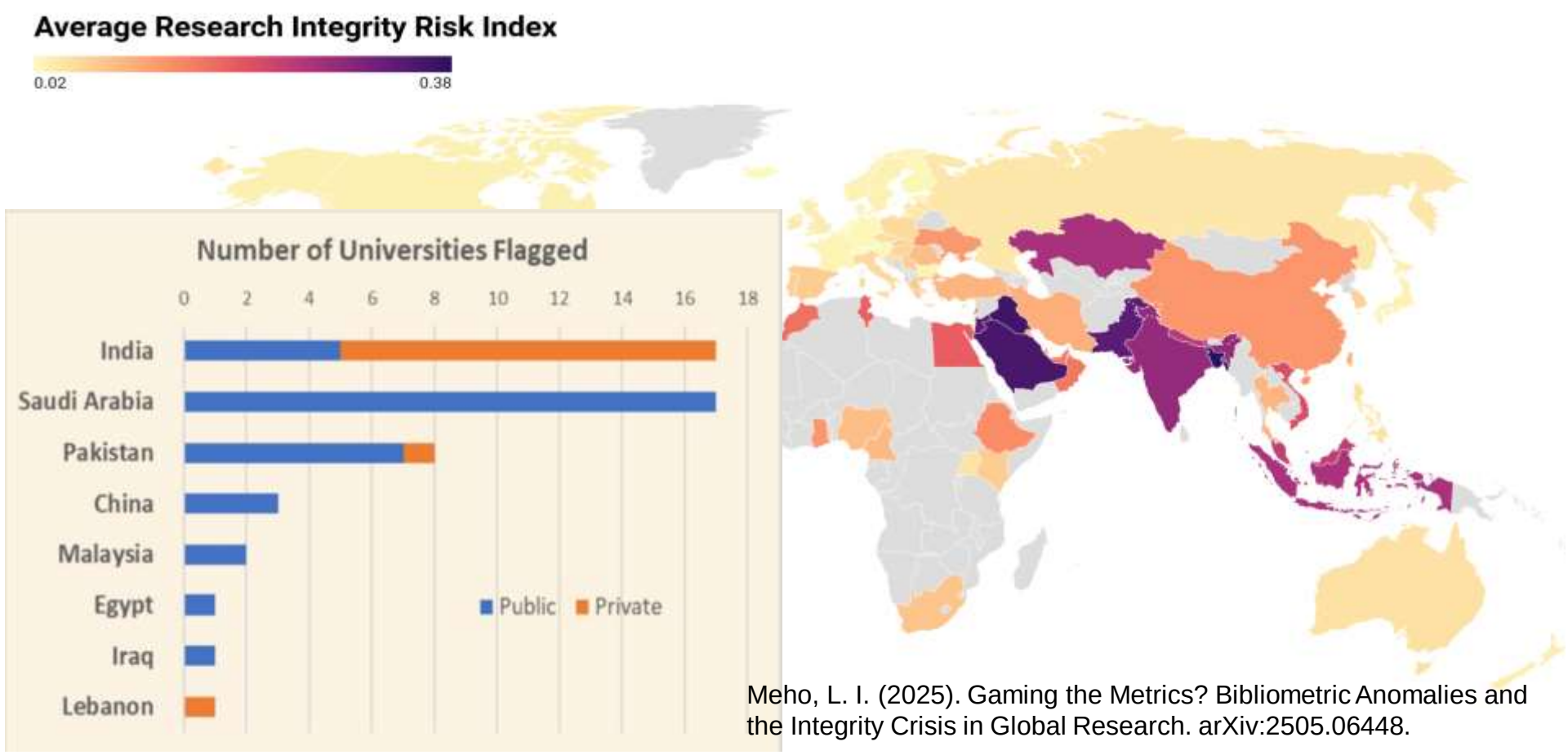
RI^2 = (Normalized Retraction Rate + Normalized Delisted Rate) / 2

- **Retraction Risk**: particularly those retracted due to data fabrication, plagiarism, ethical violations, authorship or peer review manipulation, or serious methodological errors. Calculated as the number of retractions per 1,000 articles over the preceding most recent two full calendar years

- **Delisted Journal Risk**: Quantifies the proportion of an institution's publications that appear in journals removed from Scopus or Web of Science due to violations of publishing, editorial, or peer review standards

Meho, L. I. (2025). Gaming the Metrics? Bibliometric Anomalies and the Integrity Crisis in Global Research. arXiv:2505.06448.

Tier	Percentile Range	Interpretation	Score Range (June 2025 edition)
Red Flag	≥ 95th	Extreme anomalies; systemic integrity risk	$RI^2 \geq 0.2513$
High Risk	≥ 90th and < 95th	Significant deviation from global norms	$0.1757 \leq RI^2 < 0.2513$
Watch List	≥ 75th and < 90th	Moderately elevated risk; emerging concerns	$0.0989 \leq RI^2 < 0.1757$
Normal Variation	≥ 50th and < 75th	Within expected global variance	$0.0491 \leq RI^2 < 0.0989$
Low Risk	< 50th	Strong adherence to publishing integrity norms	$RI^2 < 0.0491$



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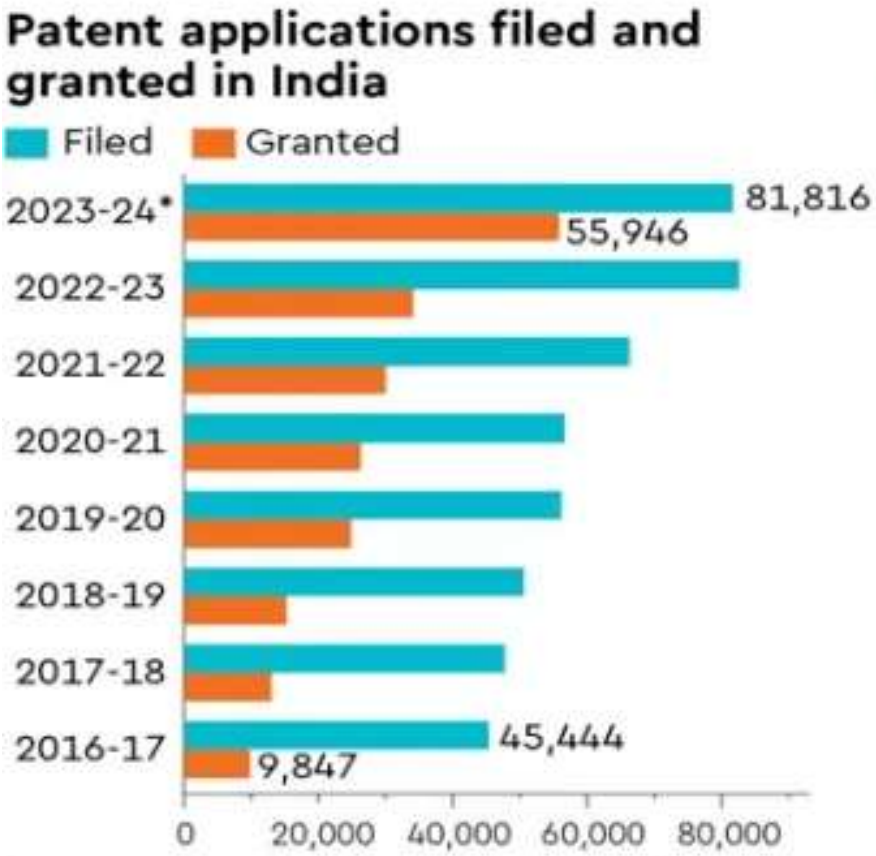
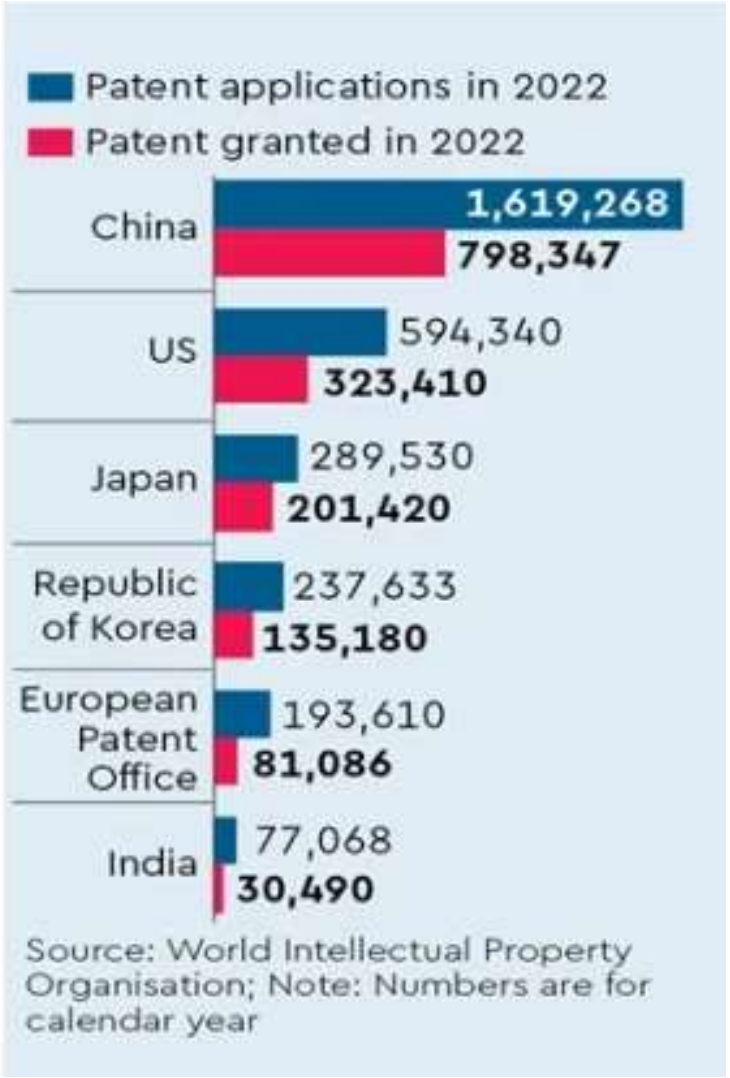
Patents

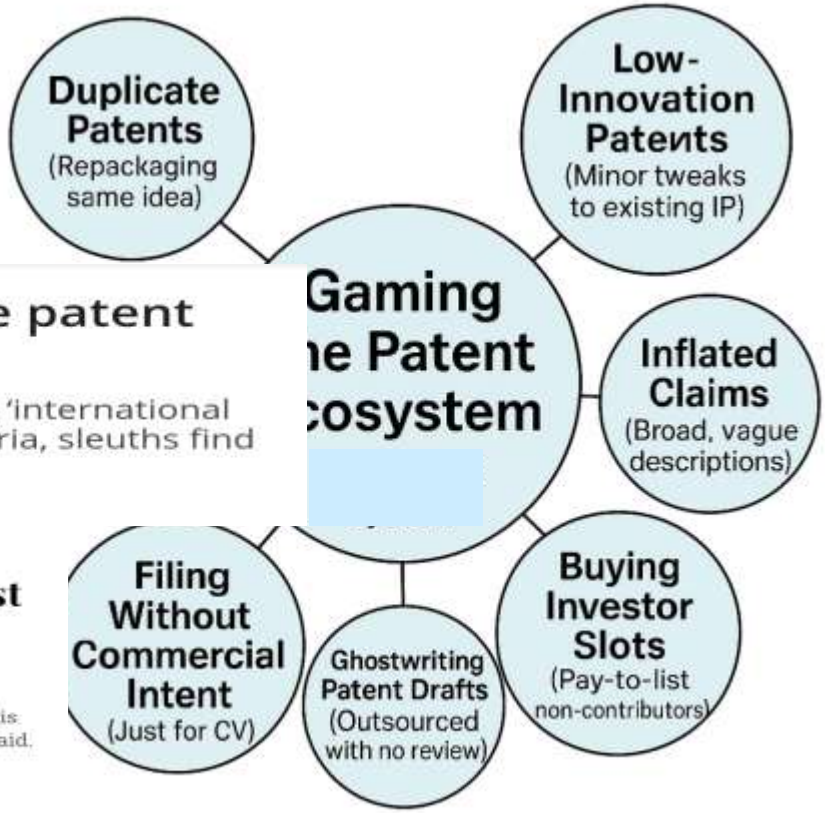


Source: Office of CGPDTM; Note: * Calculated on pro-rata the basis of number of patents filed and granted in first half of the fiscal year.



Source: World Intellectual Property Organisation; Note: Numbers are for calendar year

Patent frauds



‘Double fraud’: end Indian academics’ fake patent scam, UK urged

Dubious design registrations in the UK are being passed off as ‘international patents’ by Indian academics seeking to game promotion criteria, sleuths find

March 3, 2025

Home › Business ›

Indian patent office cautions people against fraudsters seeking money to facilitate IP applications

It said that these applications are processed strictly as per provisions of law and this office has zero tolerance for any such unethical practices, the Indian patent office said.

PTI

Last Updated : 13 November 2024, 13:25 IST

Sl. No.	Name of Scientific and Research & Development Organizations.	Applications filed
1	CHANDIGARH UNIVERSITY TECHNOLOGY BUSINESS INCUBATOR	1126
2	INDIAN INSTITUTE OF TECHNOLOGY (Collectively)	1106
3	BHARATH INSTITUTE OF HIGHER EDUCATION AND RESEARCH	779
4	SAVEETHA INSTITUTE OF MEDICAL AND TECHNICAL SCIENCES	576
5	NATIONAL INSTITUTE OF TECHNOLOGY (Collectively)	417
6	SHOBHIT INSTITUTE OF ENGINEERING & TECHNOLOGY (DEEMED TO-BE UNIVERSITY)	401
7	KALASALINGAM ACADEMY OF RESEARCH AND EDUCATION	359
8	COUNCIL OF SCIENTIFIC AND INDUSTRIAL RESEARCH (CSIR)	235
9	NOIDA INSTITUTE OF ENGINEERING AND TECHNOLOGY	220
10	VELLORE INSTITUTE OF TECHNOLOGY	183

India Research Watchdog

OPINION

Is NIRF ranking turning academia into 'lemons'?

PREMIUM

Without rigorous validation and a strong ethical foundation, it risk becoming

India's retraction crisis casts shadow over science research

BY INVITATION

Why NAAC accreditation system needs a rethink

By Prabina Ra

BY INVITATION

Ranking and citation rat race is hurting India's academic reputation

BY INVITATION

"When a measure becomes a target, it ceases to be a good measure."

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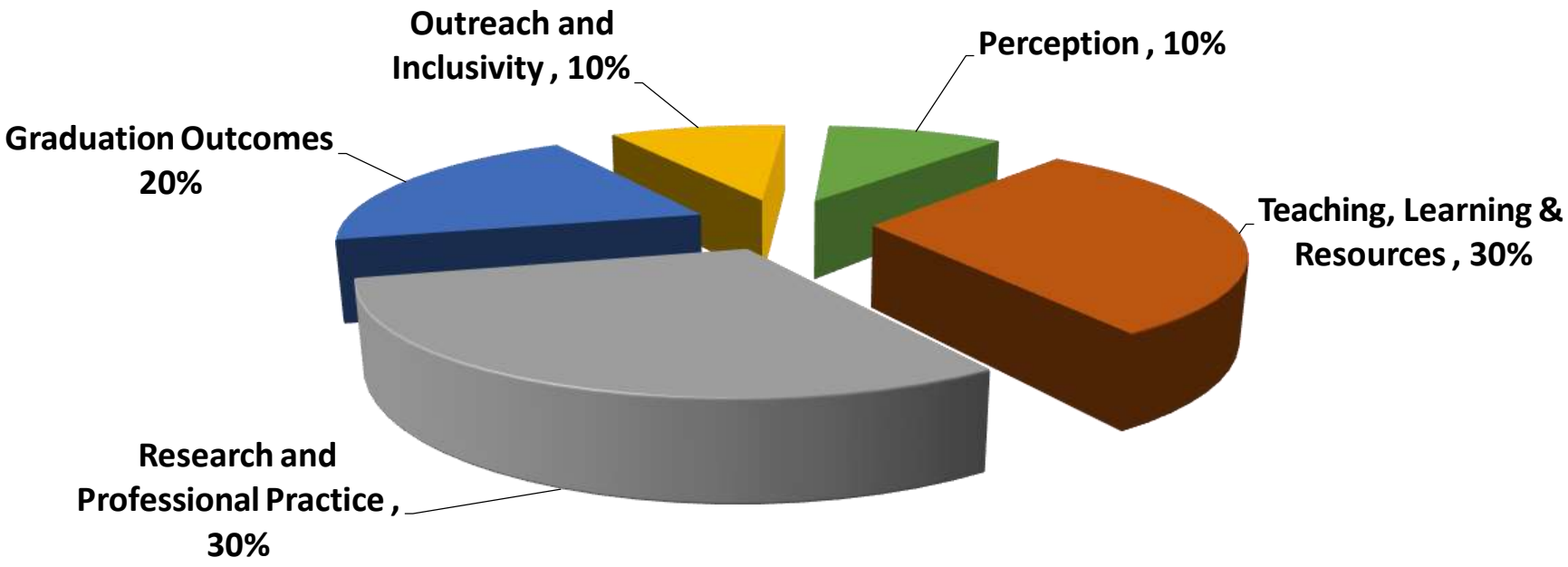
rankings, o

nature of perception rankings that introduces biases, challenges in the regional diversity metric, overlooking teaching quality, inadequate transparency in methodology, questions about data integrity and limited global benchmarking. This study emphasizes on dialogue, refinement and increased transparency to ensure that the NIRF rankings evolve into a reliable benchmark for the diverse landscape of Indian higher education.

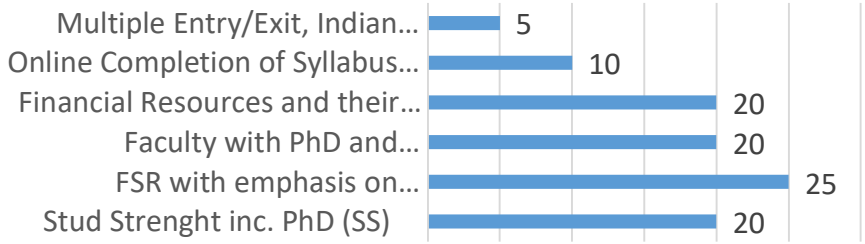
Keywords: Bibliometric assessment, higher education institutions, perception, ranking fluctuations, regional diversity.

NIRF 2024 (Overall) Ranking Parameters and Weightages

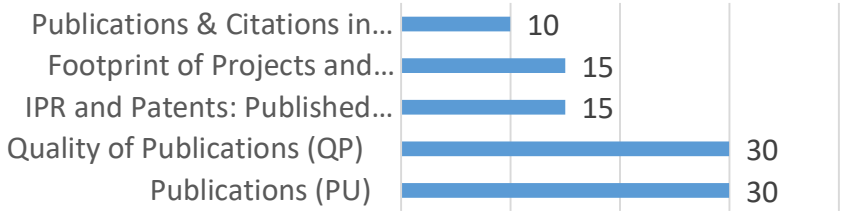


NIRF 2024 (Overall) - Methodology

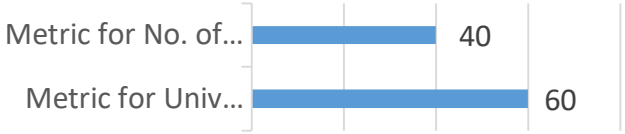
Teaching, Learning & Resources (TLR) 30%



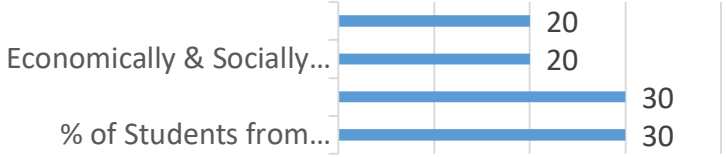
Research & Prof. Practice (RP)30%



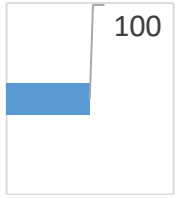
Graduation Outcome 20%



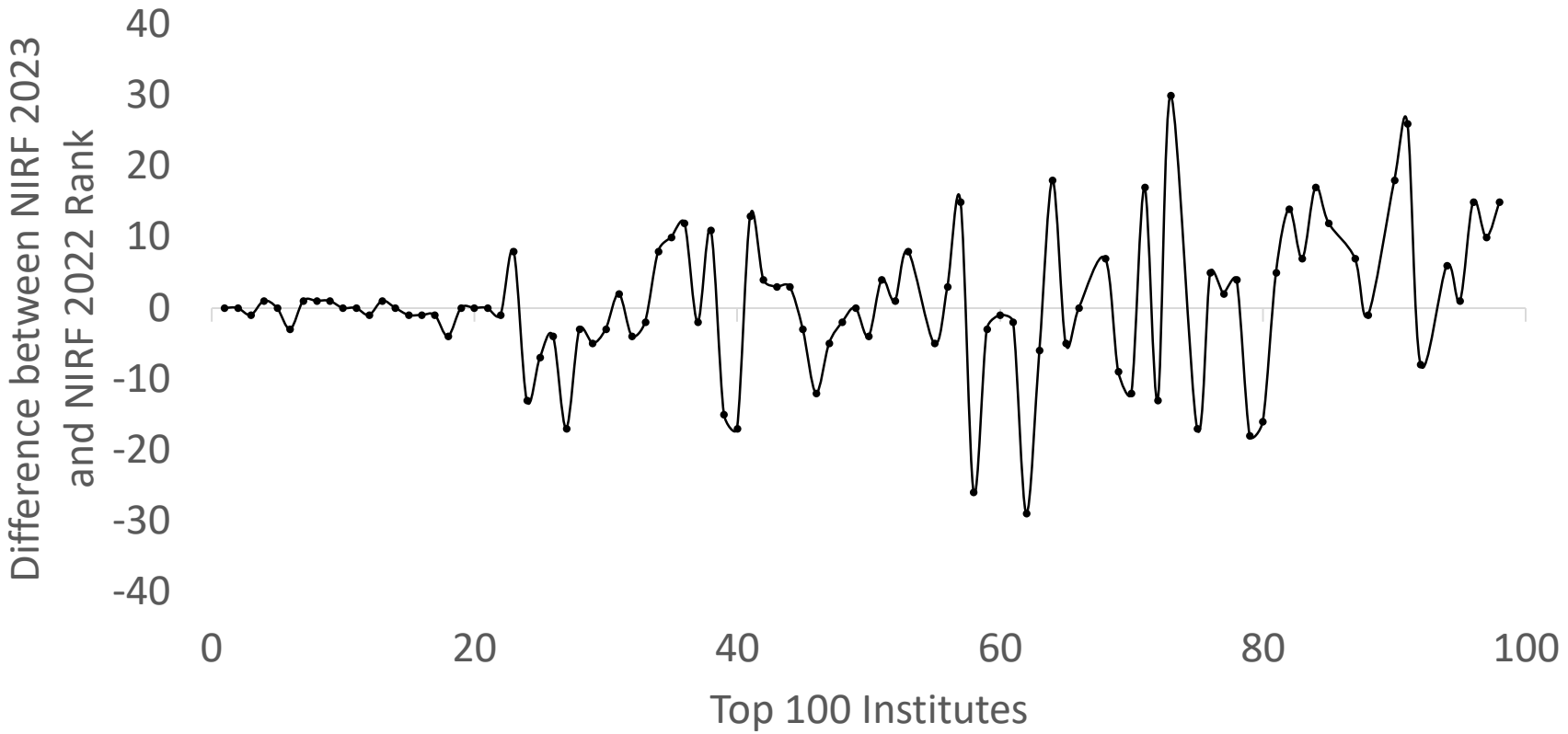
Outreach and Inclusivity 10%



Peer Perception: (PR) - 10%...



Inter annual high fluctuations in ranks



- The rankings beyond the top 20 institutions exhibit a high degree of variability (±30).

✓ **Suggestions**

- **Introduce negative marking for lack on research integrity**

How do we build world-class institutions?

Building a University is not University Buildings. It's the faculty who build great universities

Teaching

Research

Curriculum Development

Patent filing

Mentorship

Consulting

Entrepreneurship

Digital content/ Curator

Conferences

Counselling

PhD guidance

Career advise/ Placements

Administration

Outreach

Networking

Laboratory development

Examination

NEP is Indian academia's "Morill" moment...

- Last 10 years, India's HEIs have become more research oriented
- However, the R&D in Indian academic institutions is still primarily driven by North American and European models
- In mid 1800's, good "colleges" in US followed England and Germany – oriented towards classics, theology and natural sciences.
- Land-grant universities in US under the Morill Act of 1862, to focus on "such branches of learning as are related to agriculture and the mechanic arts"– created centres of research that mattered to the country.
- India seems to have found her Morill moment. Some of our research is becoming top-down – "***solution to a problem***" rather than "***solution looking for a problem***". NEP is a step in the right direction.

  (ISRO/DAE, DRDO model, NEC, IMPRINT, JATC, UBA, Grand Challenges initiatives, Immersion programmes)

Investments + Right problem sets + Talent

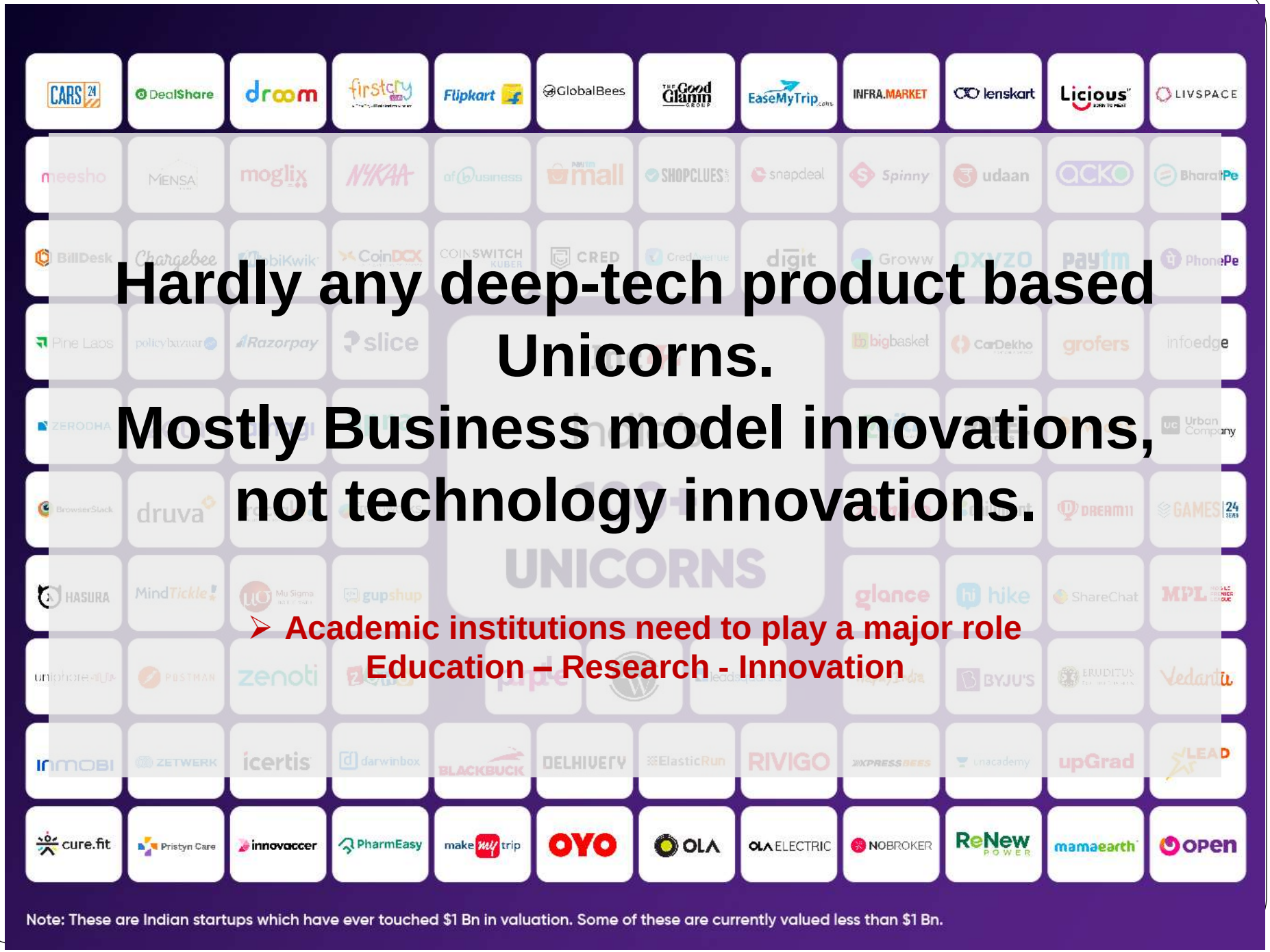
Role of HEIs…

1. Education

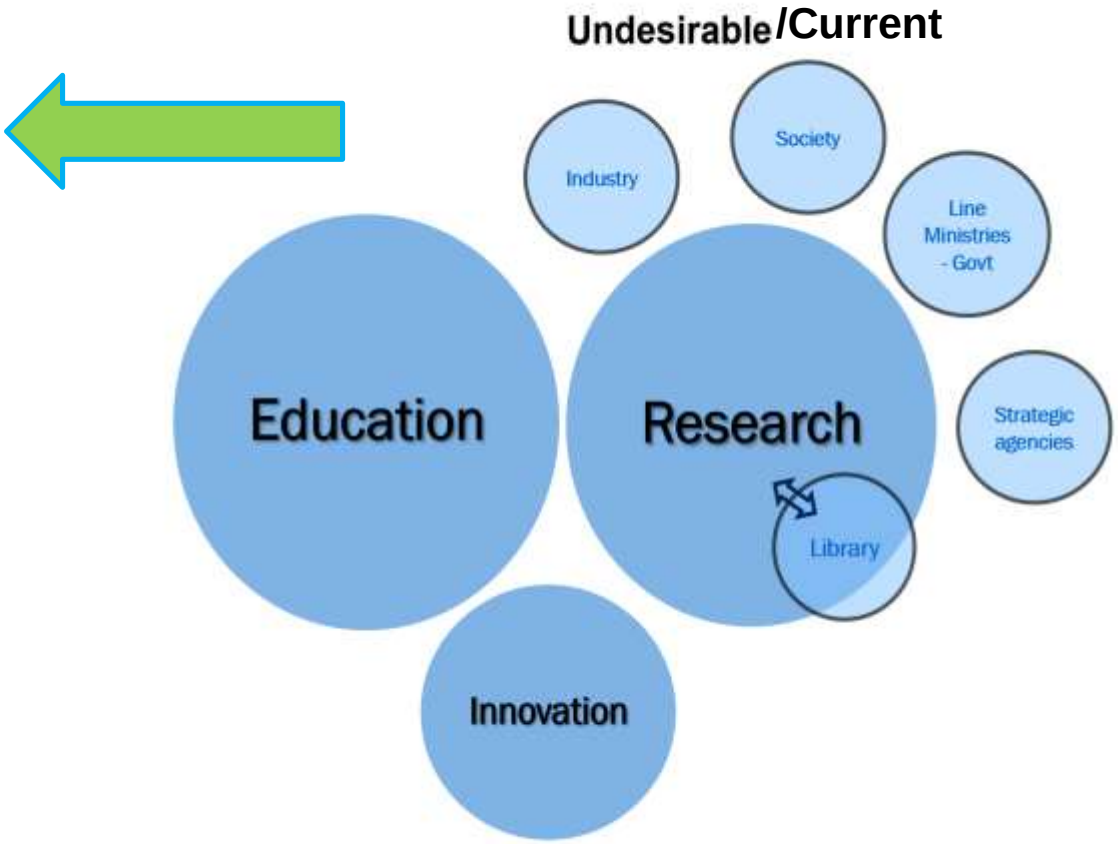
2. Knowledge Generation (R&D)

R&D : Relevance & Delivery

3. Innovation


Hardly any deep-tech product based Unicorns.
Mostly Business model innovations, not technology innovations.
UNICORNS
➢ Academic institutions need to play a major role
Education – Research - Innovation
Note: These are Indian startups which have ever touched $1 Bn in valuation. Some of these are currently valued less than $1 Bn.

An Integrated Innovation Network



1. Education: Dissemination of existing knowledge
2. Research: Generation of new knowledge
3. Innovation: Utilization of knowledge/education for public good

- Societal problems need to become projects in HEIs
- India needs to be a leader in some technology

IDEA FACTORY APPROACH AT IIT DELHI…..

- "**Idea Factory**" approach: bring unlike minds together, create the right atmosphere but structure interactions

  Bring "**unlike**" Minds together through

  - different Cultural backgrounds (Eg. Joint degree programmes, IPFP, International students and faculty, Int. Campus)
  - different Disciplinary Training (*SIRe, SoPP, ScAI, DMSE, DoD, DESE, CART, SeNSE, OPC, FIRP, M-FIRP, IITD-AIIMS, IITD-AIIA, IITD-ICAR, IITD-NII, IITD-ILBS, IITD-RCB, CoEs etc.*)
  - different Attitudes (Research Parks, Industry Day, PoP, JATC, UBA)

- Create an eco-system for high tech startups (Central facilities, space, faculty appraisals, FIRE, PHD Incubator, Student Startup action plan, 1-2-3-4 D&L, Investments in Startups, Endowment fund etc.)

5-YEAR PROGRESS AT IIT DELHI

In 5 years, IIT Delhi has turbocharged its research activities

8+5
Industry+Govt sponsored Centers of Excellence launched

75%
Faculty engaged on a funded research project

3x
Increase in number of funded research projects

4x
Increase in research funding & Startups

10k+
Publications in research journals

500+
Patents filed

350+
Industry Projects

10+
New Academic entities

225+
New Faculty

Startups founded by IIT Delhi students and alumni

zomato, Groffers, Flipkart, HealthKart, img, Groww, meesho, CarDekho, perkbox, LimeRoad, Quikr, snapdeal, udaan, inshorts, KritiKal, nagarro, TagMyTile, Trimian, eightfold.ai, bloomreach, seekout, YepMe, Lexity, rocketfuel, RIVIGO, shadowfax, Delhivery, doubtnut, Qubole, lucidata, CUROFY, Shuttl, NUTANIX, BharatPe, UpGrad, Chaayos, CASHIFY, JUGNOO, FITSO, policybazaar, MobiKwik, Clovia, bidgely, tripoto, indifi, IvyCap, SHOPCLUES, LevelUp, Productiv, KVANTUM, vyn, harness

"Today we are in touch with 275+ companies (vs. 50+, 5 years ago)." Corporate Relations Office, IIT Delhi

IIT Delhi's Self Discovery - CO

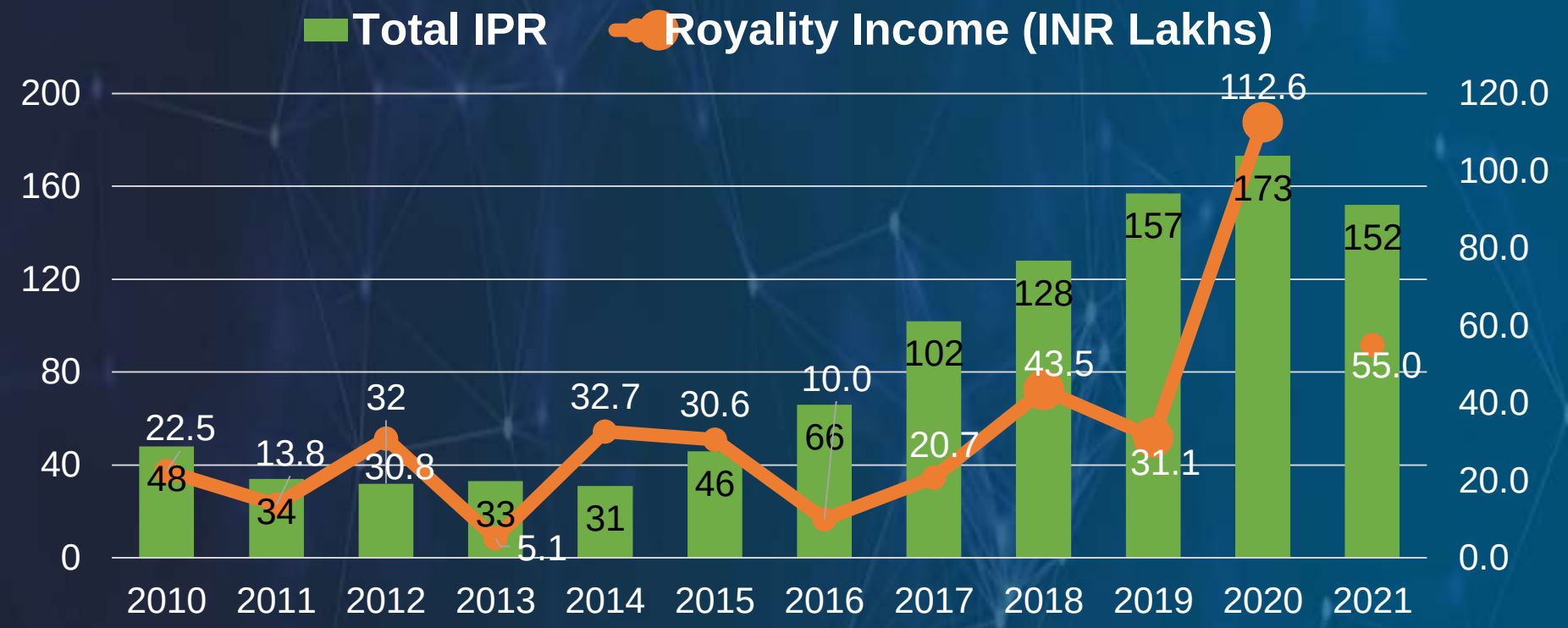
- Relevance
- Focus
- Team Spirit
- Urgency
- Nationalism
- Delivery
- Industry Connect
- INSTITUTIONAL SUPPORT

Highest number of patents (153) filed in 2020 in the history of the institute

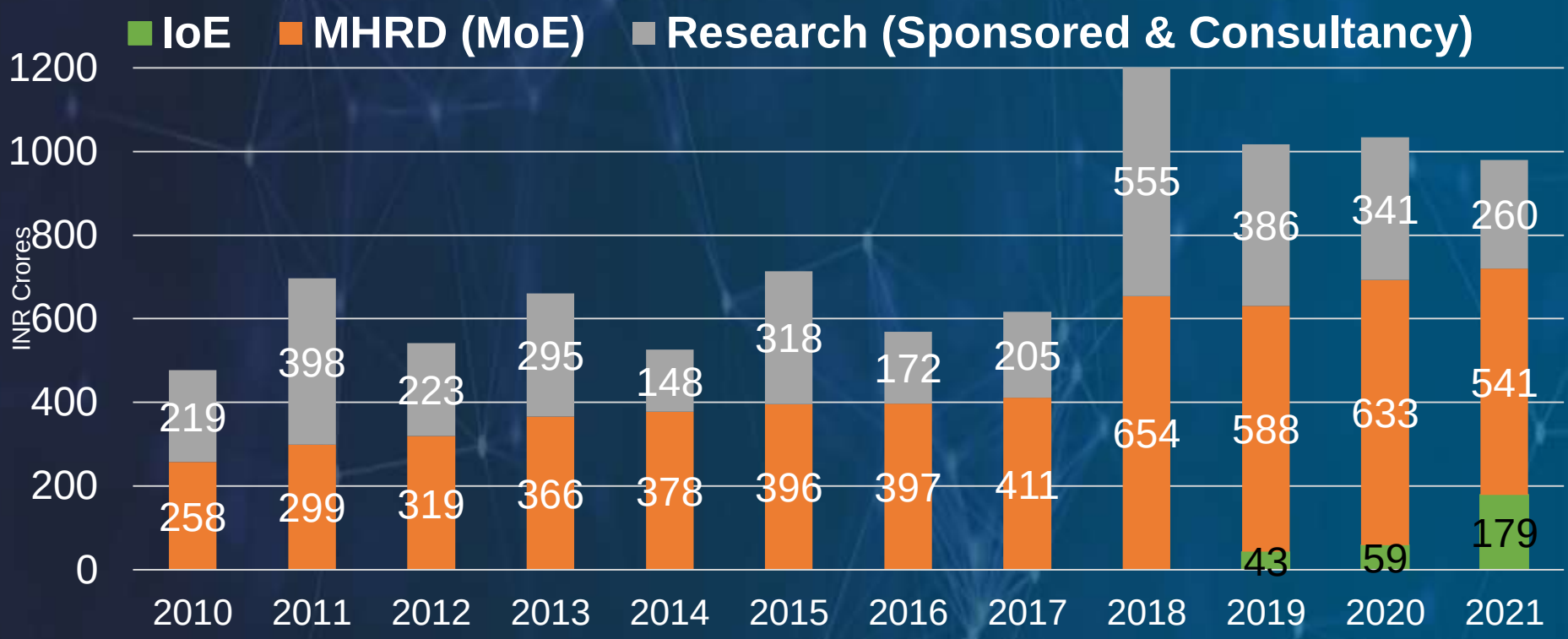
Centers of Excellence – during 6 years

CoE for Research on Clean Air	DESMI CoE on Waste to Wealth	Renew Power CoE on Energy & Environment	Yardi CoE for Sustainable Infrastructure	Industry Consortium on Artificial Intelligence
CoE on Smart Technology Enabled Manufacturing	DST CoE in Climate Modelling	ISRO Space Technology Cell (STC)	CoE in Bio-pharmaceutical Technology	DRDO - IIT Delhi Joint Advanced Technology Centre
SMITA Research Lab : CoE in Smart Textiles	Centre of Excellence on Personal Body Armour	Schlumberger CoE on Oil Technology	Daksh CoE for Law and Technology	CoE for Advance Data Management System for Highways (NHAI)
CoE in Advanced Research in Disability and Assistive Technology	CoE on Computational and Biomedical Sciences	CoE in Bioinformatics and Computational Biology	CoE on Biologically Inspired Robots and Drones (BIRD)	CoE on Quantum Technologies

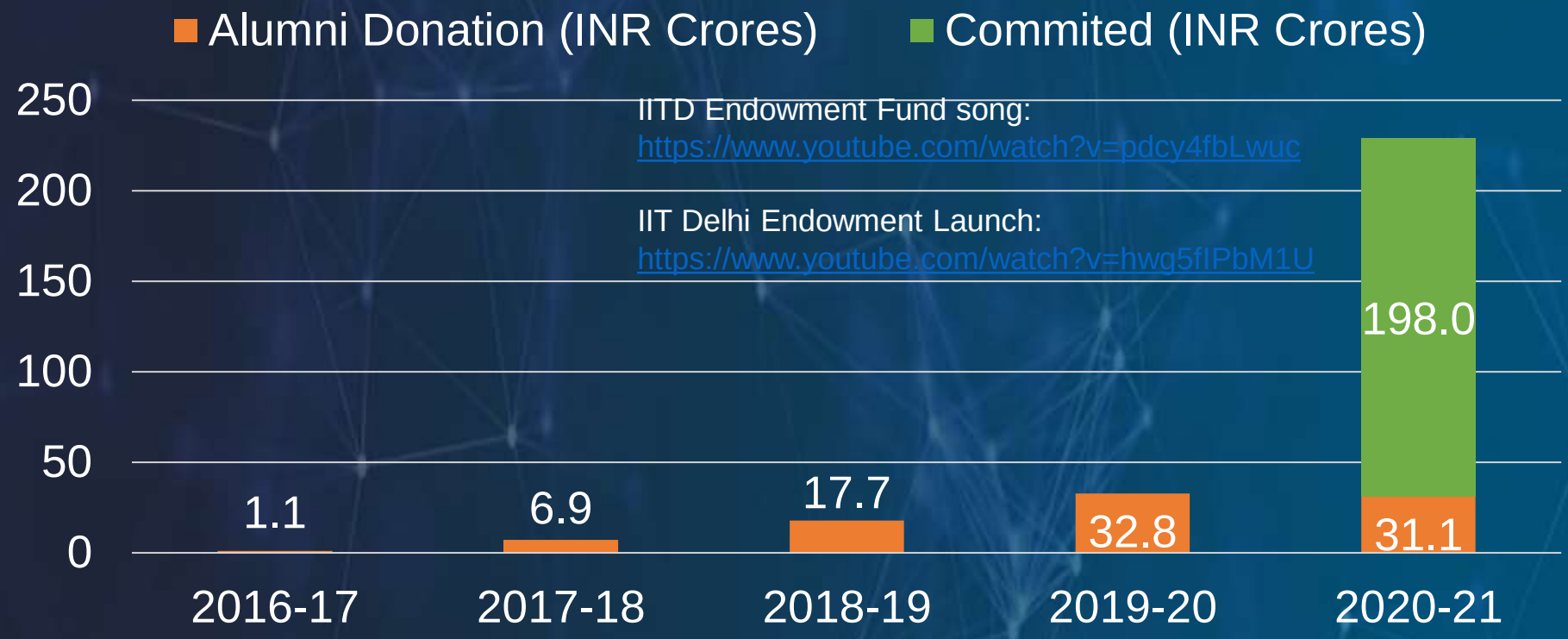
Intellectual Property Rights



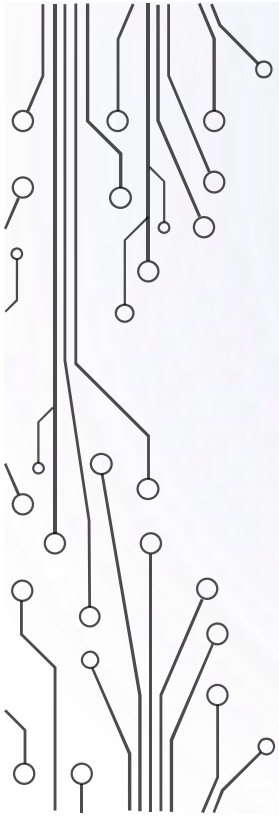
Grants and Funds



Alumni Donation



Understand your Institutional strengths….



Immersion/ Ideation

- BIRAC SPARSH
- Batch of 69 Innovation Awards
- Boeing BUILD

Product development and Validations

- BIRAC BIG
- Pfizer-IIT Delhi Innovation and IP
- Platform for Harnessing Deep tech (PHD incubator program)
- Faculty Innovation and Research-driven Entrepreneurship (FIRE)
- Sona Comstar – Safe, clean & Smart Mobility
- MEITY TIDE – EiR and Grant
- NIDHI SSS
- EIL – EngSUI
- DIO – iDEX

Pilot Scale

- NIDHI SSS
- BIRAC SEED
- Investor connects

Market Entry

- NIDHI SSS
- BIRAC LEAP
- DST CAWACH for COVID-19
- Investor connects

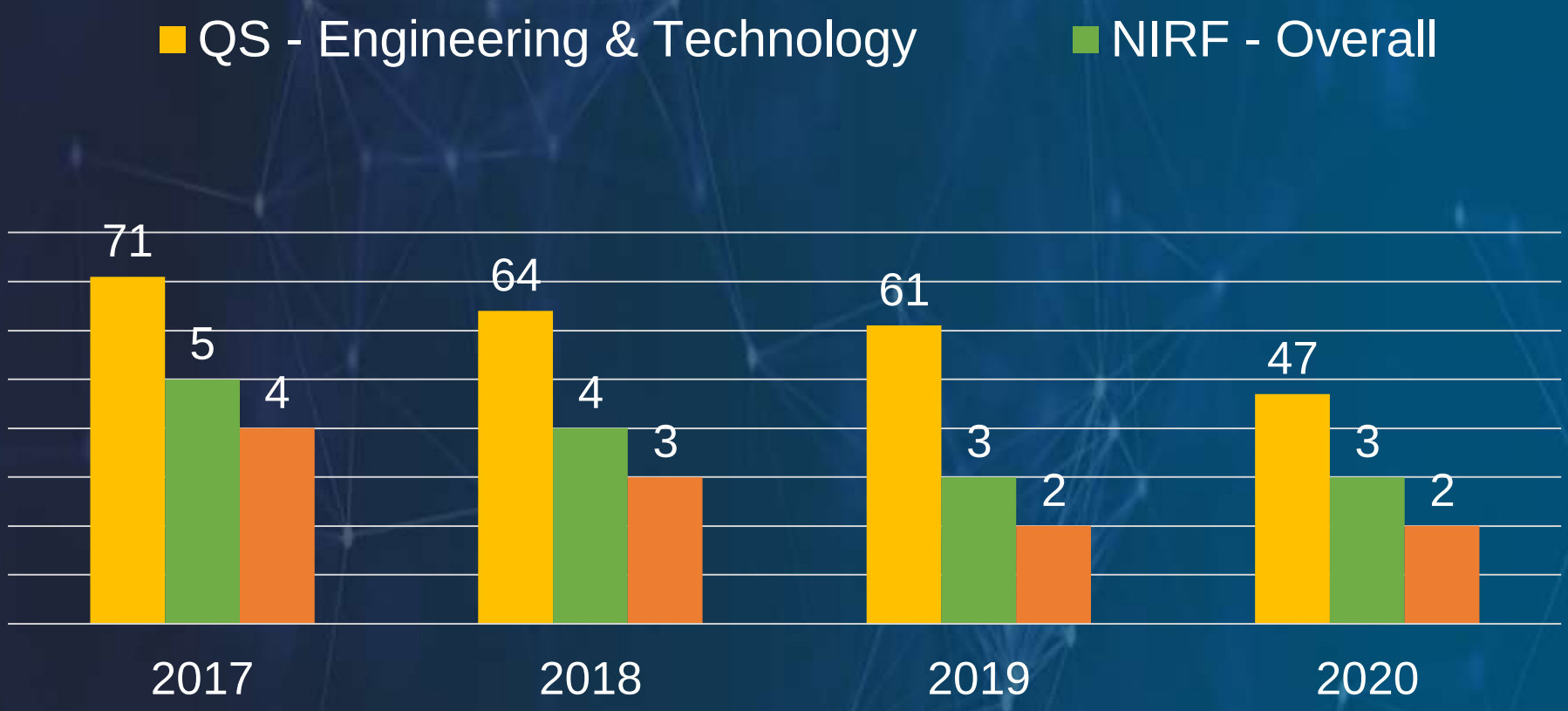
Training and Mentoring

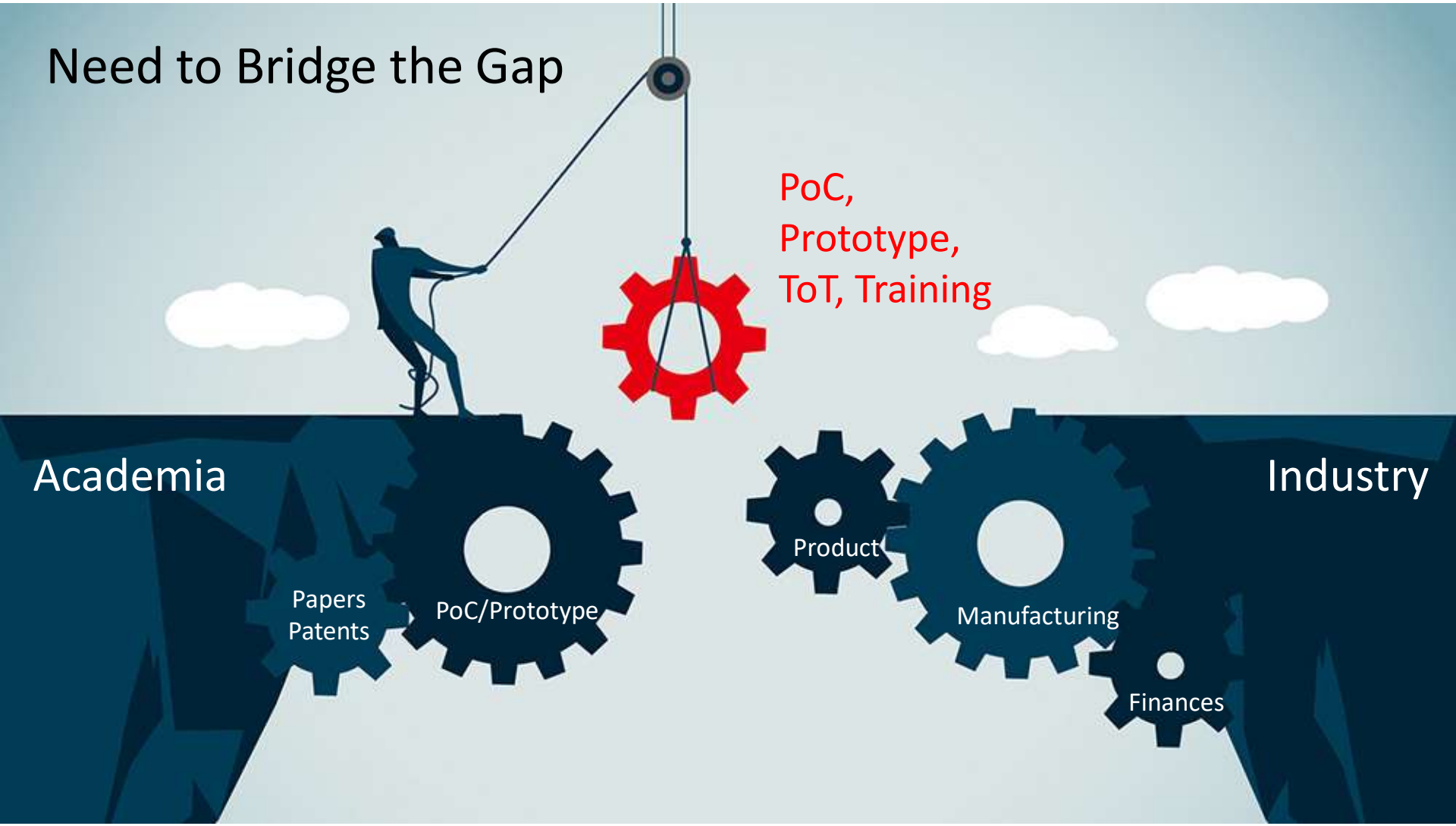
- WEE program
- Invest India WING
- Business mentoring by Alumni
- Various workshops

Innovation Awards

- POSOCO Power Systems Awards
- National Entrepreneurship Awards

IIT Delhi in Rankings




Need to Bridge the Gap
PoC,
Prototype,
ToT, Training
Academia
Industry
Papers
Patents
PoC/Prototype
Product
Manufacturing
Finances

Making Research sustainable: Patent-Publish-Prosper model

- **India ranks 6th globally in patent filings, with double-digit annual growth in the last 5 years.**

1. Catalyst for Startups

Patents are essential for deep-tech startups, ensuring investor confidence and legal safeguards for innovations.

2. Revenue Myth

In 2023, Stanford University earned 0.66% and MIT earned 0.86% of their budgets from patent licensing and technology transfers.

3. Real Value Lies Elsewhere

Startups based on patents drive the economy, with valuations running into thousands of crores in India and 100s of billions (~3 Trillion $ for Stanford) in the US.

4. Academia-Industry Collaborations are real key drivers

Patents co-filed with industry partners are far more likely to be commercialized, creating greater societal impact.

✓ Conscientious Research & Conscious Innovation

- **Conscientious research implies a research culture grounded in honesty, rigor, and ethical responsibility.**

- **Conscious innovation is about being aware of the societal consequences of what we create. It means designing technologies that are inclusive, sustainable, and humane.**

- more than half of India's population is under the age of 25, and one million people a month are expected to join the labour force over the next decade.
  - Technologies that help youth excel & acquire skills (ex: Akash tablet)
- India's massive agricultural sector employs over 50% of the population, yet accounts for only about 17% of total GDP
  - Use innovation/technology as a vehicle to improve productivity
- healthcare a major concern, rural health infrastructure hardly existent
  - 22 Million population pushed below poverty line annually due to healthcare expenditure. 750 million people live in areas where there is almost no healthcare.
- Security- a major concern area for India
- Energy – Renewables is a big issue. Not much land availability in India
- Huge Water crisis: 4% of world's water resources and 18% of world's population

>> Available, Accessible and Affordable technologies

"More with Less for More"

The Five Key Technology Platforms

IT

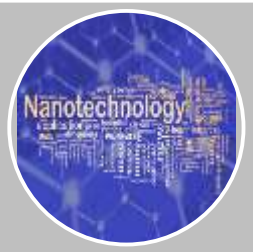
Saudi Arabia Crude oil exports In 2019: USD 133.6 Billion

Indian IT Exports in 2019: USD 137 Billion *(NASSCOM)*

BT

Largest provider of generic drugs globally. 50% of global vaccines, 40% of generic demand in the US and 25% of all medicines in UK *(www.ibef.org)*

NT



Ranked 3rd in the world for knowledge generation *(Nature Nanotechnology)*

CT

India ranked 5th in AI/ML citations *(CSRankings.com)*

QT

Strong tradition of basic research

The 5 Ts

India has done well where clear goals are set. Examples are ISRO, DAE etc. A top down approach is the key for translation of knowledge to wealth.

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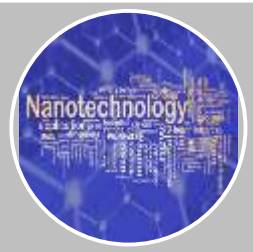

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Low-Cost Sensor Platforms and Systems

- A Low Cost Cardiac Diagnostic System *(Medical doctors)*
- A Vapour Phase Explosive Detection System *(Security Agencies - PSA)*
  - NEMS Platform
  - Vibration Energy harvesting for sensors
- Soil Moisture & NPK Sensors for Agricultural applications *(Farmers)*
- Organic Dosimeters *(medical doctors)*
- Summary

Low-Cost Sensor Platforms and Systems

- A Low Cost Cardiac Diagnostic System *(Medical doctors)*
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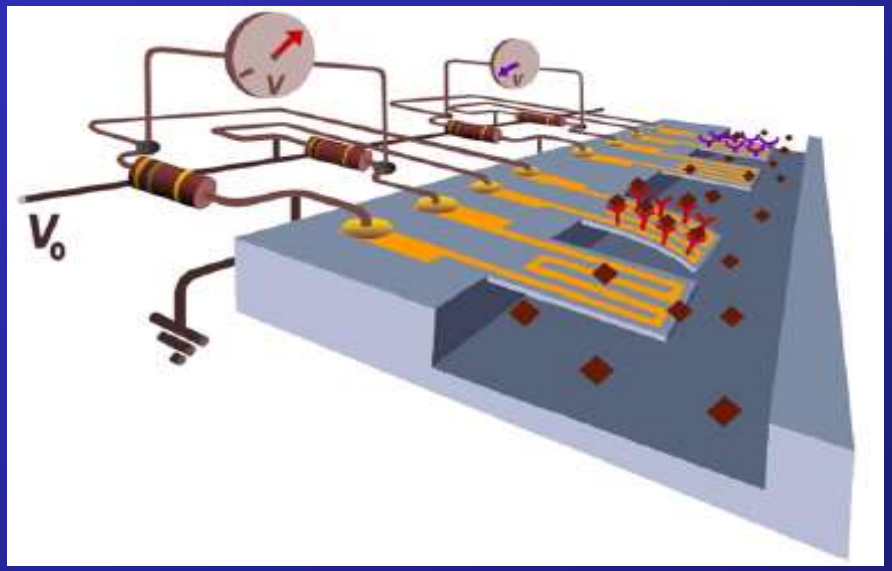
- Summary

Sensor Array: Cantilevers

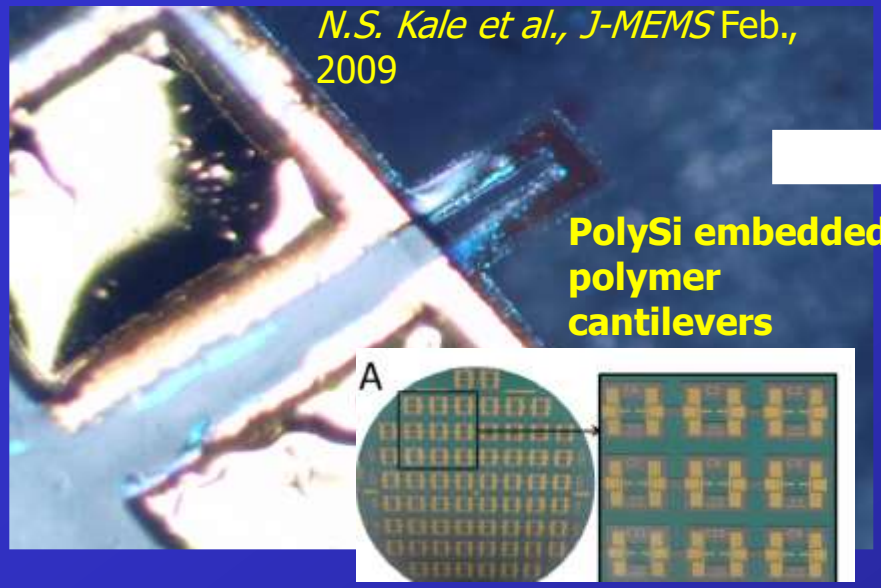
- Based on resonating structure 0r deflection:
  - ⇨Attachment changes mass or stiffness of resonating structure and thence resonant frequency
  - ⇨Attachment changes the surface stress leading to a bending of the cantilever

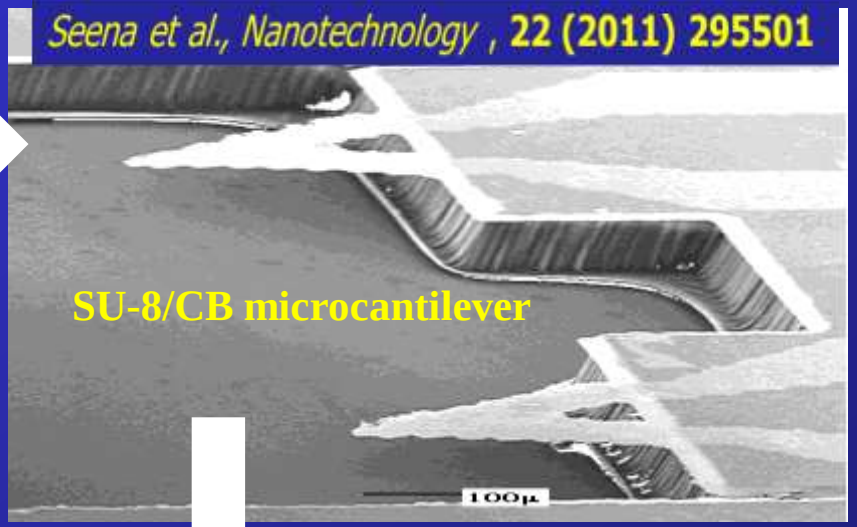


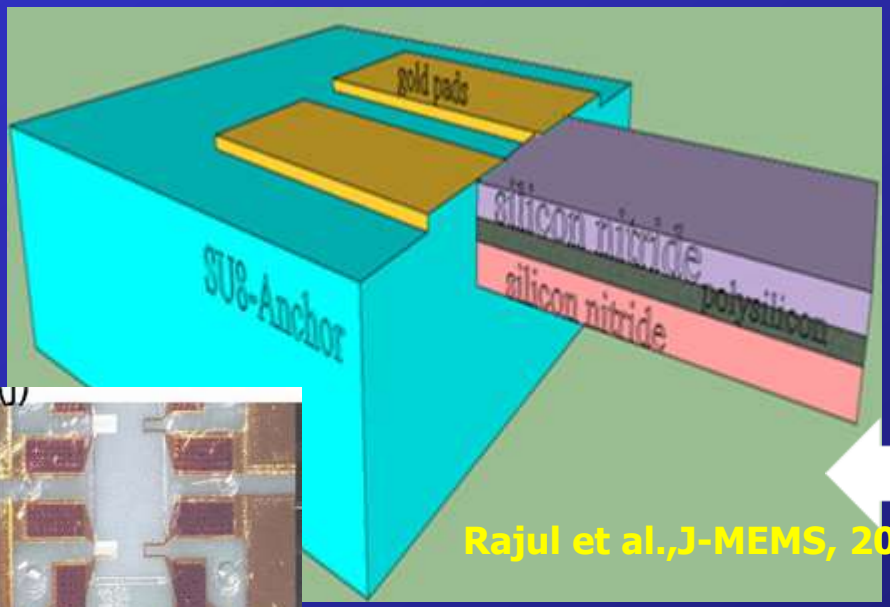
$$\Delta z = \frac{3 \cdot \Delta\sigma \cdot (1-\nu) \cdot l^2}{E \cdot t^2}$$

G.F.=$(\Delta R/R_o)/\varepsilon$

Piezo-resistive Polymer Cantilevers@ IITB



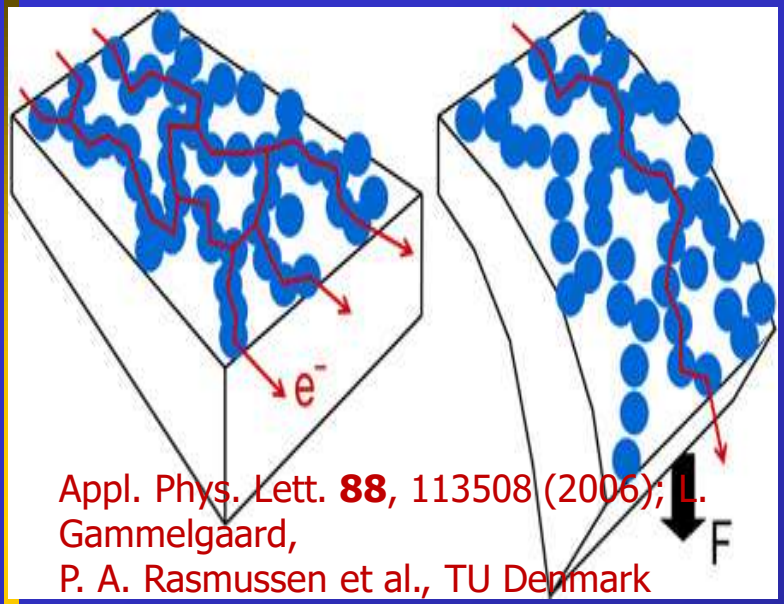




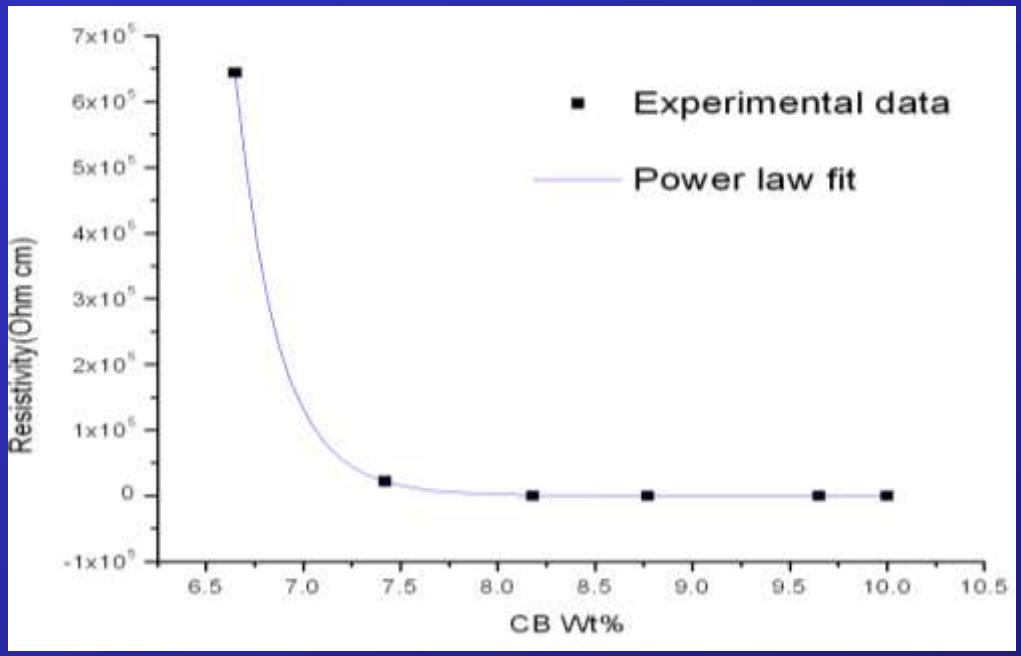
Rajul et al.,J-MEMS, 2014

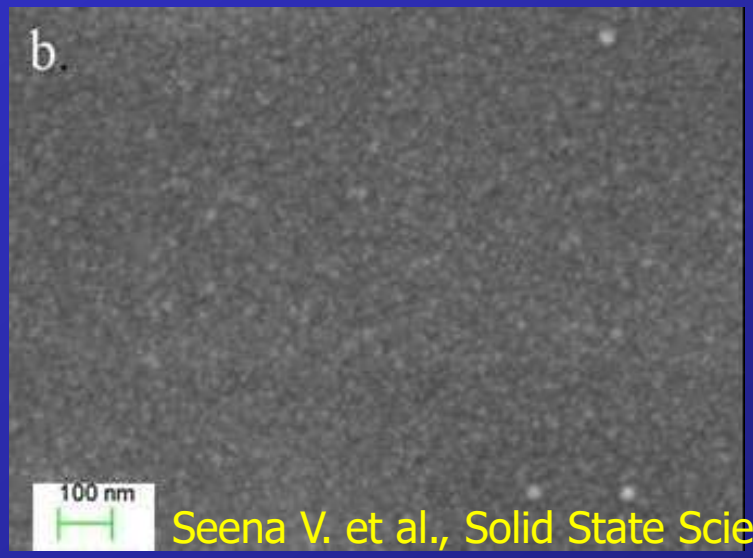
Nano-wire embedded polymer cantilevers

Polymer Cantilevers with embedded Carbon Black particles



Appl. Phys. Lett. **88**, 113508 (2006); L. Gammelgaard,
P. A. Rasmussen et al., TU Denmark





- CB/Polymer composite conducts for CB concentration above percolation threshold
- Conduction due to tunneling between two aggregates : $\Delta R/R$ due to change in tunnel distance upon application of strain
- Expected to be highly sensitive

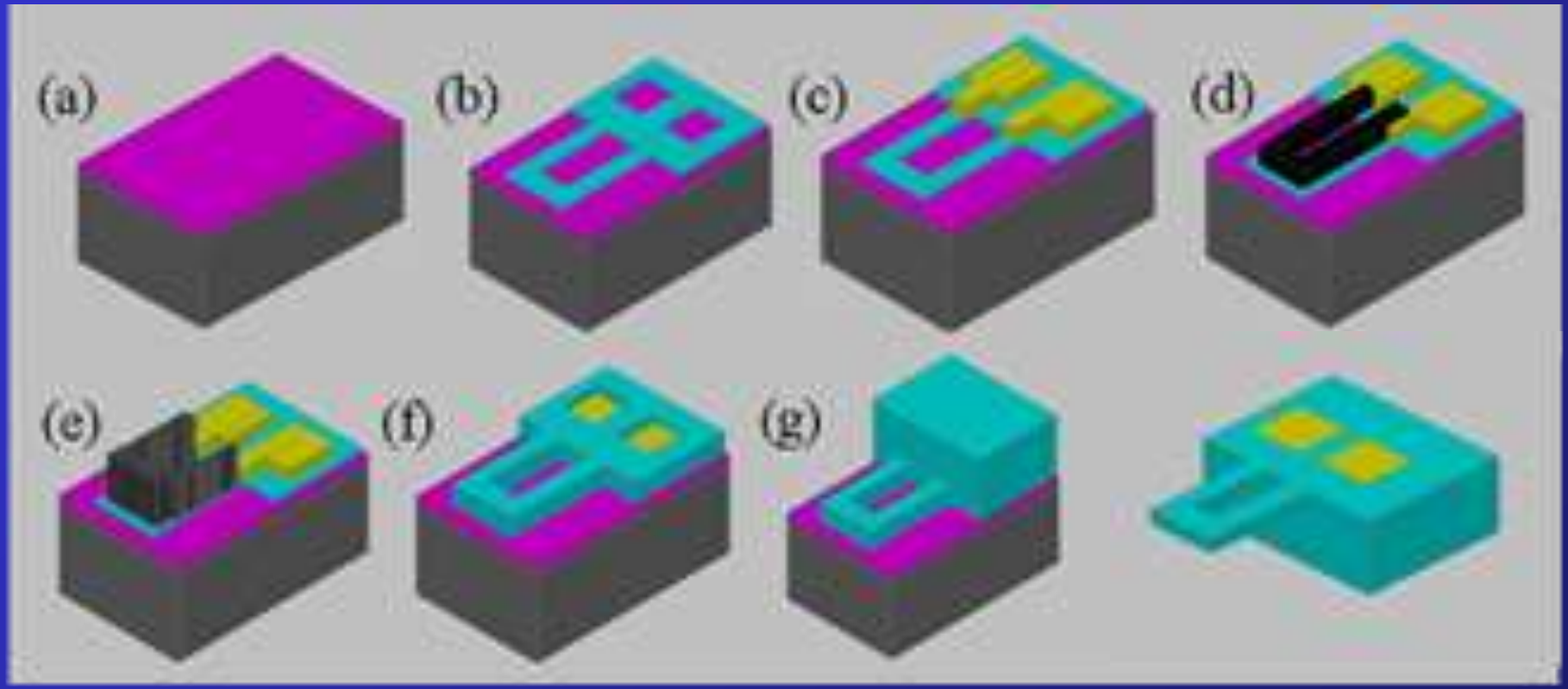
Seena V. et al., Solid State Sciences (Elsevier), Volume 11, Issue 9, September 2009

V.R. Rao: rrao@ee.iitb.ac.in

Instead of nano-particles, can we use vertically standing nano-wires embedded between two polymer cantilever layers?

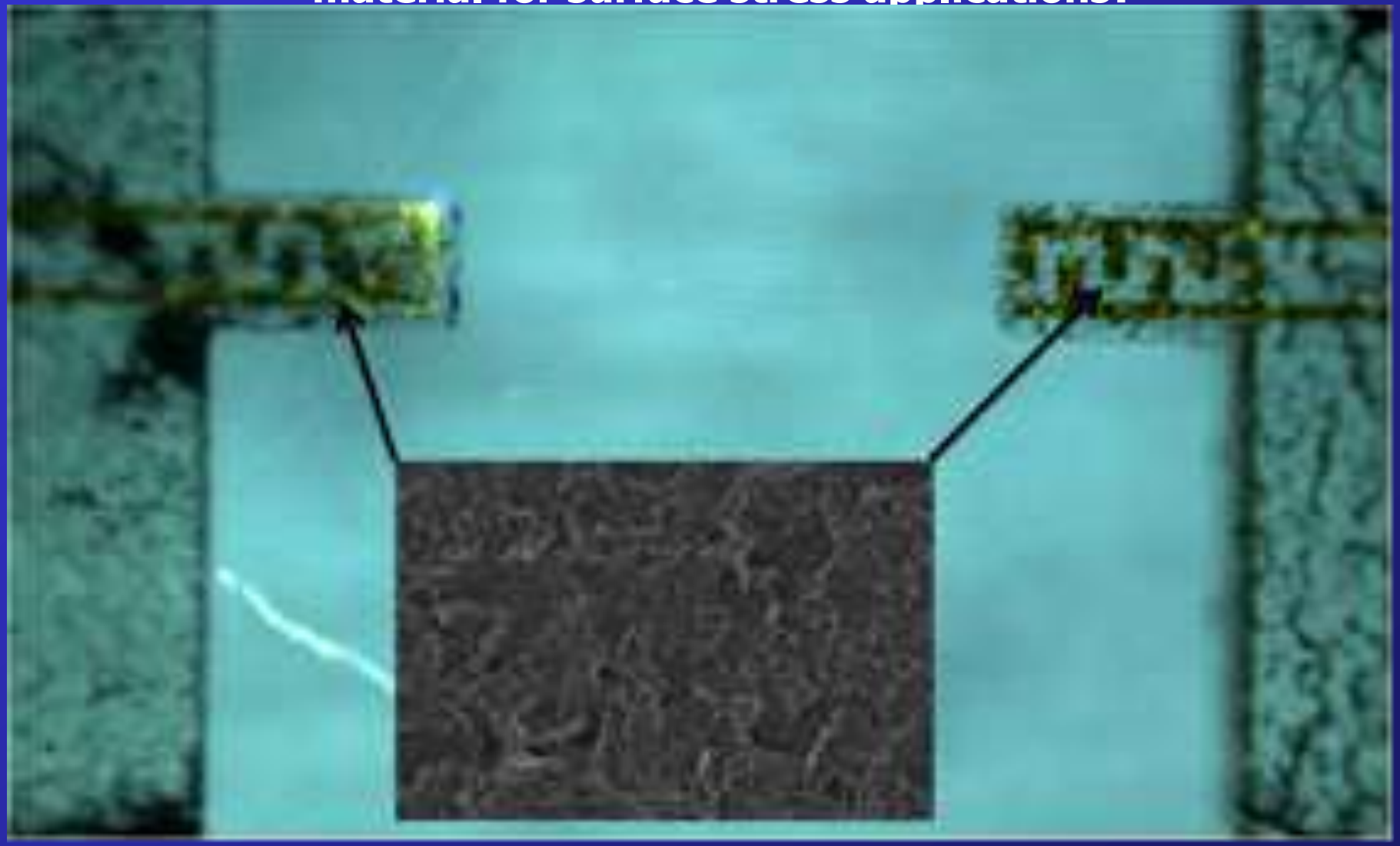
- Larger surface area for interactions, so higher gauge factors

ZnO Vertical Nanowire Embedded Strain Sensing Cantilever

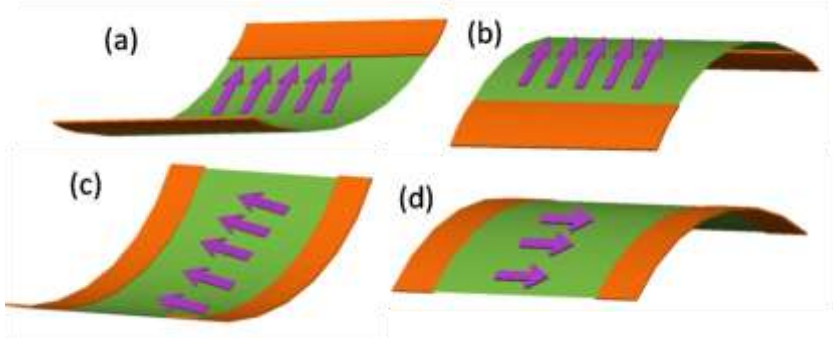


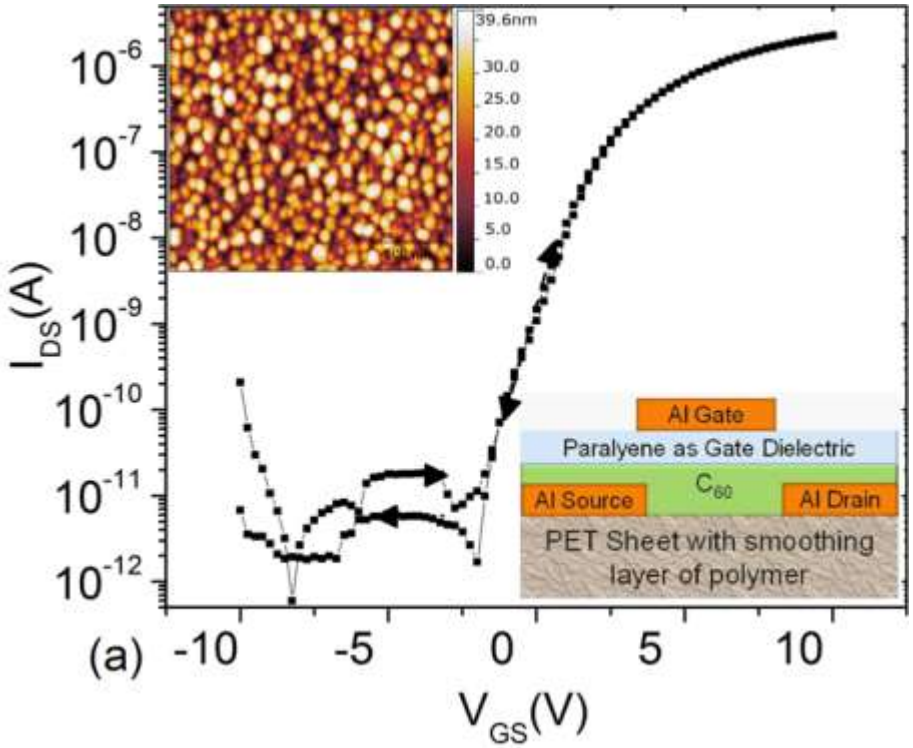
(a) Silicon dioxide grown on a silicon wafer (b) First encapsulation layer of SU-8 (c) Patterned Cr/Au layer for contact. (d) Pattering of ZnO seed layer (e) Vertical Growth of ZnO Nanowire (f) Bottom encapsulation layer of SU-8. (g) Pattering of SU-8 anchor layer.

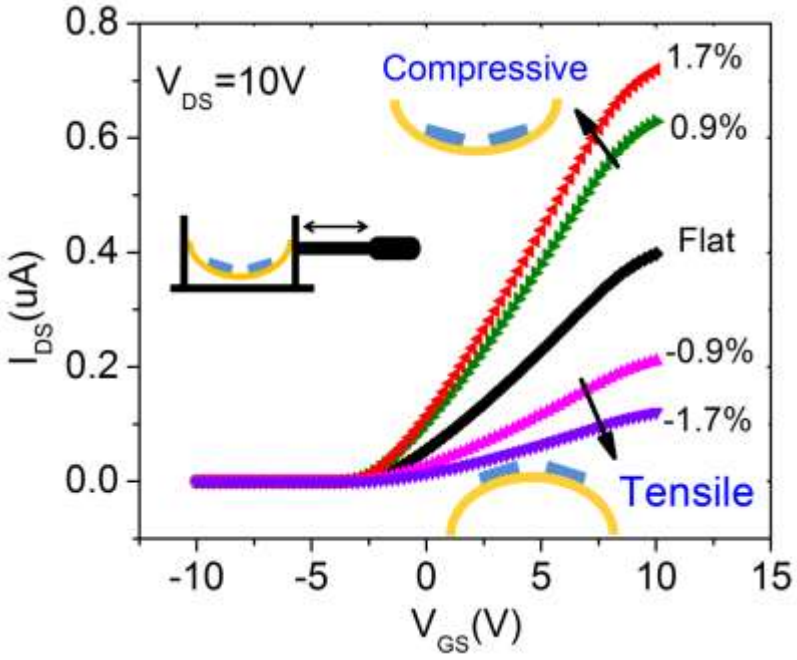
Can we combine the high gauge factor values reported for Graphene (K>1000) with a low stiffness polymer material for surface stress applications?

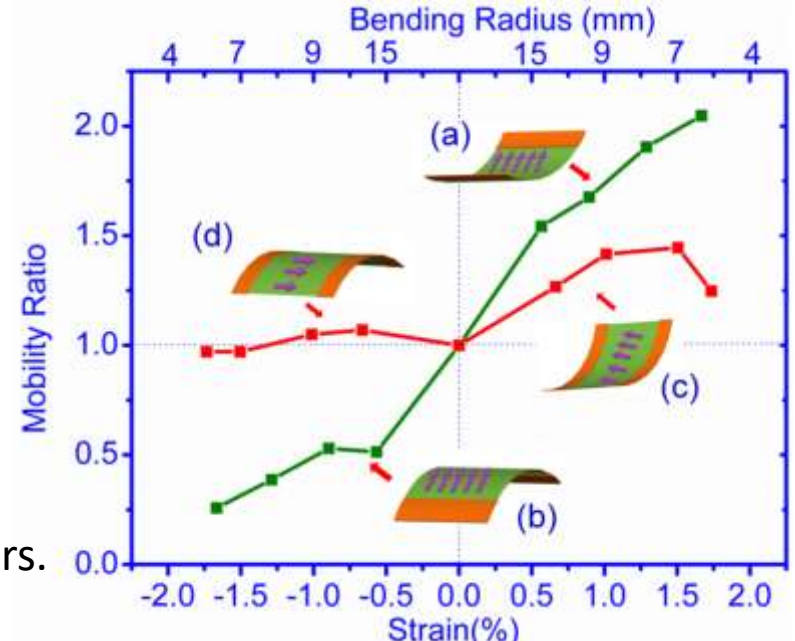


Effect of Strain- C_{60} Organic Materials









Strain induced anisotropic effect on electron mobility in C60 based organic field effect transistors. Akash et al., Appl. Phys. Lett. 101, 083305 (2012);

Polymer microcantilever with integrated OFET

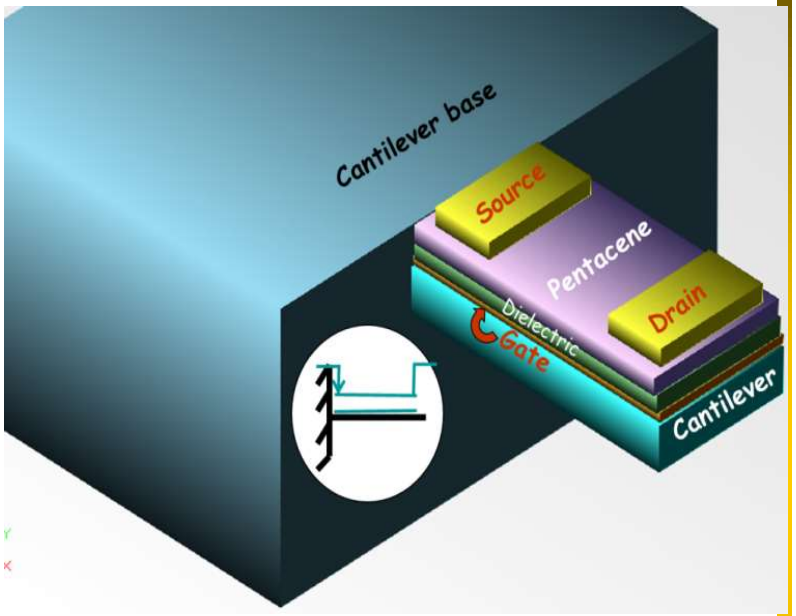
[B] Design and Fabrication of CantiFET

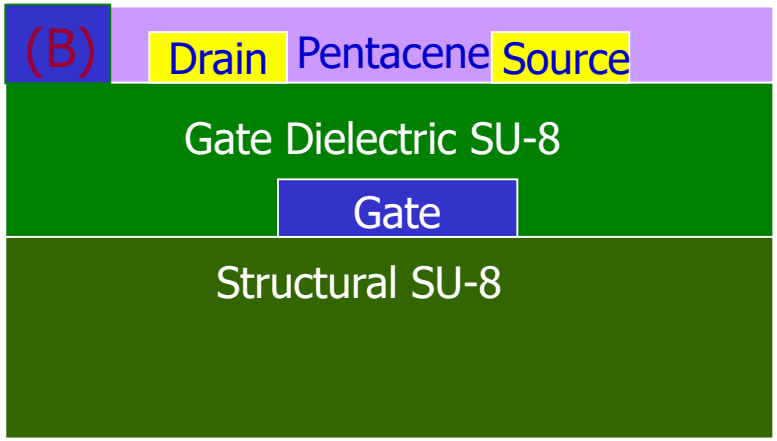
Geometrical details of CantiFET

Parameter	Value
1. Cantilever length	340 µm
2. Cantilever width	170 µm
3. Cantilever overall thickness	1.9 µm
4. Die area	4 mm X 4 mm

Layer details of CantiFET

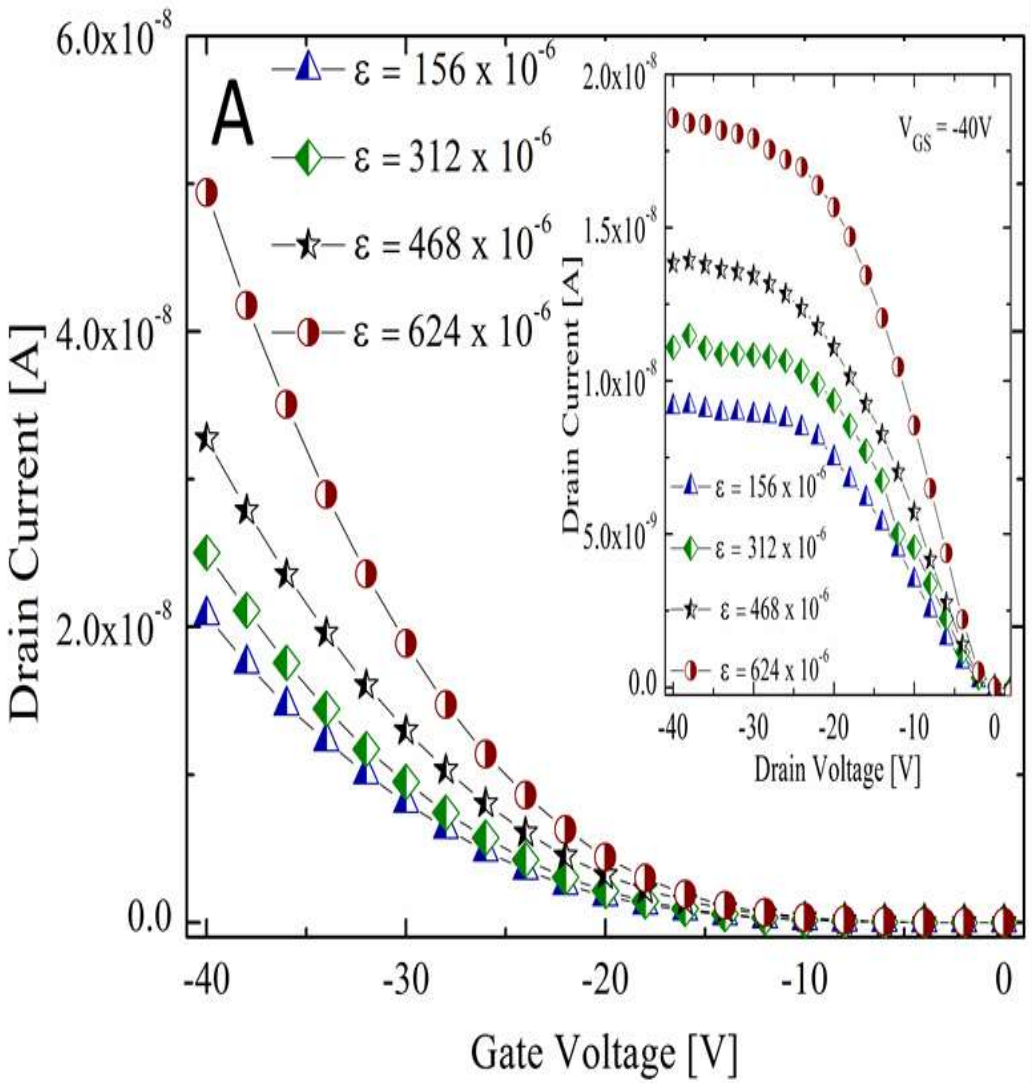
Layer No	Material	Thickness
1. Cantilever first layer	SU-8	1 µm
2. Gate	Cr/Au	5nm/ 80 nm
3. Gate Dielectric	SU-8	900 nm
4. Source/ Drain	Cr/Au	5nm/ 80 nm
5 .Organic semiconductor	Pentacene	40-50 nm

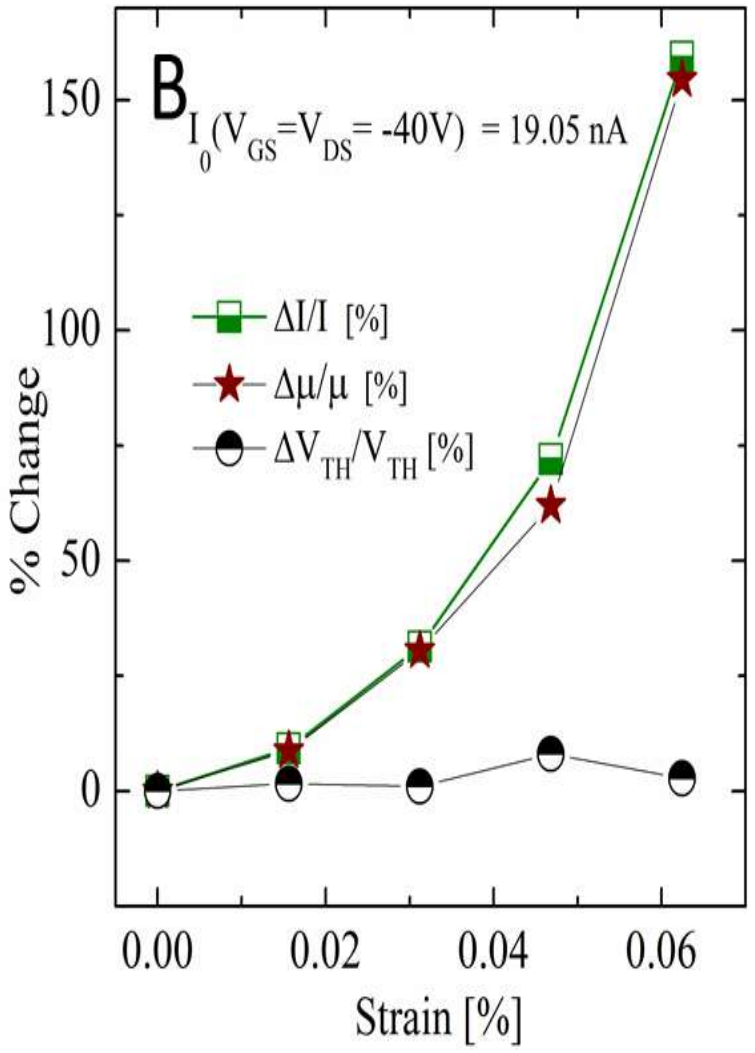




(A) Planar and (B) Cross sectional schematic of CantiFET device

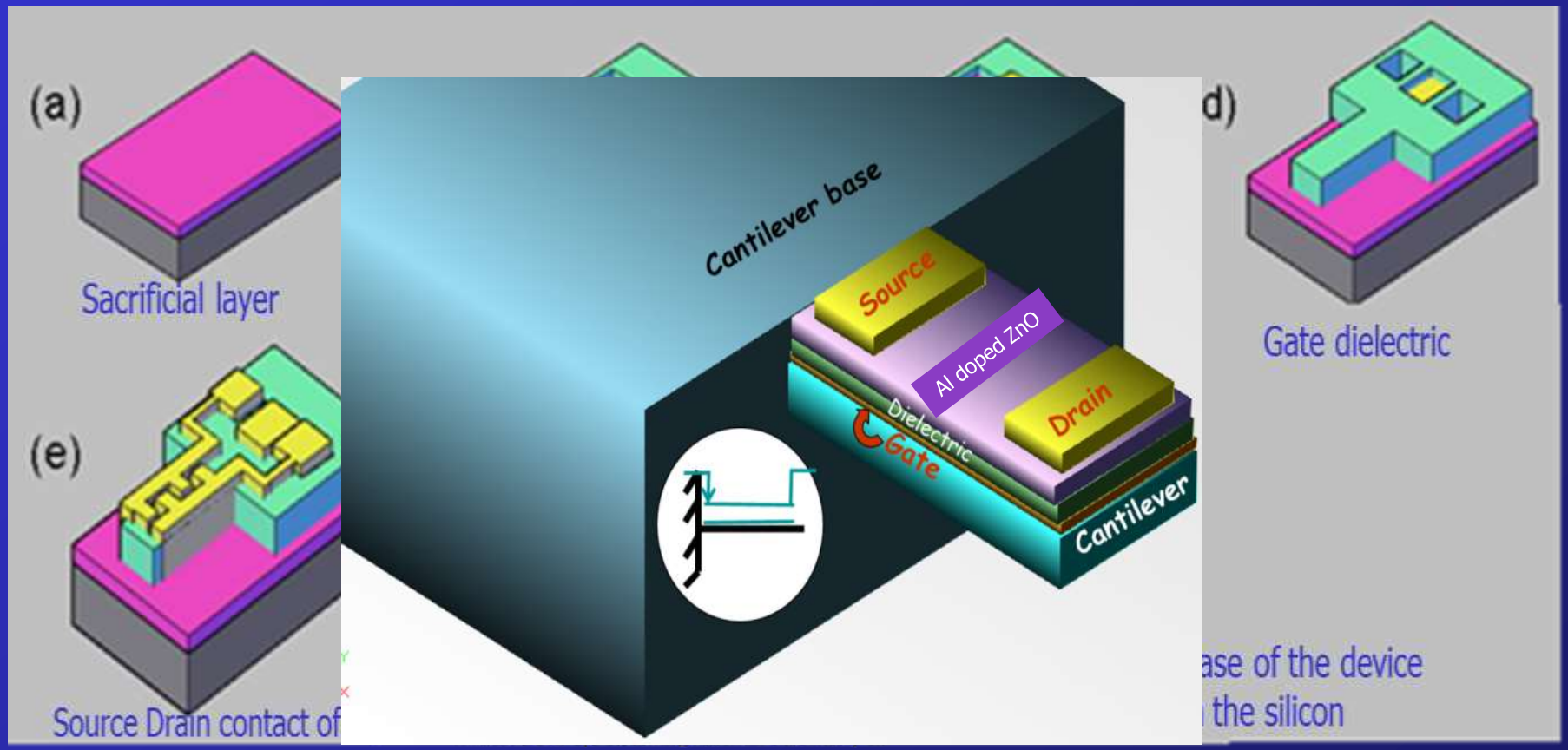
Polymer microcantilever with an integrated OFET

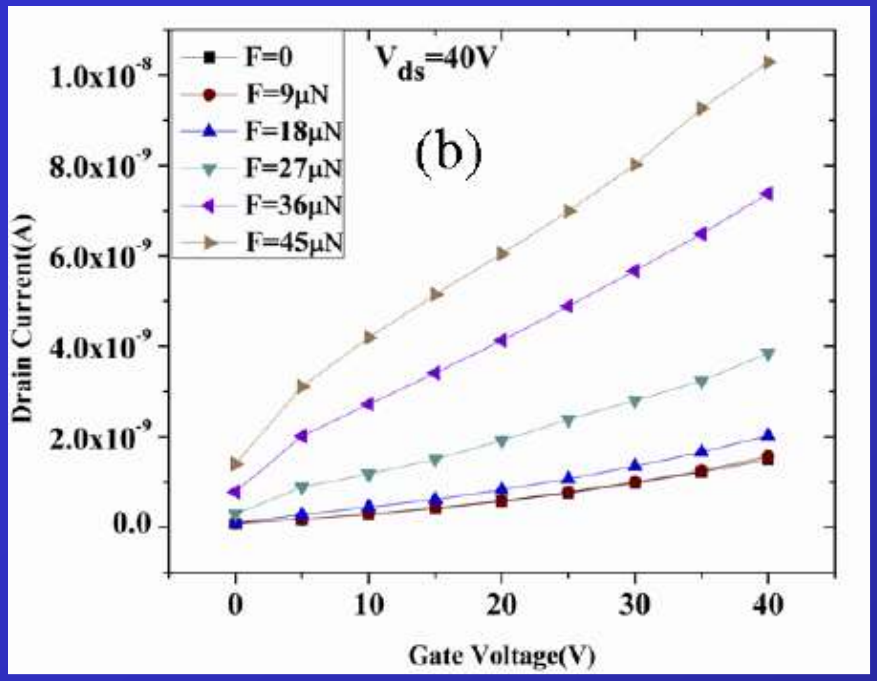


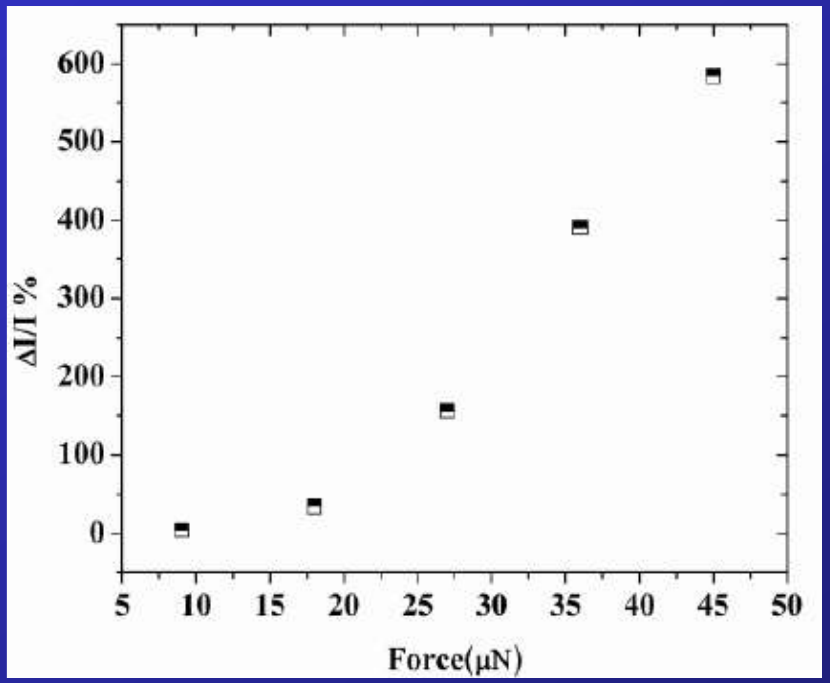


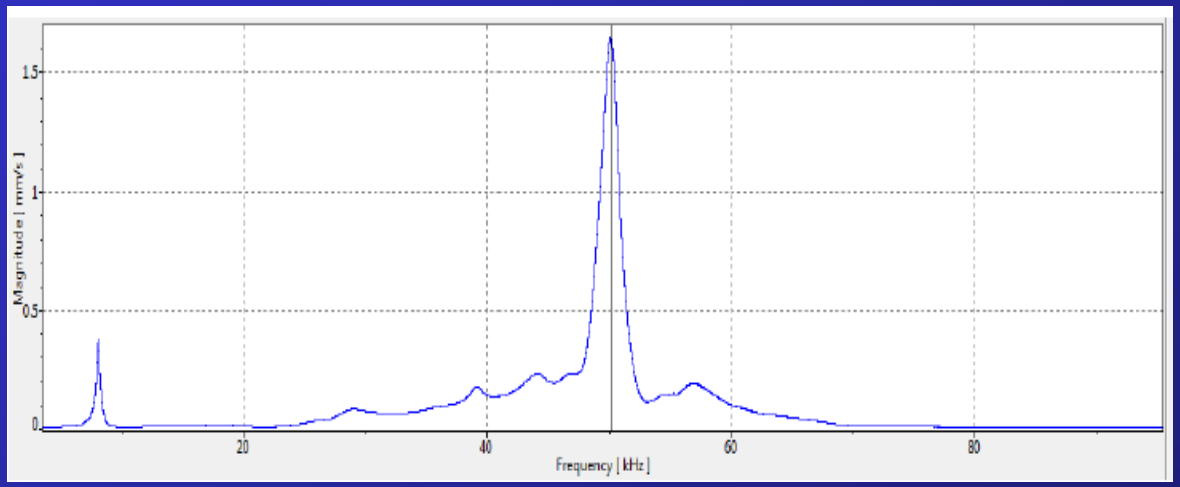
CantiFET Deflection Characterization

CantiFET as a Strain Sensor









Strain sensitivity: 116 ppm/nm in ΔI/I for nm of deflection

Combined effect of piezo-electricity + Piezo-resistivity

Prasenjit Ray, V.Ramgopal Rao, "Al- Doped ZnO thin-film transistor embedded micro-cantilever as a piezoresistive sensor", APPLIED PHYSICS LETTERS 102, 064101 (2013)
Prasenjit Ray et al., "Plastic deformation study of vertical Zinc oxide nanowires for polymer cantilever based sensor applications", IEEE Transactions on Nanotechnology, Vol. 13, No. 4, July 2014

Parameter	Our work	Ref[1]	Ref[2]	Ref [3]	Ref [4]
Deflection sensitivity (ppm/nm)	128	4.8	0.3	> 1	~100

Our work:

Prasenjit Ray, V. Ramgopal Rao, "ZnO Nanowire Embedded Strain Sensing Cantilever: A New ultra-sensitive Technology Platform", IEEE/ASME J-MEMS, April 2013

Prasenjit Ray, V.Ramgopal Rao, "Al- Doped ZnO thin-film transistor embedded micro-cantilever as a piezoresistive sensor", APPLIED PHYSICS LETTERS 102, 064101 (2013)

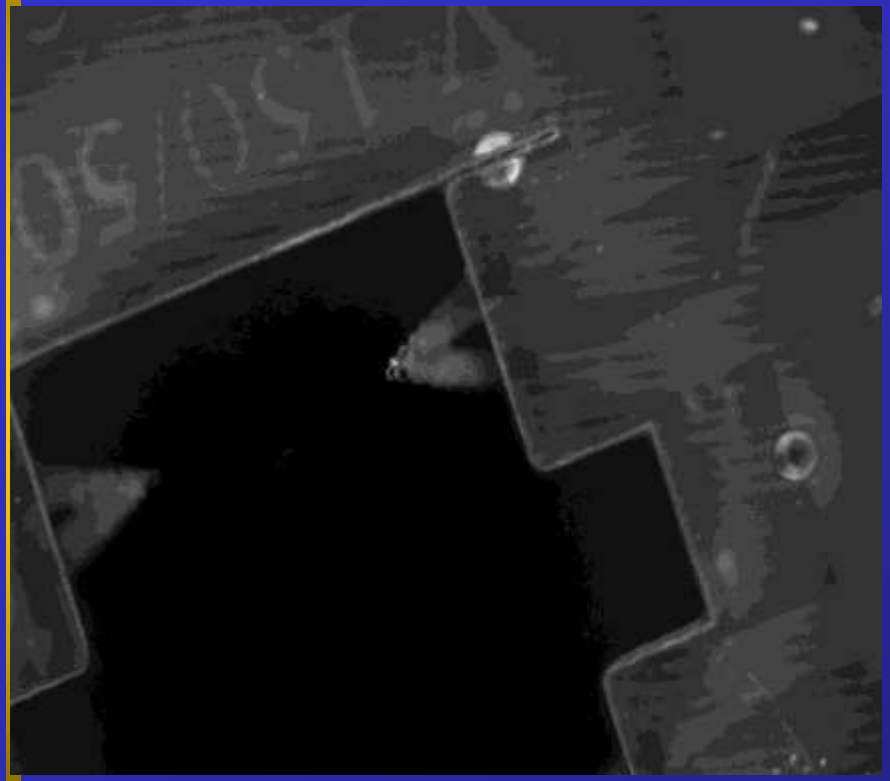
Ref-1: X.Yu,J. Thaysen,O. Hansen and A. Boisen , "Optimization of sensitivity and noise in piezoresisitve cantilevers" *Journal of Applied Phy* 92 (2002) pp6296-6301.

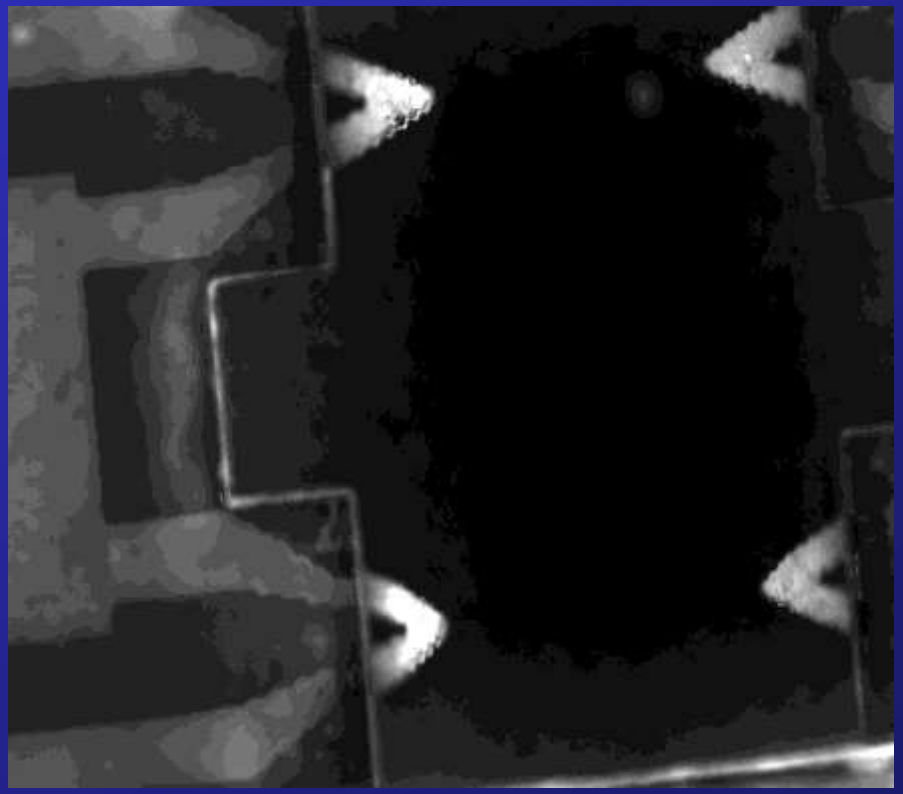
Ref-2: J. Thaysen, A.D. Yalqinkaya, R.K. Vestergaard, S. Jensen, M.W. Mortensen, P. Vettiger "SU-8 Based Piezoresistive Mechanical sensor" in proceedings of *IEEE MEMS* 2002, pp 320-323

Ref-3: V. Seena, A. Rajoriya, A. Fernandes, K. Dhale, P. Pant, S. Mukherji, V. Ramgopal Rao "Fabrication and characterization of polymer composite microcantilever sensors for explosive detection" in proceedings of 23rd *IEEE MEMS*,2010 Hong Kong, pp 851-854.

Ref-4: M.F. Regulez, J. A. Plaza, E.L.Tamayo,A.S. Paulo "Lithography guided horizontal growth of Silicon nanowires for fabrication of ultrasensitive piezoresistive strain gauge", Microelectronic Engineering,87 pp 1270-1273,2010

Polymer Cantilevers with antibody immobilization on the surface



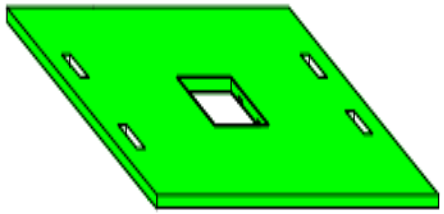


Before Antibody Immobilization

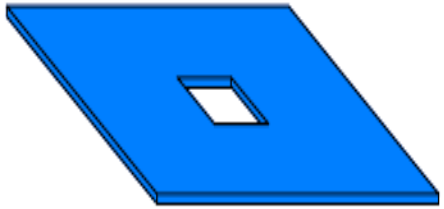
After Antibody Immobilization

M. Joshi et al., Applied Surface Science, Vol.253,No.6, pp.3127-3132, January, 2007

Cantilever-Liquid Cell Integration: Selective Immobilization

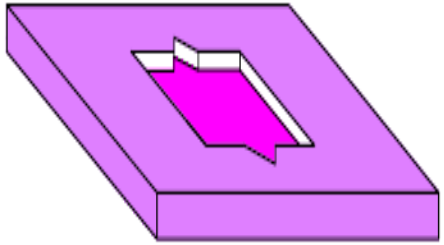


PDMS Die containing microchannels

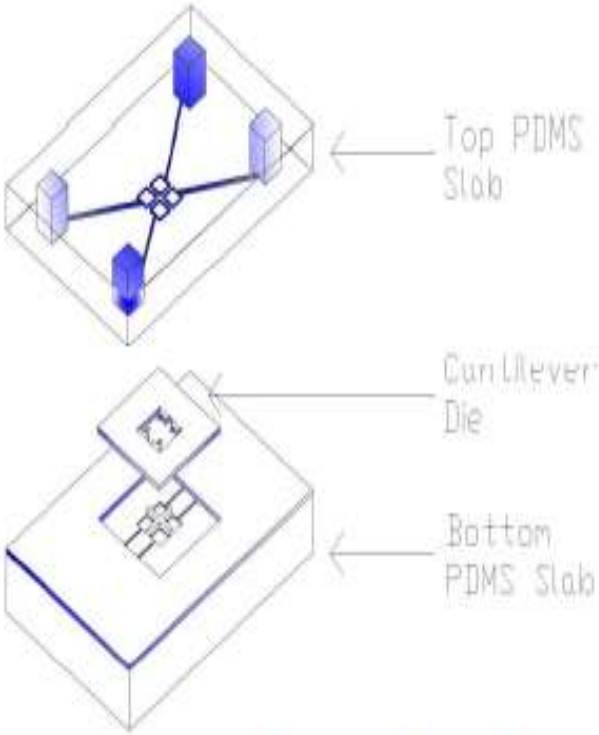


PDMS Slip to cover microchannels

Cantilever Die

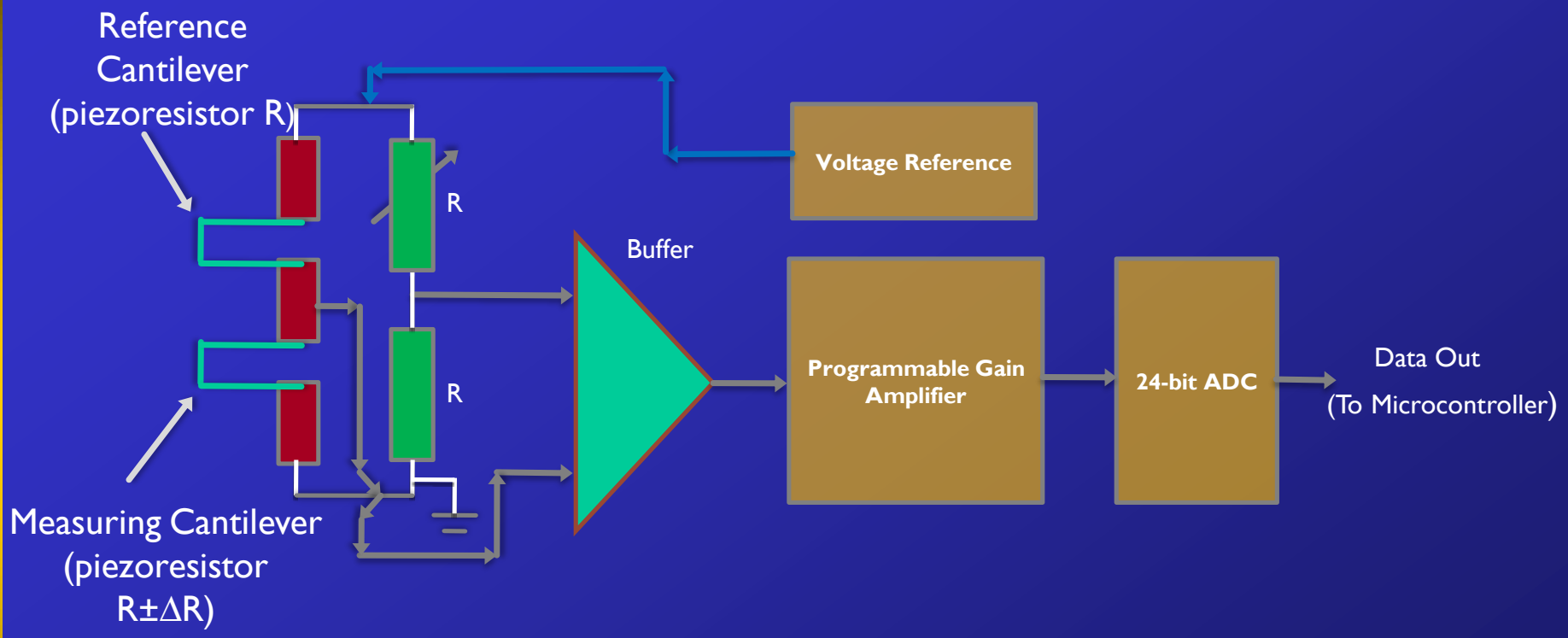


PDMS Substrate with groove for cantilever die to sit-in



Picture of the PDMS based Selective Immobilization set-up

Cantilever Characterization System

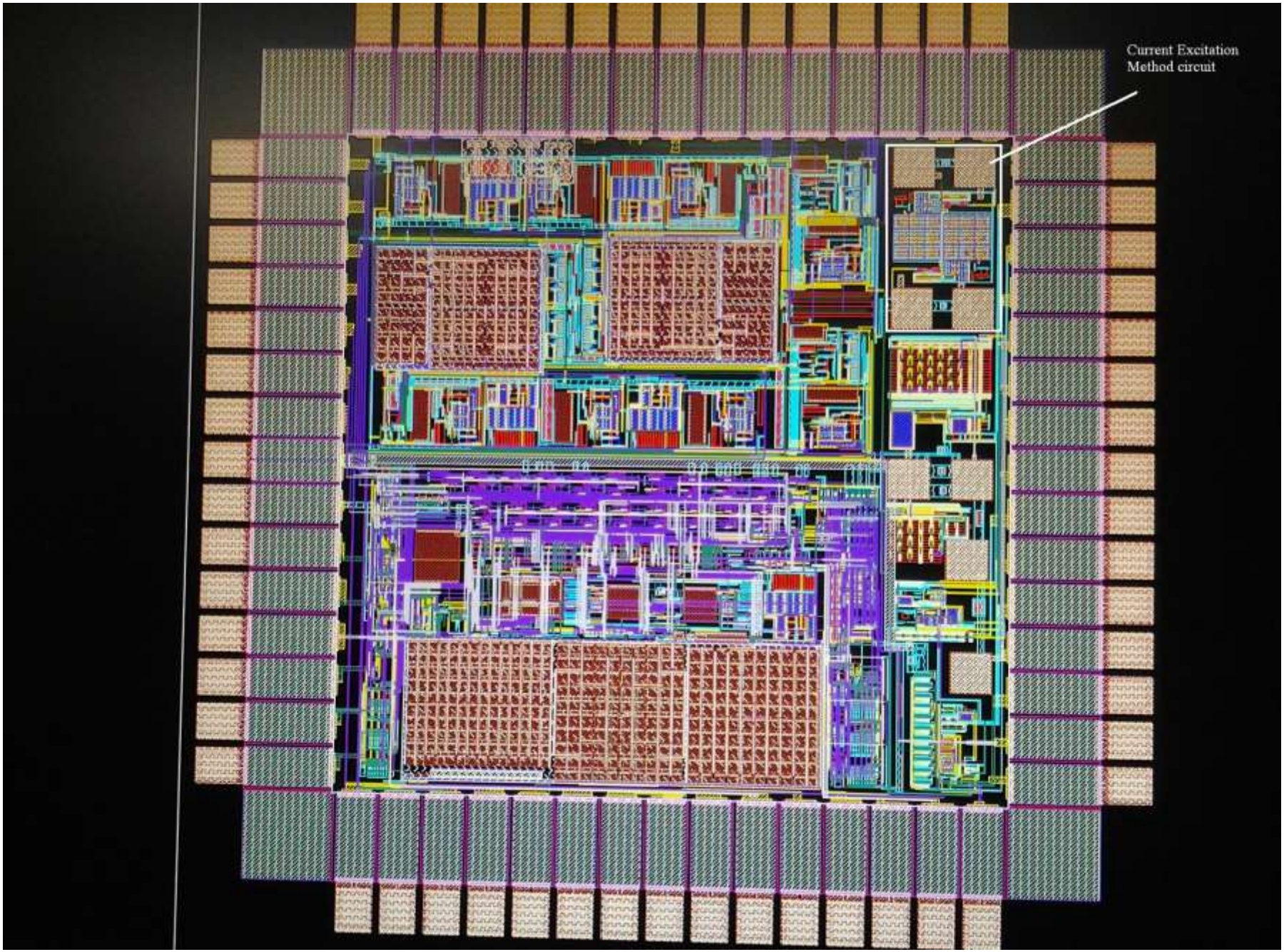


Wheatstone Bridge based ΔR/R measurement system

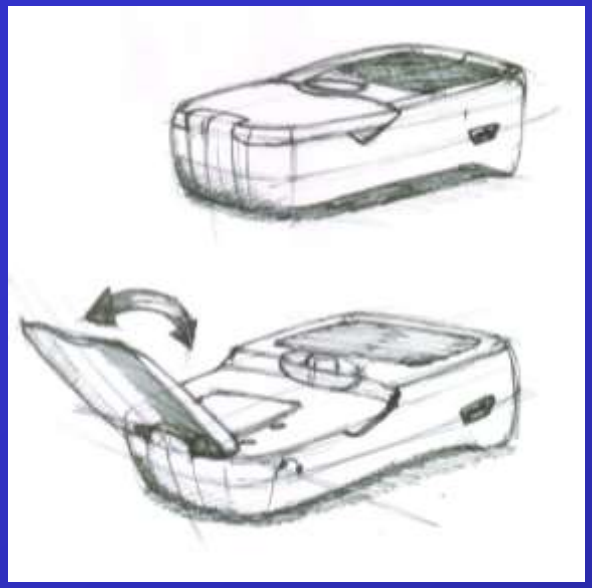
Neena et al., "Current Excitation Method for Δ*R* Measurement in Piezo-Resistive Sensors with a 0.3-ppm Resolution" IEEE Transactions on Instrumentation & Measurement, March 2012

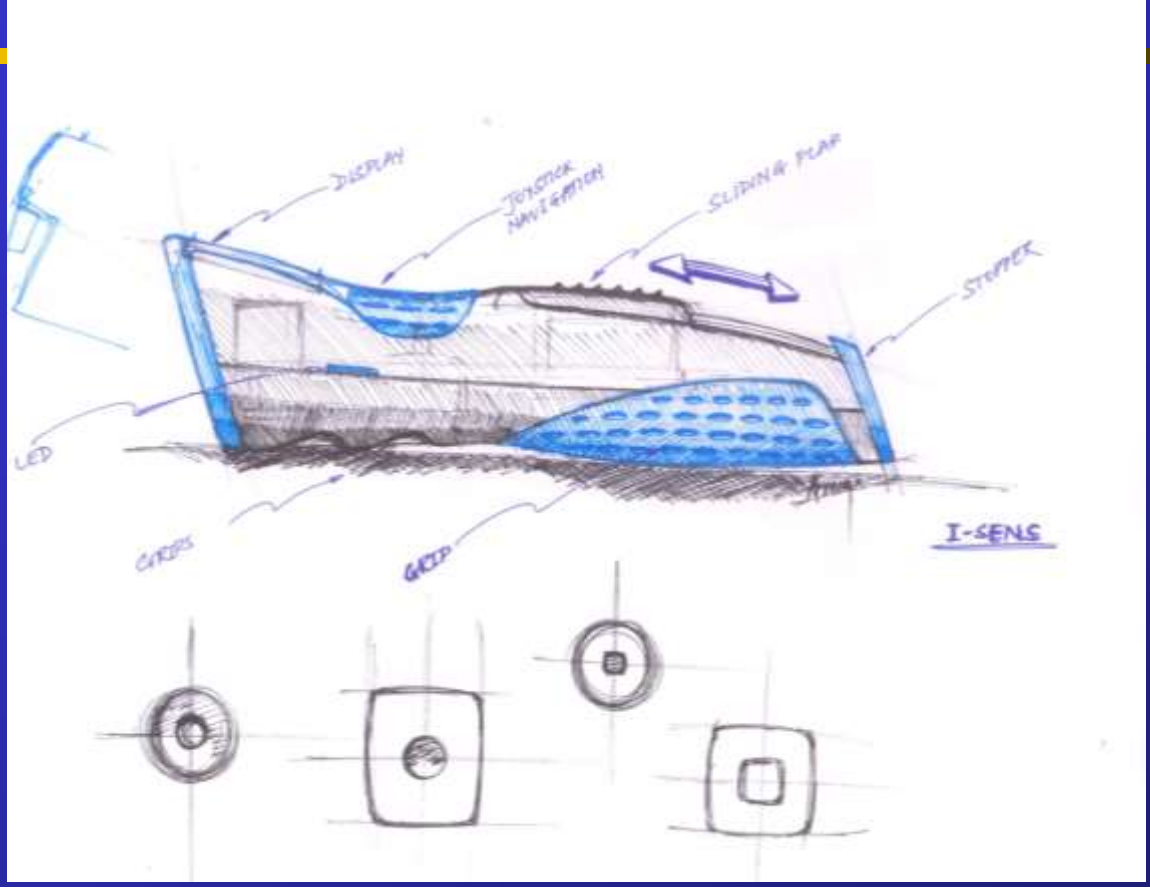
Neena et al. "Piezoresistive 6-MNA Coated Microcantilevers with Signal Conditioning Circuits for Electronic Nose Applications", ASSCC, 2012

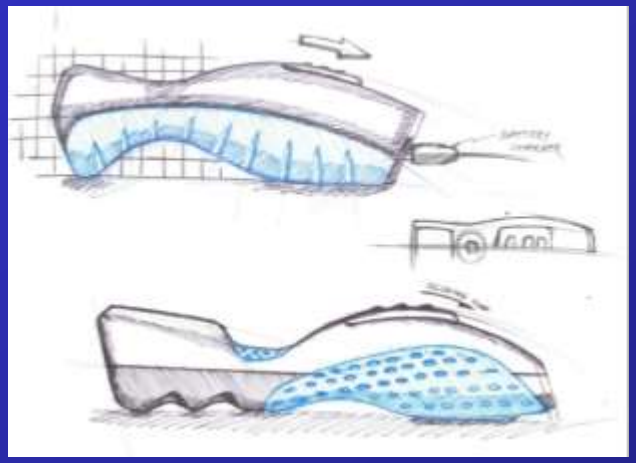
Sudip et al., IEEE Sensors Journal, Vol. 15, July2015

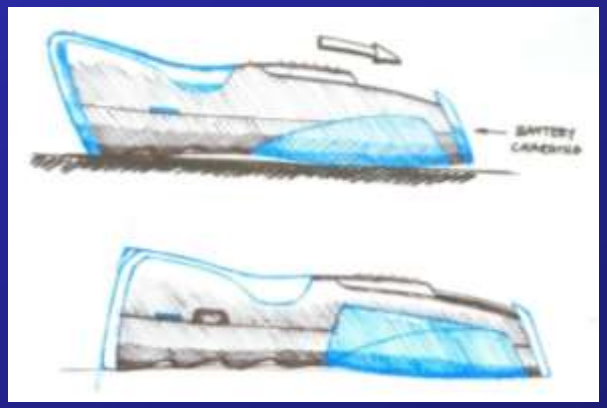

Current Excitation
Method circuit

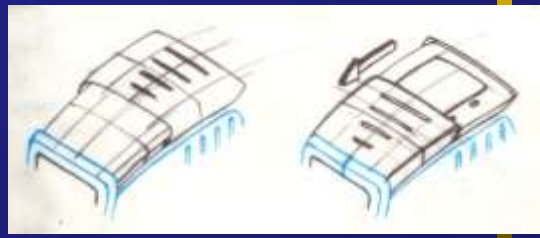
Exploratory Sketches - iSens



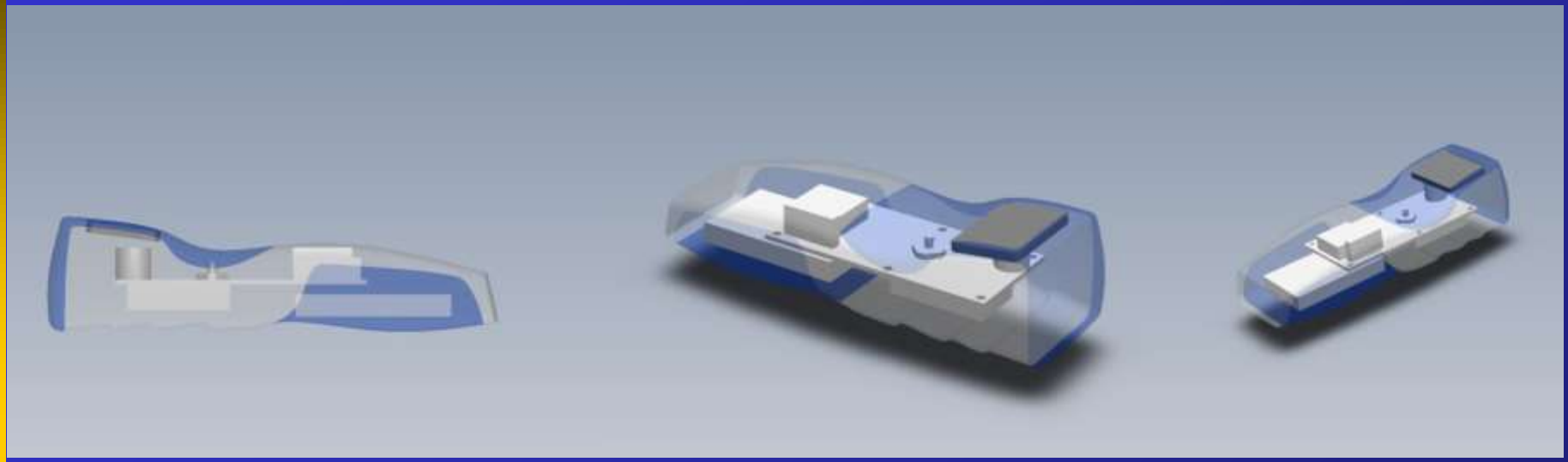


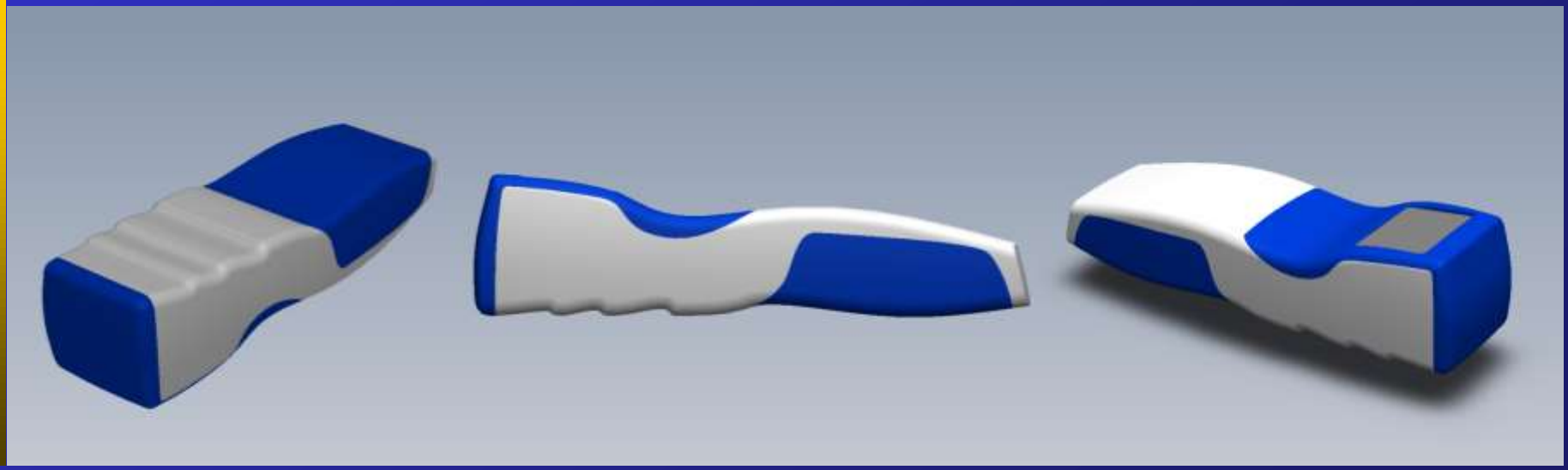






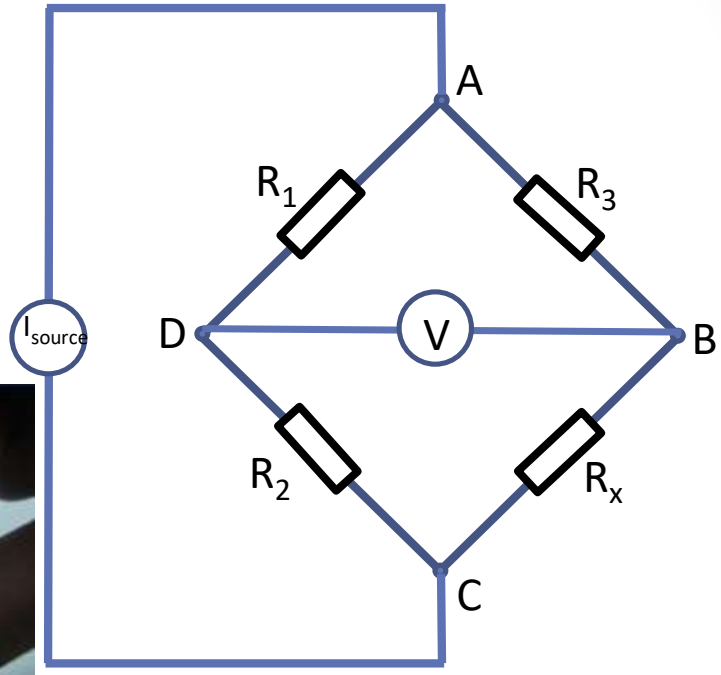
CAD Packaging of Components





Ver-2 for Hospital Trials:
iSens Working prototype built jointly with NanoSniff Technologies Pvt. Ltd.

Electrical readout



12 lead heart monitor with a thermal printer

Prof. Dinesh Sharma et. al.

- The unit is battery operated.
- It has a user interface with a pictorial guide for attachment for any one of the 12 standard ECG leads.
- This allows a minimally trained person to take an ECG, which has obvious advantages in a rural setting.
- ECGs can be collected by a field operator with printouts and then examined at the hospital by a doctor.

This is a portable ECG unit with a printer, which can be easily carried by a doctor in a briefcase

V.R. Rao: rrao@ee.iitb.ac.in

Low-Cost Sensor Platforms and Systems

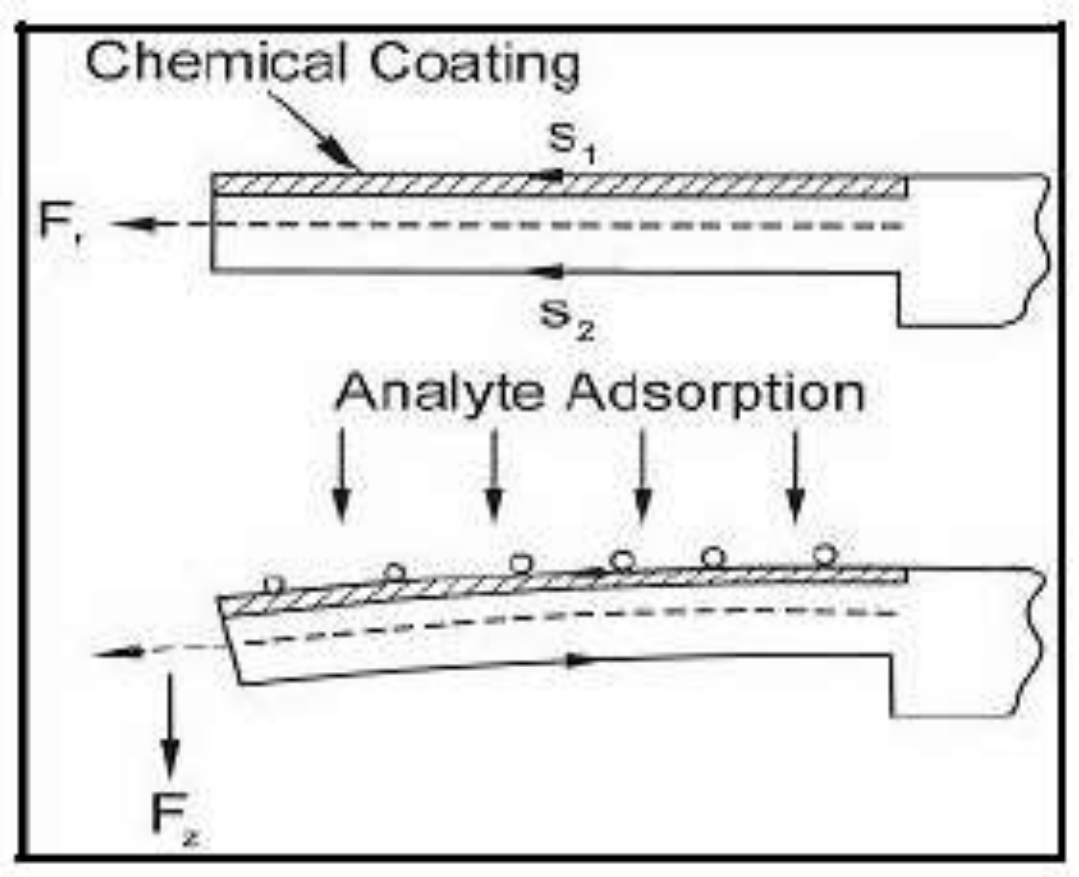
- A Low Cost Cardiac Diagnostic System *(Medical doctors)*
- A Vapour Phase Explosive Detection System *(Security Agencies - PSA)*
  - NEMS Platform
  - Vibration Energy harvesting for sensors
- Soil Moisture & NPK Sensors for Agricultural applications *(Farmers)*
- Organic Dosimeters *(medical doctors)*
- Summary

Explosive Detection- Challenges ..2

Popular Name	Chemical Formula	Decomposition Temp. (°C)	Molecular Mass (g/mol)	Density at 20°C (g/cm^3)	Vapor Pressure at 25°C (torr)
TNT	$C_7H_5N_3O_6$	240	227.13	1.654	~ 6.0×10^{-6}
RDX	$C_3H_6N_6O_6$	170	222.12	1.820	~ 5.0×10^{-9}
PETN	$C_5H_8N_{12}O_4$	190	316.14	1.773	~ 1.5×10^{-8}

Currently available sensor systems suffer from several problems, viz. cost, size, sensitivity, selectivity

Cantilever based Explosive Detection @ IIT Bombay

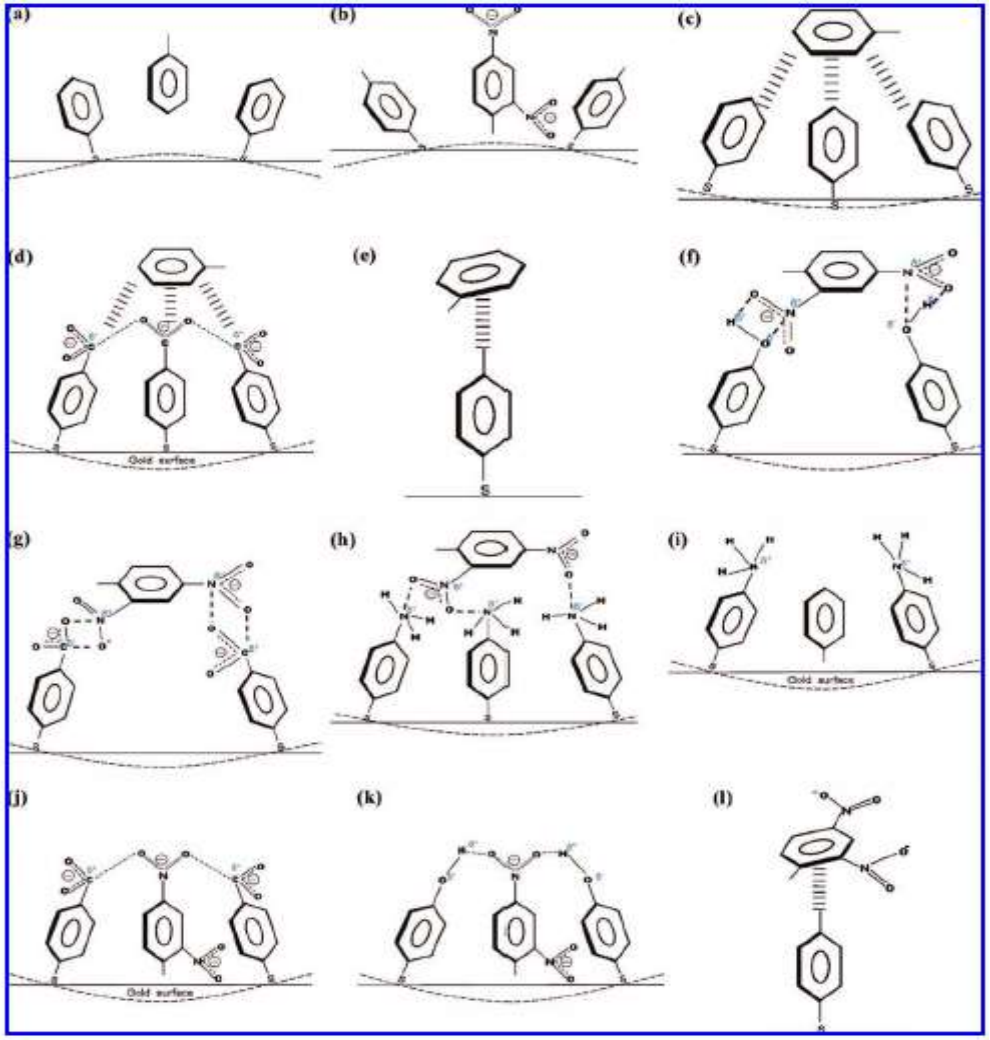


- Surface coatings

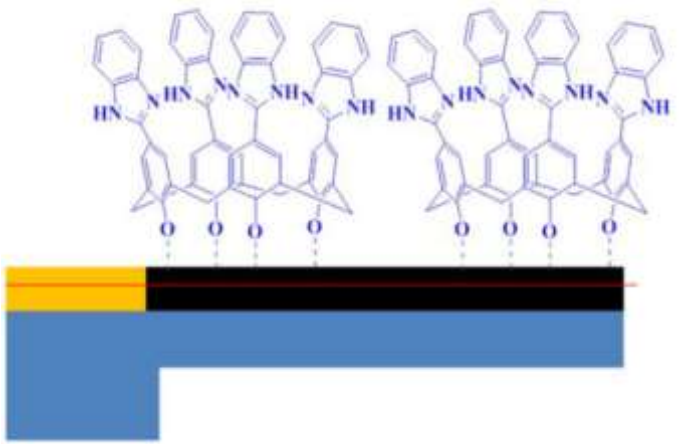
(a) 4-mercaptobenzoic acid (4-MBA)
(b) Fluoroalcohol polysiloxane polymer (SXFA)
(c) Porphyrin coating on cantilevers
(d) 6-Mercaptonicotinic Acid [6- MNA]
(e) Calaxyrenes
(e) Other proprietary coatings

- **Polymer Piezo-resistive SU-8 Cantilevers (recently with Parylene coatings)**

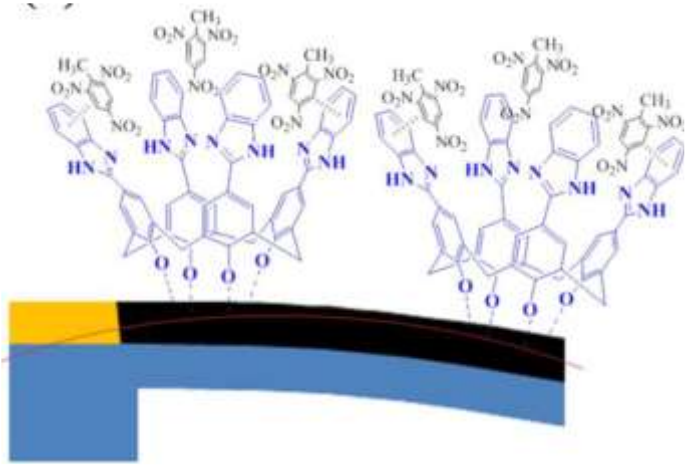
Calixarene coated polymer composite cantilevers for explosive detection



Jointly with Prof. C.P.Rao, Chemistry-IITB



Initial cantilever position



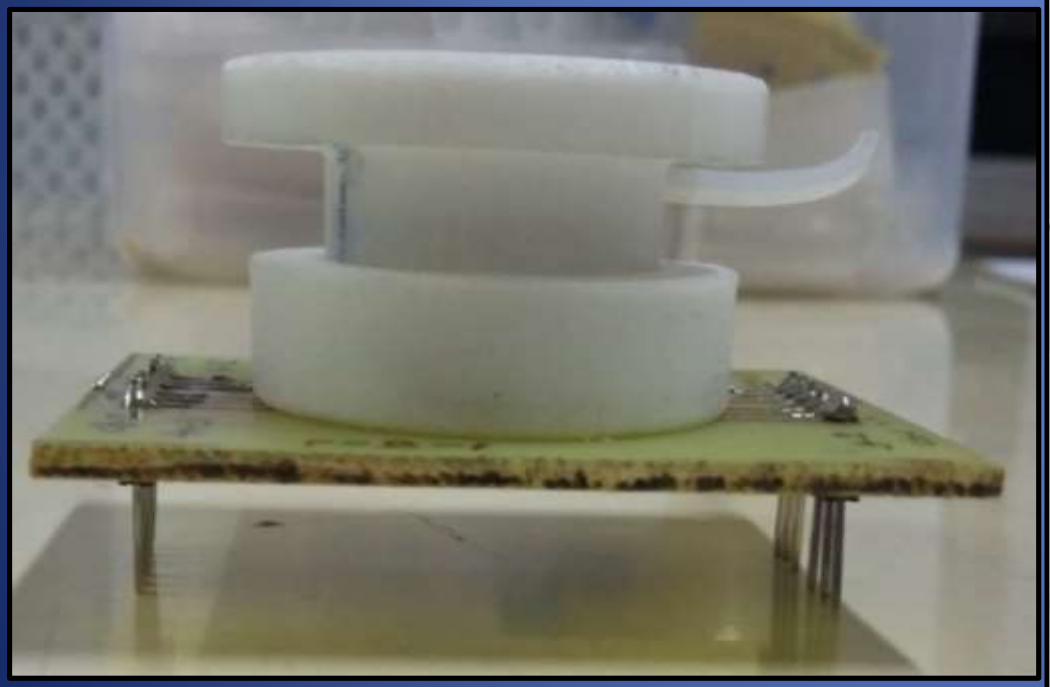
Cantilever bending

M. Kandpal et al., ACS Applied Materials & Interfaces, 2013, 5 (24), pp 13448-1345

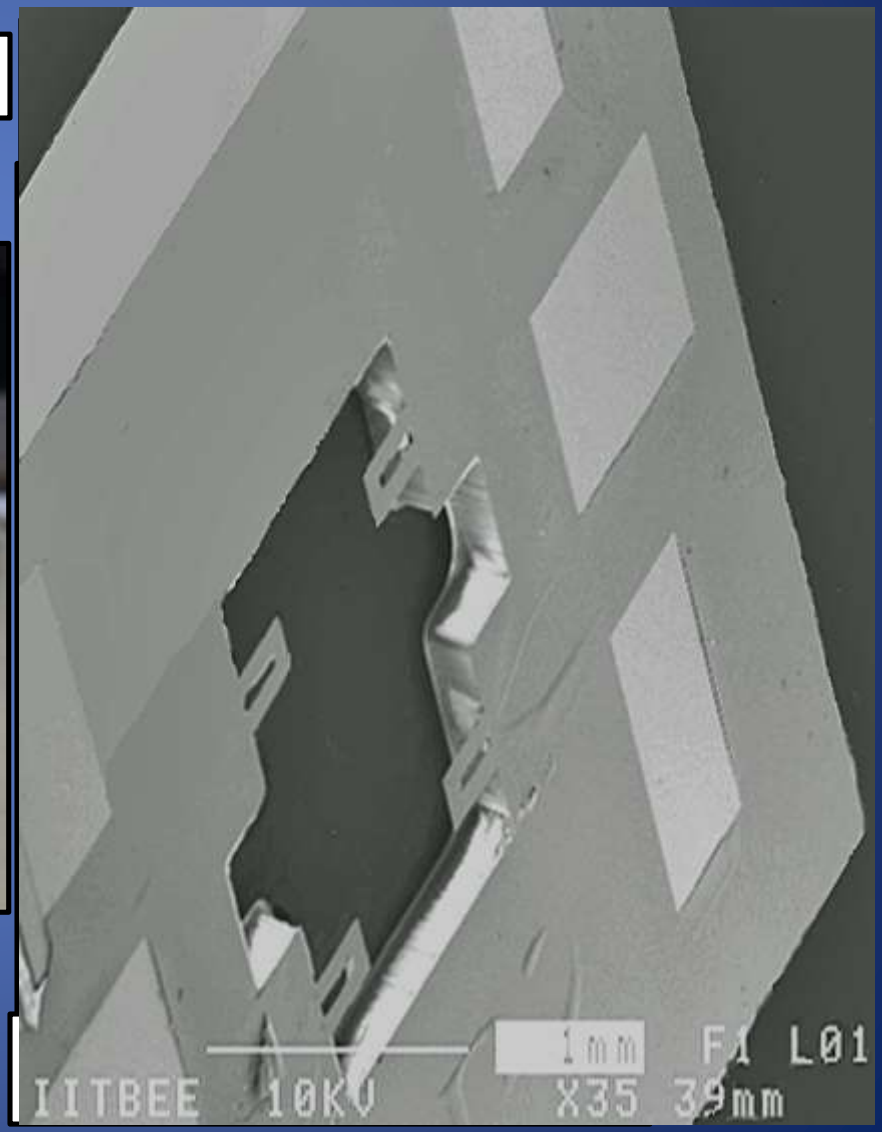
4-Channel Sensor Packaging

Four cantilevers need to be mounted on PCB in a optimized way so as to minimize flow cell volume else it will adversely affect sensor sensitivity and response time.

4-Channel Sensor Packaging



4-Channel Sensor cartridge with flow cell assembly

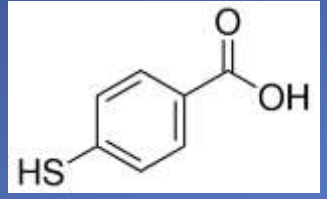


4-Channel Coatings Protocol Development

CH-1

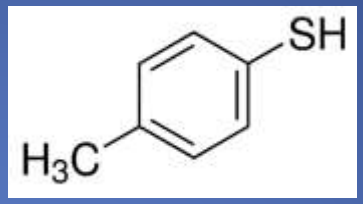
Uncoated

CH-2



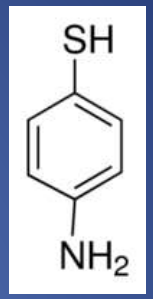
4-MBA

CH-3



4-MBT

CH-4



4-ATP

Basis of coatings selection (for multichannel PR approach):

- Three coatings selected with different functional/head group, will give different patterns/unique signature to the exposed explosives and non explosives.

- One channel is left uncoated for reference.

- Responses of these individual coatings to explosives were previously verified in a single channel approach.

- Three coatings were successfully coated on a cantilever surface using solution phase thiol chemistry in IPA solvent and were tested using 4-channel system.

X-niff: Electronic Nose Prototype (*Version-4*: 4C1015)

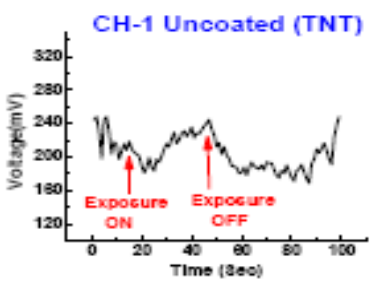
X-niff version 4-with an Integrated PR processing unit and display system, in a single standalone unit.

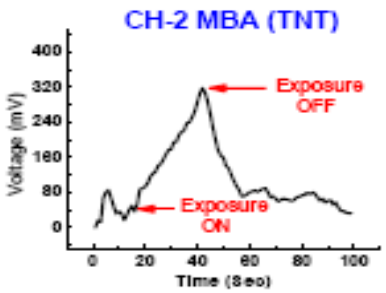
Vijay S Palaparthy et al., "E-Nose: Multichannel Analog Signal Conditioning Circuit with Pattern Recognition for Explosive Sensing" IEEE Sensors Journal, vol. 20, no. 3, pp.1373-1382, 2020, doi: 10.1109/JSEN.2019.2946253.

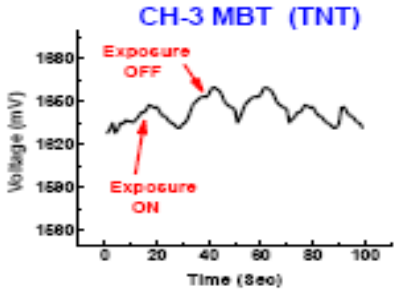
4-Channel Testing

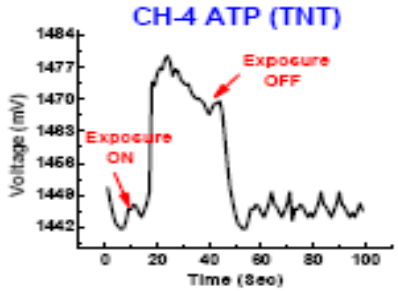
4 Channel System responses to explosives

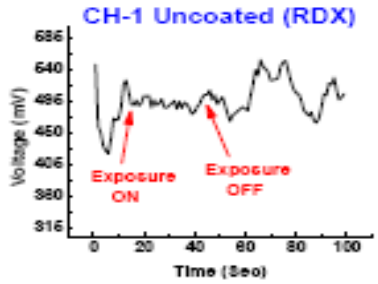
Responses to explosive

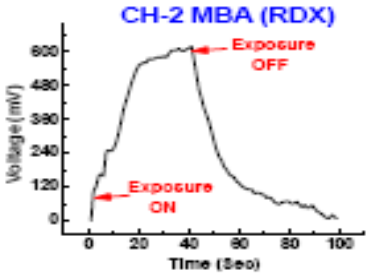


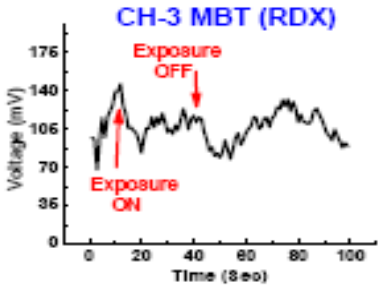


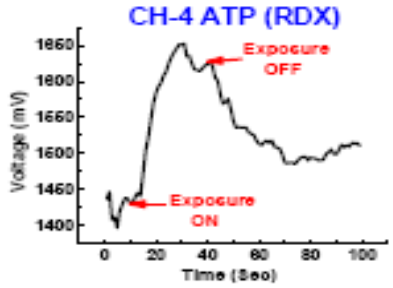


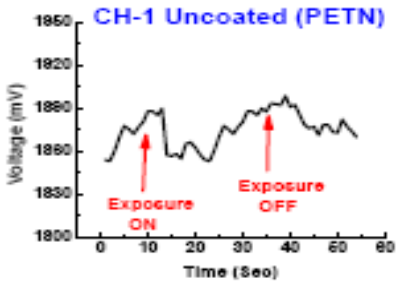


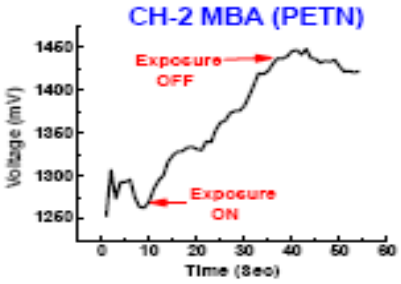


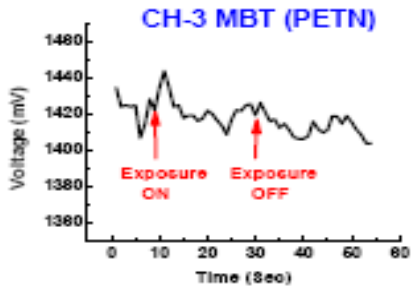


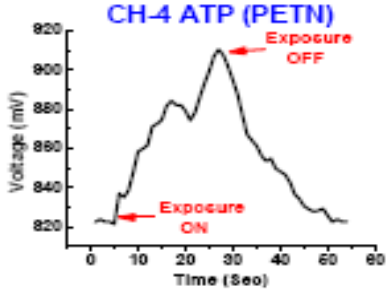












Vijay S Palaparthy et al, "Hybrid Pattern Recognition for Rapid Explosive Sensing with Comprehensive Analysis", IEEE Sensors Journal, vol. 21, no. 6, pp. 8011-8019, 15 March15, 2021

X-niff: Vapor phase sensing for explosives……

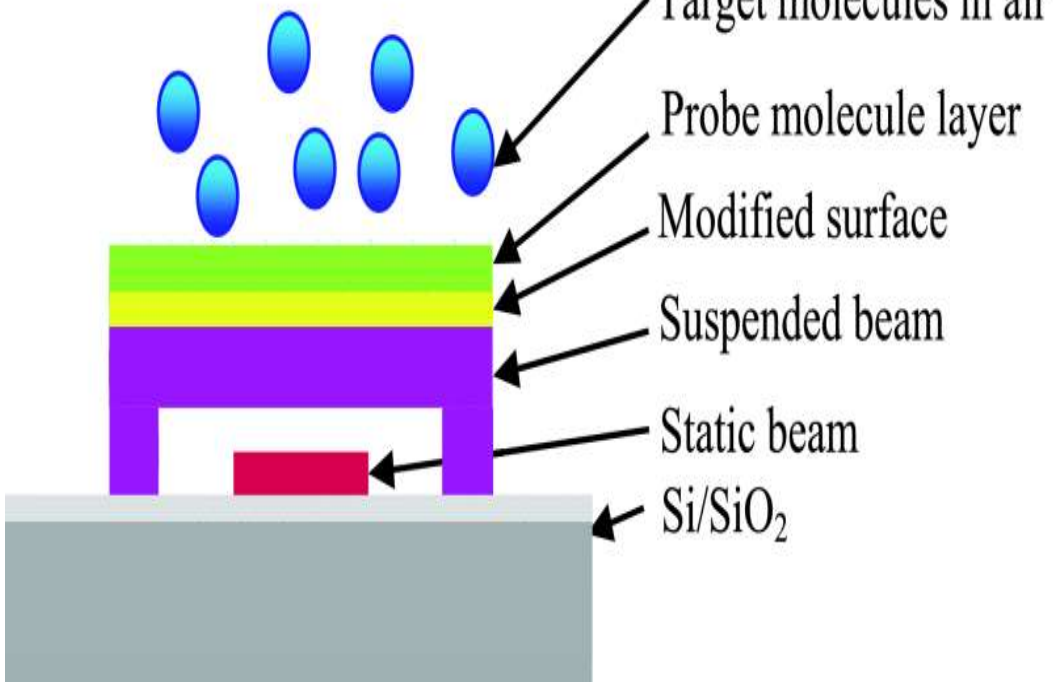
Collaboratiing Partners:

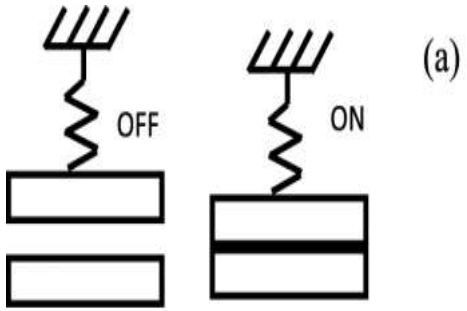
1. SCL for Cantilevers
2. Support from PSA office….

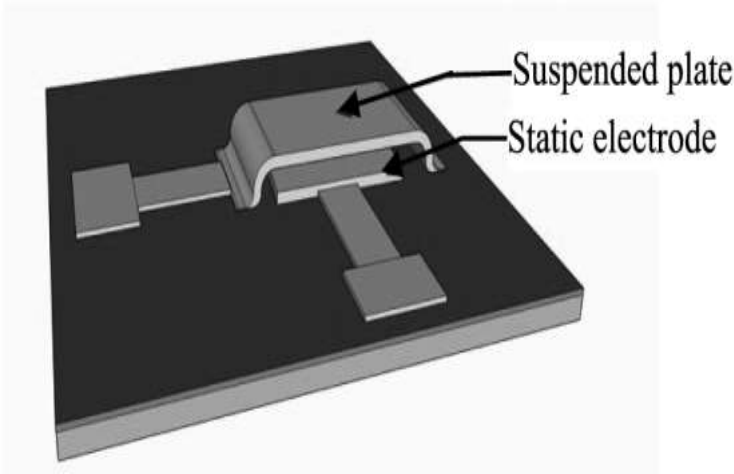
Low-Cost Sensor Platforms and Systems

- A Low Cost Cardiac Diagnostic System *(Medical doctors)*
- A Vapour Phase Explosive Detection System *(Security Agencies - PSA)*
  - NEMS Platform
  - Vibration Energy harvesting for sensors
- Soil Moisture & NPK Sensors for Agricultural applications *(Farmers)*
- Organic Dosimeters *(medical doctors)*
- Summary

A Physics based approach to Explosive detection

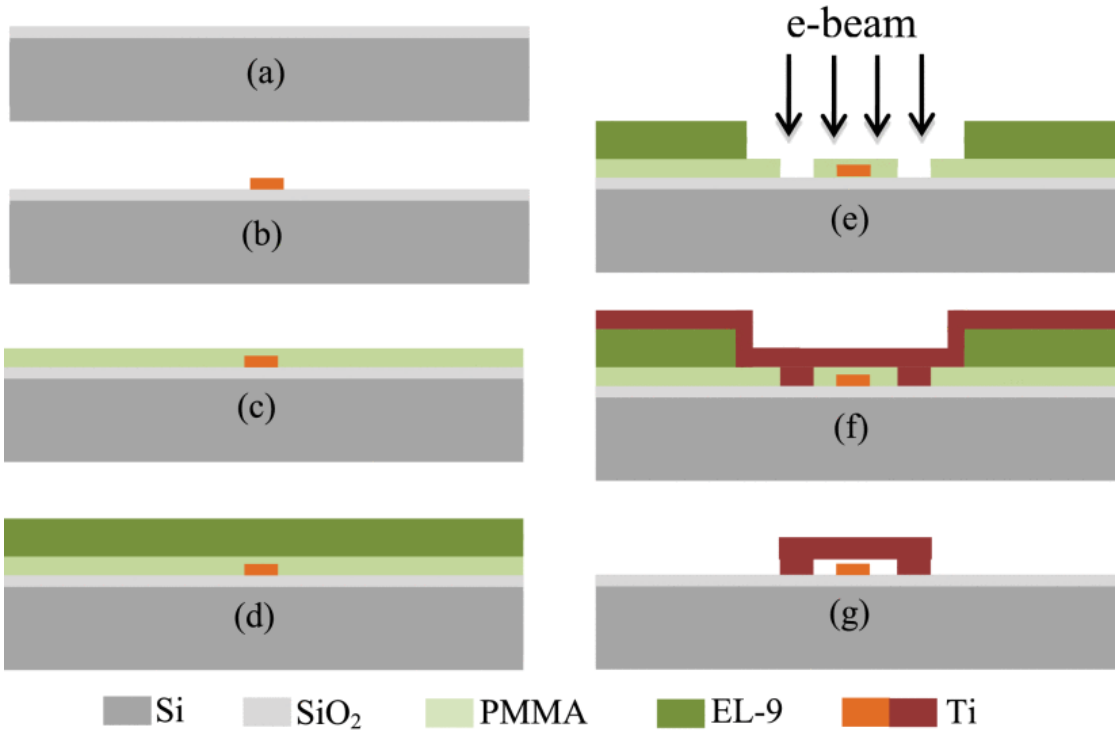






Neena A. Gilda, Gayatri P. Vaidya, Maryam Shojaei Baghini, V. Ramgopal Rao, "Multi-functional, CMOS compatible Nano-Electro-Mechanical Relays for Vapor Phase Explosives Detection", (IEEE/ASME) Journal of Microelectromechanical Systems (J-MEMS), Page(s): 616 – 623, April 2017

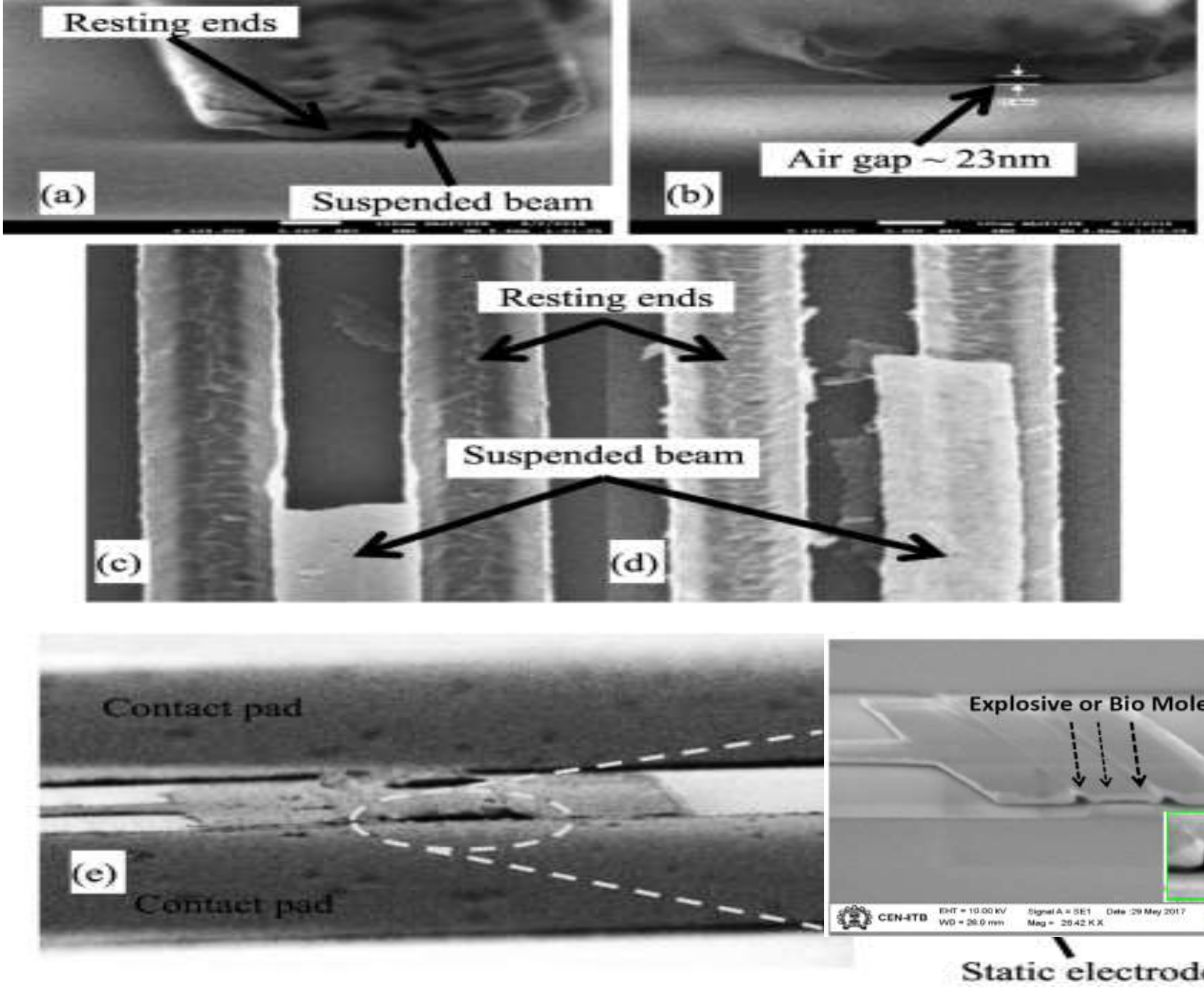
Fabrication of Multi-functional, CMOS compatible Nano-Electro-Mechanical Relays for Vapor Phase Explosives Detection

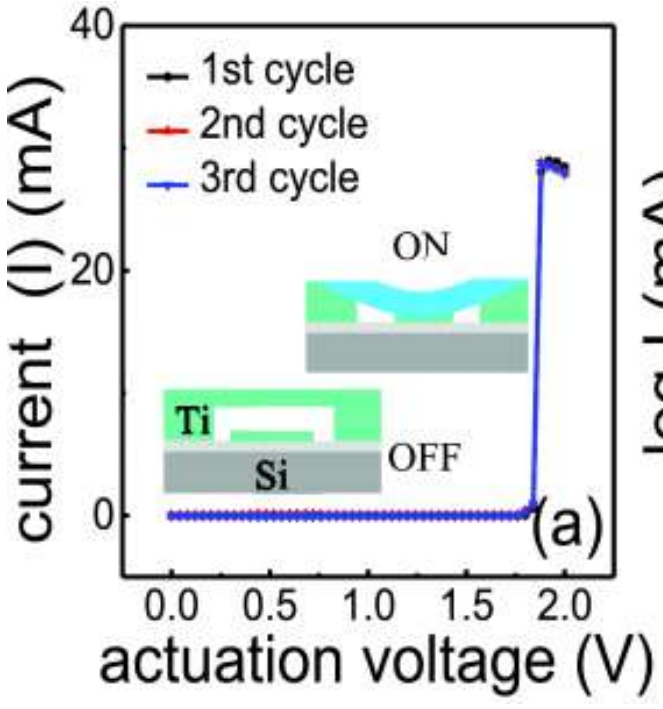


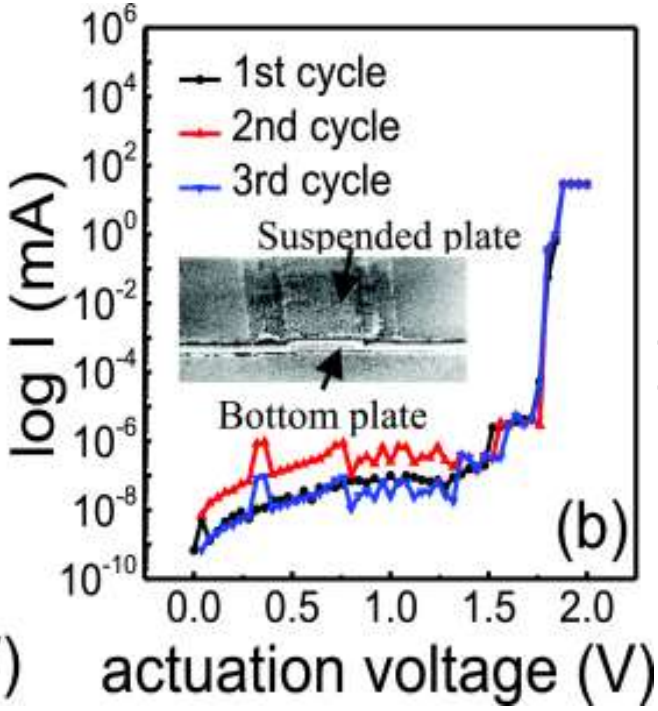
(a) 100nm SiO2 by thermal oxidation, (b) EBL patterning and deposition of 20nm-thick Ti as a static electrode, (c), (d), and (e) PMMA bilayer and grey scale electron beam lithography process, (f) deposition and release of suspended beam metal (20nm Ti) by a standard lift-off process, (g) final NEM relay structure.

Fabrication flow of the fabricated NEMS

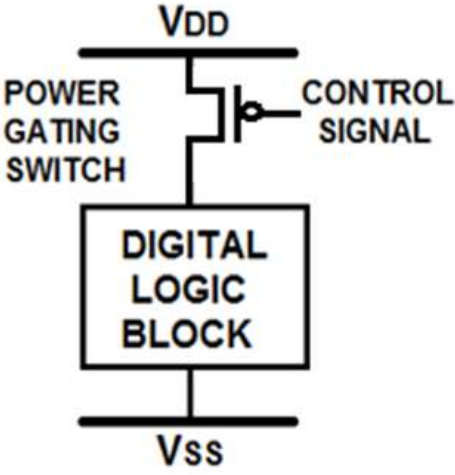
S. Saha *et al.*, "Stand-by Power Reduction Using Experimentally Demonstrated Nano-Electromechanical Switch in CMOS Technologies," *IEEE Transaction on Electron Device (TED), Vol. 68, No. 2, Feb. 2021.*

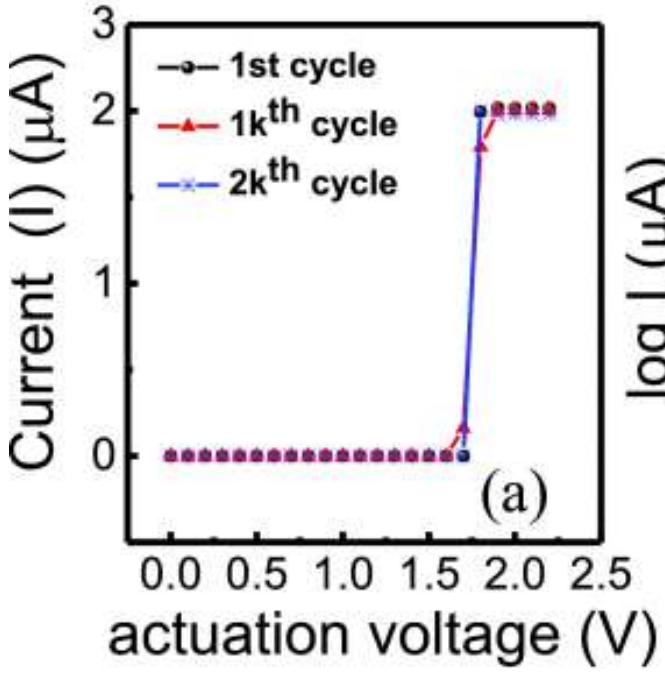

Resting ends
Suspended beam
(a)
Air gap ~ 23nm
(b)
Resting ends
Suspended beam
(c)
(d)
Contact pad
(e)
Contact pad
Explosive or Bio Molecule
Static electrode

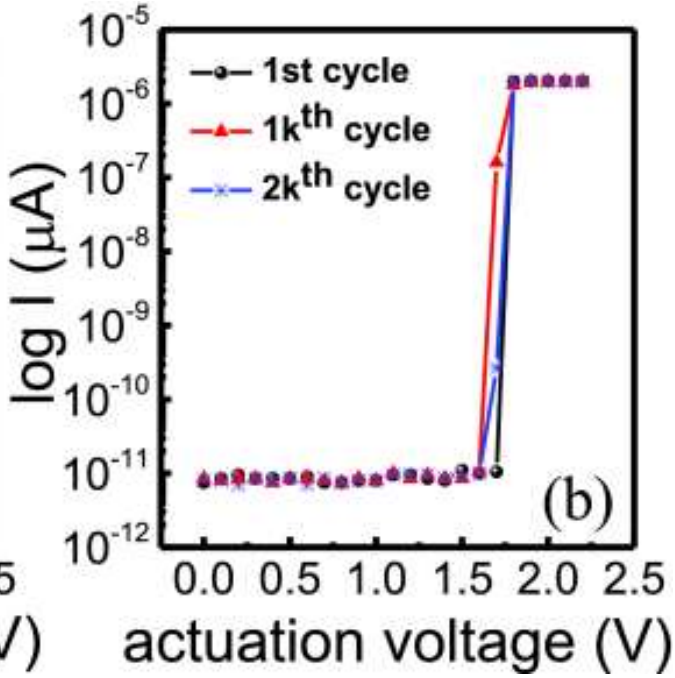




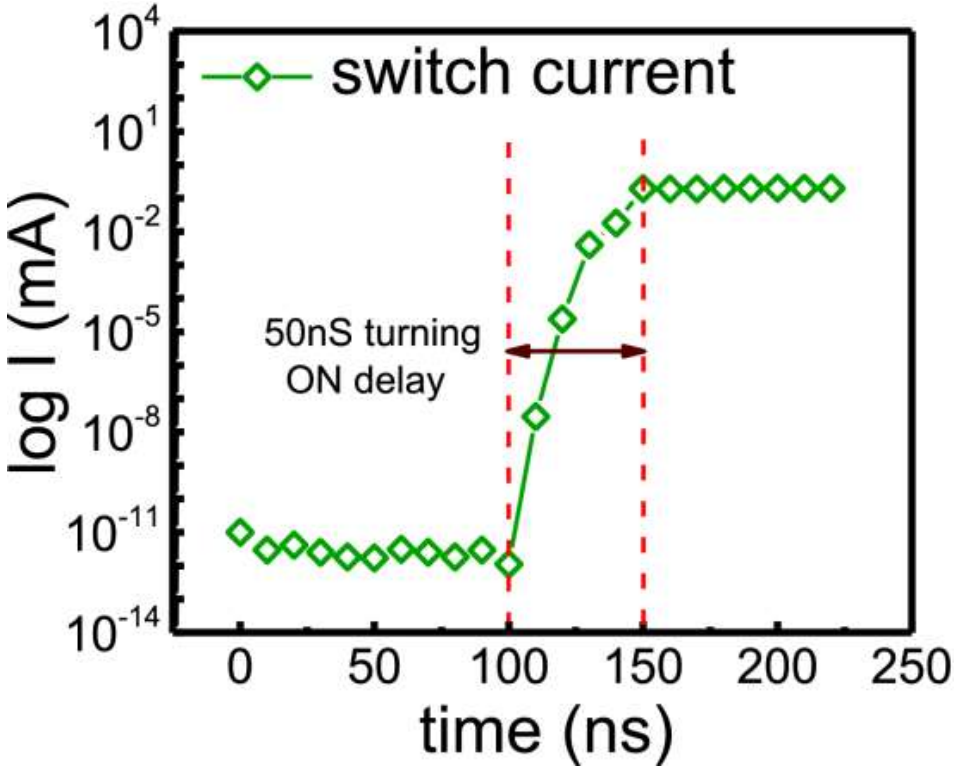
Sumit Saha et al.,"Stand-by Power Reduction using Experimentally Demonstrated Nano Electro-Mechanical Switch in CMOS Technologies", IEEE Transactions on Electron Devices, vol. 68, no. 2, pp. 746-752, Feb. 2021

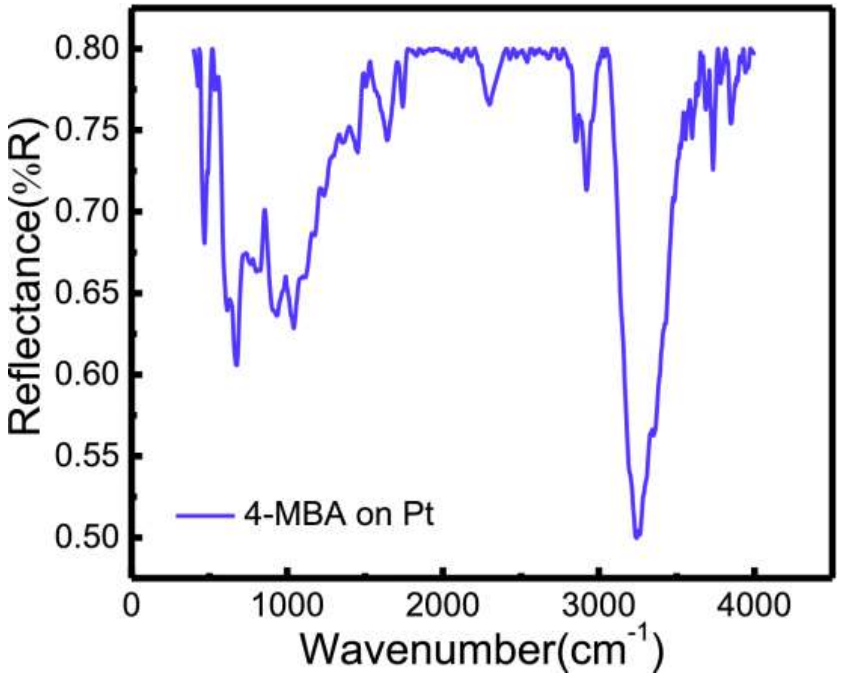


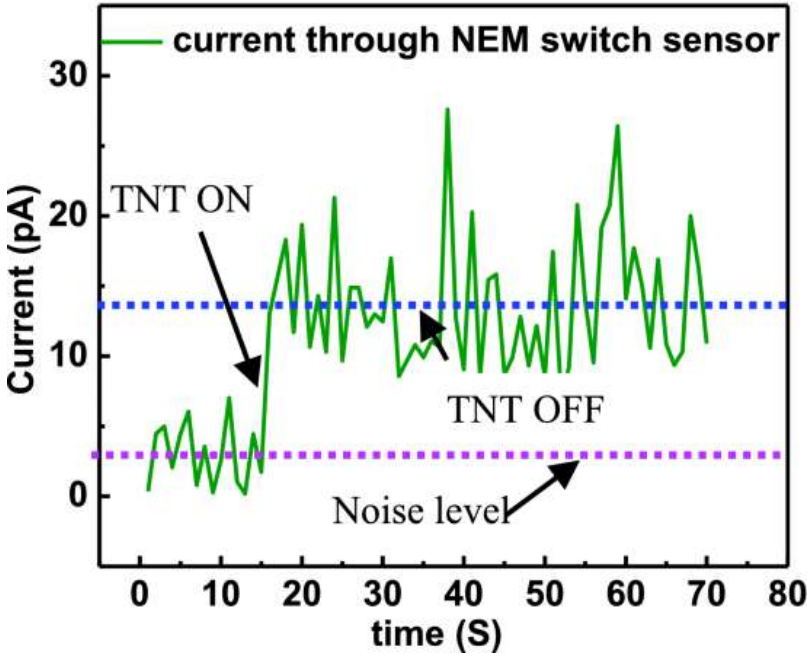


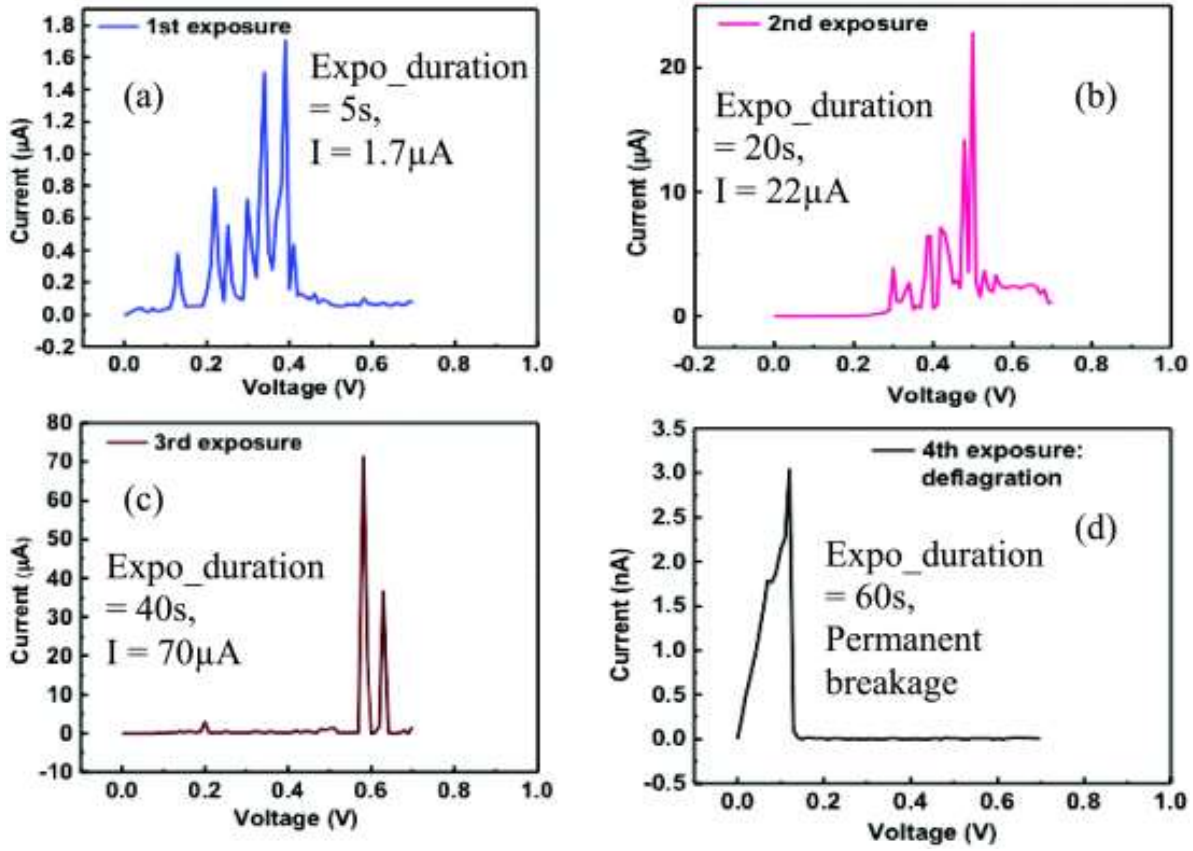


Intel supported project

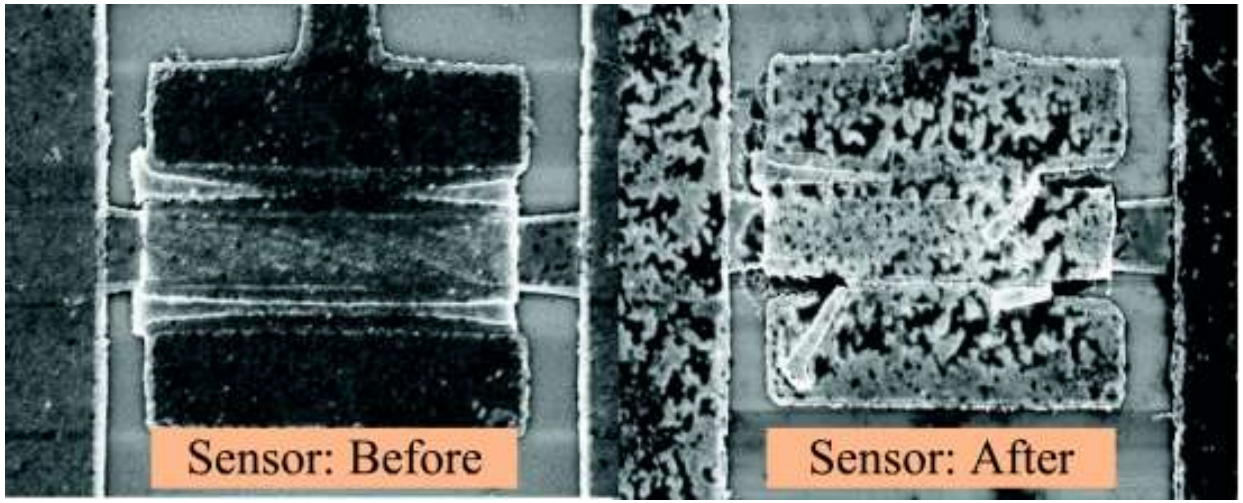

switch current
50nS turning
ON delay
log I (mA)
time (ns)


4-MBA on Pt
Reflectance(%R)
Wavenumber(cm-1)


current through NEM switch sensor
TNT ON
TNT OFF
Noise level
Current (pA)
time (S)



Neena et al., "Multi-functional, CMOS compatible Nano-Electro-Mechanical Relays for Vapor Phase Explosives Detection", (IEEE/ASME) Journal of Microelectromechanical Systems (J-MEMS), Page(s): 616 – 623, April 2017



NANOSNIFFER™
Explosive Trace Detector

"System and Method of Detecting Explosive Compounds Based on Rapid Deflagration and Differential Micro-Calorimetry", US Patent # 10605756, Grant Date: March 31, 2020 (Patentee & Licensee: NanoSniff Technologies Private Ltd.)

"Microheater Based Explosive sensor", Indian Patent No. 263931, Grant Date: 27-Nov-2014

explosives within 10 secs

TNN | Apr 10, 2021, 04:28 IST

A- A+

NEWS BRIEF

NanoSniffer: IIT Bombay Incubated Startup Develops World's First Microsensor-Based Explosive Trace Detector

Union Education Minister, Shri Ramesh Pokhriyal 'Nishank' launches NanoSniffer, a Microsensor based Explosive Trace Detector

Nanosniffer is world's first Explosive Trace Detector using microsensor technology – Union Education Minister

NanoSniffer is a 100% Made in India product in terms of research, development & manufacturing – Shri Ramesh Pokhriyal 'Nishank'

This affordable device will reduce our dependency on imported explosive trace detector devices - Shri Ramesh Pokhriyal 'Nishank'

Home-grown Explosive trace detector device (ETD) - NanoSniffer can detect explosives in less than 10 seconds - Union Education Minister

Posted On: 09 APR 2021 3:03PM by PIB Delhi

Union Education Minister, Shri Ramesh Pokhriyal 'Nishank' today launched NanoSniffer, the world's first Microsensor based Explosive Trace Detector (ETD) developed by NanoSniff Technologies, an IIT Bombay incubated startup. Director, IIT Delhi, Shri V. Ramgopal Rao, and senior officials of the Ministry were present on the occasion.

NanoSniffer has been marketed by Vehant Technologies, a spin-off from a former IIT Delhi incubated startup Kritikal Solutions.

{ EXPLOSIVE TRACE DETECTORS }

20 NanoSniffers to be set up at airports

Neha LM Tripathi
neha.tripathi@htlive.com

NEW DELHI: The Airports Authority of India (AAI) is in the process of installing 20 units of NanoSniffers, the domestically developed explosive trace detectors (ETD), at checkpoints of various airports in a bid to strengthen their safety and security, people familiar with the development said.

NanoSniffers will be placed at airports such as Dehradun, Pantnagar, Adampur, Bareilly, Gorakhpur, Kanpur, Varanasi and Kushinagar, among others, and the installation will be completed by June this year, AAI officials said.

"AAI will be installing NanoSniffers at some of its airports by June. These are the world's first microsensor-based ETDs that can detect dangerous explosives like nitroglycerine, ammonium nitrate and RDX in less than 10 seconds," an AAI official told HT.

NanoSniffer is a micro-electromechanical sensor-based ETD which uses a physics-based approach for detection of explosives. "NanoSniffer uses a special paper swipe for collecting particles from the surfaces of bags, zippers, handles, or contraband materials which is flagged as risky by the X-ray machine," said a second official.

The technology used in the device was designed and developed by an IIT Bombay incubated company, NanoSniff Technologies, and is manufactured by Vehant Technologies.

An official associated with technology said, "The USP of the device is that it has higher selectivity, thereby giving low false alarms, and higher purge rate which makes the detector usable within seconds even after a suspicious item is detected. This prevents wastage of time when passengers are in a queue to be screened."

NanoSniffer was launched as the world's first microsensor-based ETD by former Union education minister Ramesh Pokhriyal in April 2021. At the launch, Pokhriyal had said that NanoSniffer is a step towards Prime Minister Narendra Modi's vision of a self-reliant India.

"Given the threats which India faces, explosives and contraband detection has become a norm at high security locations like airports, railways and metro stations, hotels, malls, and other public places," he had said.

NanoSniffer can detect explosives in less than 10 seconds and it also identifies and categorizes explosives into different classes.

"The total cost of ownership of the device is almost half of the imported ETDs, thereby providing a major price advantage to airport buyers," said Kapil Bardeja, CEO & Co-Founder, Vehant Technologies.

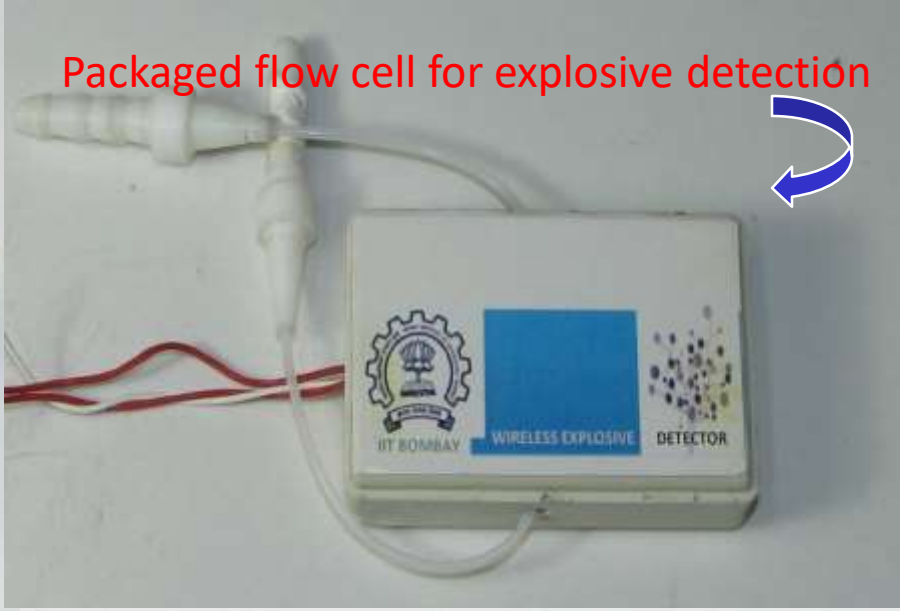
Low-Cost Sensor Platforms and Systems

- A Low Cost Cardiac Diagnostic System *(Medical doctors)*
- A Vapour Phase Explosive Detection System *(Security Agencies - PSA)*
  - NEMS Platform
  - Vibration Energy harvesting for sensors
- Soil Moisture & NPK Sensors for Agricultural applications *(Farmers)*
- Organic Dosimeters *(medical doctors)*
- Summary

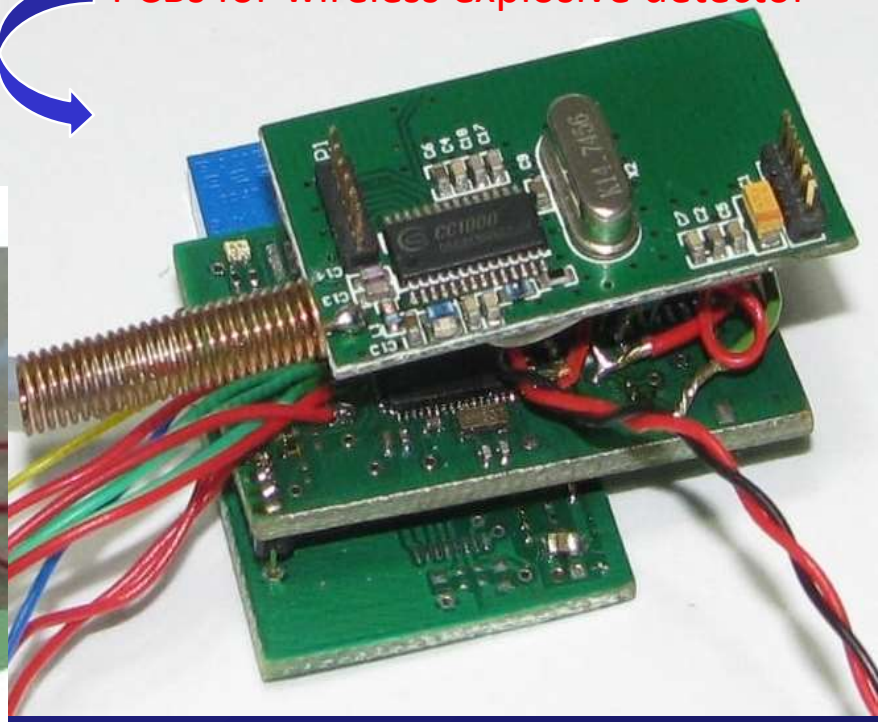
Miniaturized wireless explosive detector

Fully automated and stand off detection

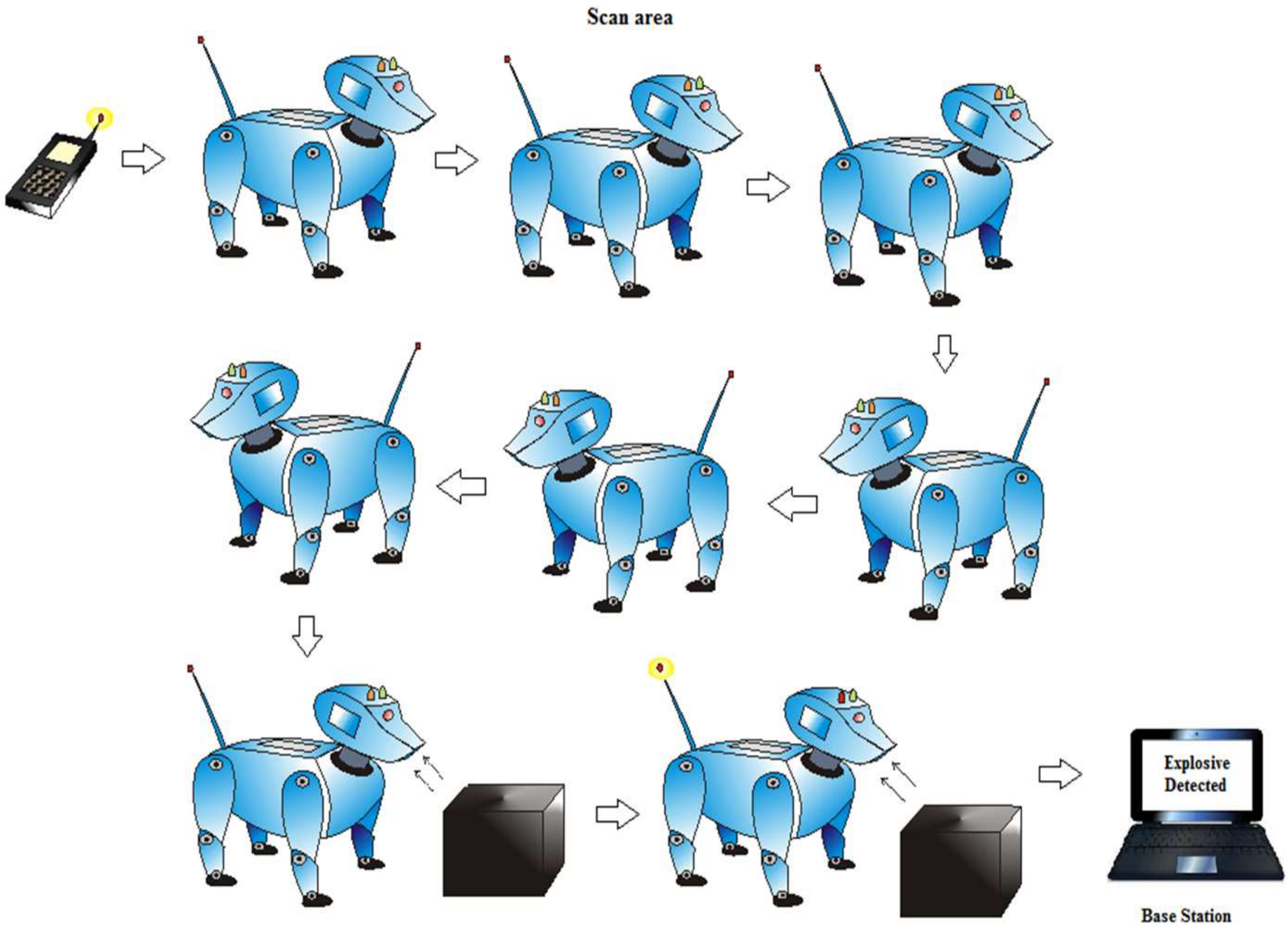
Packaged flow cell for explosive detection



PCBs for wireless explosive detector



Packaging: CMET PUNE


Scan area
Explosive Detected
Base Station

"E-Nose" to Sniff out Explosives

An ultra-sensitive (parts-per-billion level) nano-electro-mechanical sensor

A rechargeable Li-Po battery

Wireless Transmission Module

A real dog's nose 100 to 10 Million times more sensitive than humans. In laboratory tests dogs were able to detect 1 to 2 parts billion routinely and in some cases 500 parts per trillion, below the detection limit of any available equipment today.


IIT BOMBAY
WIRELESS EXPLOSIVE
DETECTOR
0
1
2
3
4
5
6

Nano-composite Piezoelectric Cantilevers

- **Transduction applications**
- **Energy Scavenging**

- Piezoelectric Photo-patternable Polymer Composites
  - ZnO
  - Various multiferroic materials
- Multiferroic materials

❖ ***Self powered wireless Sensor Networks***

- Mrunal A. K et al., "Electrical Actuation and Readout in a Nano-electro-mechanical Resonator based on a Laterally Suspended Zinc Oxide Nanowire ", Nanotechnology, Vol. 23 (2012) 025501
- Prashanthi et al., "A Novel Photo-Plastic Piezoelectric Nanocomposite for MEMS Applications", IEEE/ASME Journal of MEMS(J-MEMS), April 2012
- Prashanthi et al"Local piezoelectric response of ZnO nanoparticles embedded in a photosensitive polymer", Physica Status Solidi RRL 6, No. 2, 77-79 (2012)
- M. Kandpal et al., "Photopatternable nano-composite (SU-8/ZnO) thin films for piezo-electric applications", Appl. Phys. Lett. 101, 104102 (2012)

$FASnI_3$ (Formamidinium tin iodide)

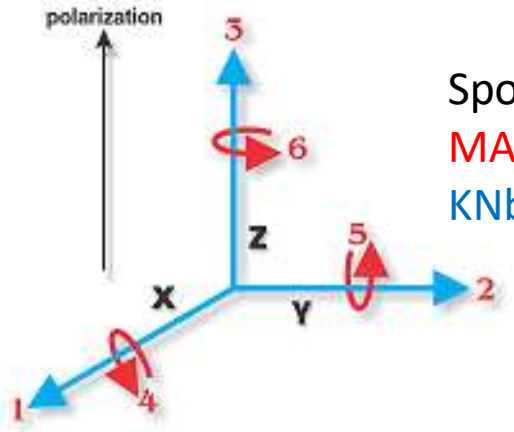
- ***In this study, Formamidinium tin iodide ($FASnI_3$)*** has been demonstrated to be an **lead-free organic-inorganic hybrid piezoelectric material.**

- *The phenomena of achieving a switchable polarization by means of exposure of light and/or stress is termed as 'photoferroic effect' and 'piezoelectric effect' respectively.*

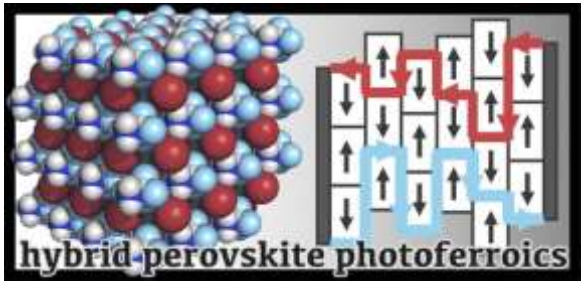
- *Thus, it will be of interest to explore the possibilities of simultaneously harnessing energy from different sources and distinct mechanisms using a single perovskite material.*

- *Current results is focused on understanding their behaviour on the basis of their piezoelectric property.*

- *Here , we explore the piezo response property of $FASnI_3$ by Piezoresponse Force Microscopy*



Spontaneous electric polarization
MAPbI3 → 38 μc/cm^2
KNbO3 → 30 μc/cm^2



A. Walsh et al Nano Lett., 2014, 14 (5), pp 2584–2590
Dallolio, S. Phys. Rev. B 1997, 56, 10105

Comparison table

Material	d_{33} (Bulk)	d_{33} (thin film)
$BaTiO_3$	260 pC/N	~30 pm/V
KNN	160 pC/N	~21 pm/V
PMN-PT	1100-1800 pC/N	~50-100 pm/V
PZT	300 pC/N	~37-42 pm/V
AlN	28 pC/N	3-5 pm/V
ZnSnO3	27-28 pC/N	~ 20 pm/V
FASnI3	**-**	**~ 73 pm/V**

Richa Pandey et al., "Microscopic Origin of Piezoelectricity in Lead-free halide Perovskite: Application in Nanogenerator Design", ACS Energy Letters, Publication Date (Web): 2019, 4, 5, 1004–1011

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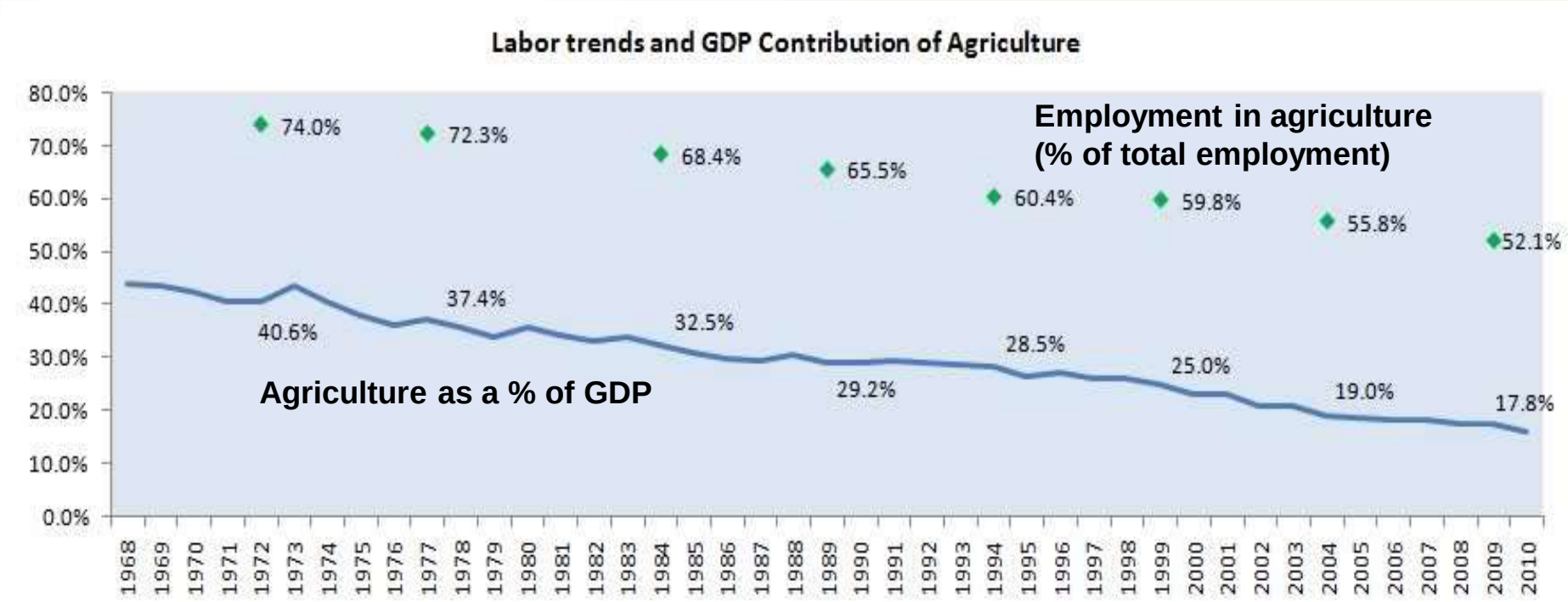
- **Soil Moisture & NPK Sensors for Agricultural applications** *(Farmers)*
- Organic Dosimeters *(medical doctors)*
- Summary

What is the Problem with Indian Agriculture?

- Agricultural productivity on a per capita scale in India is amongst the lowest in the world …in 2013-14 just 14% of GDP



Soil health card

SOIL HEALTH CARD		
Farmer's Details		
Name		
Address		
Village		
Sub-District		
District		
PIN		
Aadhaar Number		
Mobile Number		
Soil Sample Details		
Soil Sample Number		
Sample Collected on		
Survey No.		
Khasra No. / Dag No.		
Farm Size		
Geo Position (GPS)	Latitude:	Longitude:
Irrigated / Rainfed		

Name of Laboratory	

SOIL TEST RESULTS

S. No.	Parameter	Test Value	Unit	Rating
1	pH			
2	EC			
3	Organic Carbon (OC)			
4	Available Nitrogen (N)			
5	Available Phosphorus (P)			
6	Available Potassium (K)			
7	Available Sulphur (S)			
8	Available Zinc (Zn)			
9	Available Boron (B)			
10	Available Iron (Fe)			
11	Available Manganese (Mn)			
12	Available Copper (Cu)			

- **7.4 Million cards issued to farmers in India.**
- **Effective implementation of Soil Health card requires on-field, portable, simple-to-use sensors for various soil nutrients**

Objective : Realising scientific farming practices in India

Prototype 1
Volatile tracking

Tracking volatiles on-field and during storage to indicate the state of crop/produce.

Prototype 2
Pathogen detection

Early-stage non-invasive detection of pathogens

Prototype 3
Micro-and macro-nutrients

Qualitative and quantitative detection of soil nutrients

Prototype 4
Moisture, pH and salinity

Automated moisture assessment and irrigational control

Easy-to-use and deploy, low-cost sensor systems for precise qualitatitve and quantitative determination of soil nutrients.

Depleting ground water levels in country cause of concern

Agriculture Sector Biggest User Of Water

Vishwa.Mohan@timesgroup.com

GOING DOWN & DOWN

Depleting ground water level in the country:

No. of wells analysed across the country during 2003-13 to find out ground water level | **10,219**

Comparison of ground water data for the pre-monsoon 2013 with decadal mean of the pre-monsoon (2003-12) shows the following result:

No. of wells showing fall | No. of wells showing rise | No. of wells

A low cost soil moisture sensor specifically developed for Indian farmers which will:

- ✓ profitable for the farmer
- ✓ sustainability of agriculture
- ✓ Excess water leeches the nutrients to environment

PM Modi calls for 'per drop, more crop'

Vishwa Mohan, TNN | Jul 30, 2014, 01.07AM IST

THE TIMES OF INDIA

The Central Ground Water Board (CGWB) has told the ministry of water resources that around 66% of the wells, which are analyzed to keep a tab on ground water level, showed decline in its level in 2013 as compared to the average of preceding 10 years (2003-12) period. Of the 10,219 wells that the CGWB — a government agency — analyzed, it found that 5,699 wells had reported decline during that period. It also concluded that agriculture sector is the biggest user of water followed by domestic and in-

Punjab	72
Kerala	71
Karnataka	69
Meghalaya	66
Haryana	65
West Bengal	64
Delhi	62

(Figures in %)

Rise in water level in wells

Dadar& Nagar Haveli	80
Arunachal Pradesh	66
J&K	62
Madhya Pradesh	58
Puducherry	57

OTHER BASIC FACTS

- **India** has **18% of the world's population**; It has **4% of water resources** of the world
- **Annual per capita availability of water decreases** from **6,042** cubic metre in the year **1947** to **1,545** cubic metre in **2011**
- Annual per capita availability of water was **1,816** cubic metre in **200**

MAKING SOIL TESTING ACCESSIBLE

https://www.soilsens.com

NutriSens is a glucometer for soil that facilitates **on-site rapid soil analysis and advising the farmer about precision fertilizer usage** thus solving the problem of overuse of fertilizers.

Patent application number 202121042852

SOILSENS

ON-SITE SOIL TESTING

PUSA KRISHI

SOILSENS

TRAINING WOMEN FARMERS (SHG)

PUSA KRISHI

DEMONSTRATION TO AGRI ENTERPRISES

Soil Moisture Sensor

- Measures soil moisture (GWC %) at an accuracy of ± 3%.
- Ultrafast response time
- Gives moisture in terms of frequency.
- Can be integrated with any third party hardware.

Design of Frequency Domain Sensor Based Soil Moisture Measurement System, (IPA No. 3418/MUM/2015).

Private and confidential © SoilSens 2022

SoilSens Station

- On-site rapid soil moisture, temperature, atmospheric humidity and temperature analysis
- Advising the farmer about precision irrigation and detecting an early onset of diseases
- Can be used with any soil or any crop,
- Farmers can improve yield, save water, and reduce crop loss due to disease and pests

CISCO has partnered with **SoilSens** for SS Station

Automated Multi-Sensor and Multi Technique Measurement System for Agriculture Related Applications, (IPA No. 3054/MUM/2015).

Design of Time Domain Reflectometry soil Moisture Measurement System, (IPA No. 3419/MUM/2015).

Portable soil moisture meters

- Small farmers/farms can't deploy individual soil monitoring systems on farms
- The system can be shared among farmers
- Data can be uploaded to the cloud
- Irrigation advisories can be given
- Can be used for on-site soil calibration

"System, device and method for generating field profile", Patent Application Ref Number-202021029109, 8-7-2021 (SS)

SOILSENS PRODUCT PORTFOLIO

01

IoT Station with multiple sensors

02

Portable smart moisture meter

03

Weather System

04

Soil Moisture Sensor

05

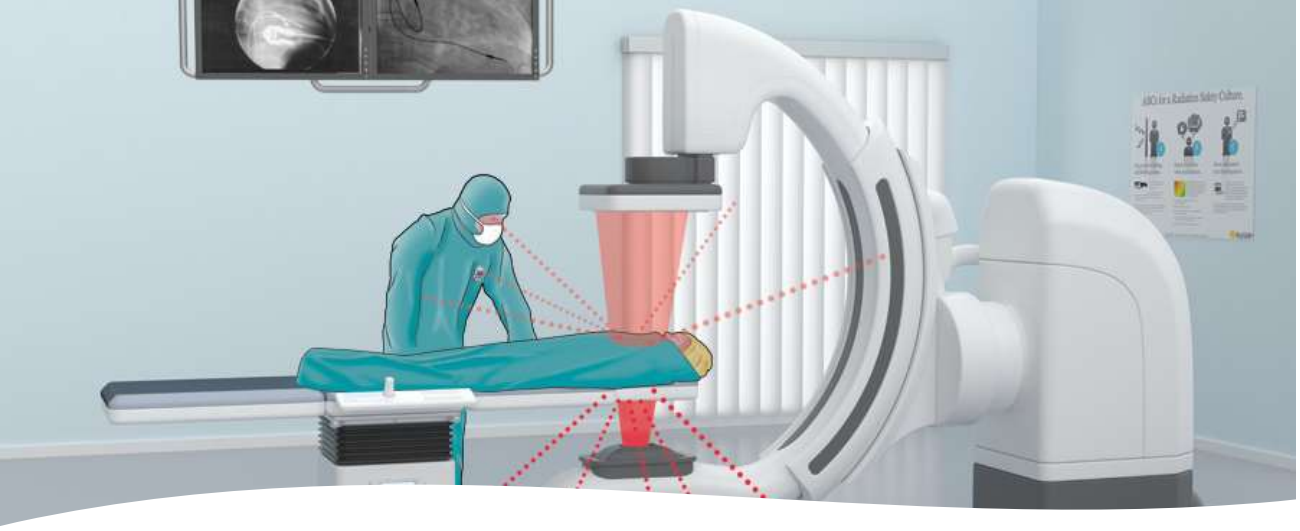
NutriSens: A glucometer for soil

ASHOKA TRUST FOR RESEARCH IN ECOLOGY & THE ENVIRONMENT

Private and confidential © SoilSens 2022

Low-Cost Sensor Platforms and Systems

- A Low Cost Cardiac Diagnostic System *(Medical doctors)*
- A Vapour Phase Explosive Detection System *(Security Agencies - PSA)*
  - NEMS Platform
  - Vibration Energy harvesting for sensors
- Soil Moisture & NPK Sensors for Agricultural applications *(Farmers)*
- Organic Dosimeters *(medical doctors)*
- Summary



Dosimeters for Radiation Therapy

Harshil N. Raval, Shree Prakash Tiwari, Ramesh R. Navan, and V. Ramgopal Rao, "Determining ionizing radiation using sensors based on organic semiconducting material," Applied physics letters, vol. 94, pp. 1233041-1233043, 2009.

Harshil N. Raval and V. Ramgopal Rao, "Low-Operating-Voltage Operation and Improvement in Sensitivity With Passivated OFET Sensors for Determining Total Dose Radiation," IEEE Electron Device Letters, IEEE, vol. 31, pp. 1482-1484, 2010.

Sonam Jain, Ashwini Gajarushi, Ankur Gupta, V. Ramgopal Rao, "A Passive Gamma Radiation Dosimeter using Graphene Field Effect Transistor", IEEE Sensors Journal, vol. 20, issue 6, pp.2938-2944, March 2020

Sonam Jain, Sandeep G. Surya, Praveen Kumar, Ankur Gupta, V. Ramgopal Rao, "Sensitivity Improvement of Medical Dosimeters using solution processed TIPS-Pentacene FETs", IEEE Sensors Journal, vol. 19, no. 12, pp. 4428-4434, June 2019, doi: 10.1109/JSEN.2019.2901810

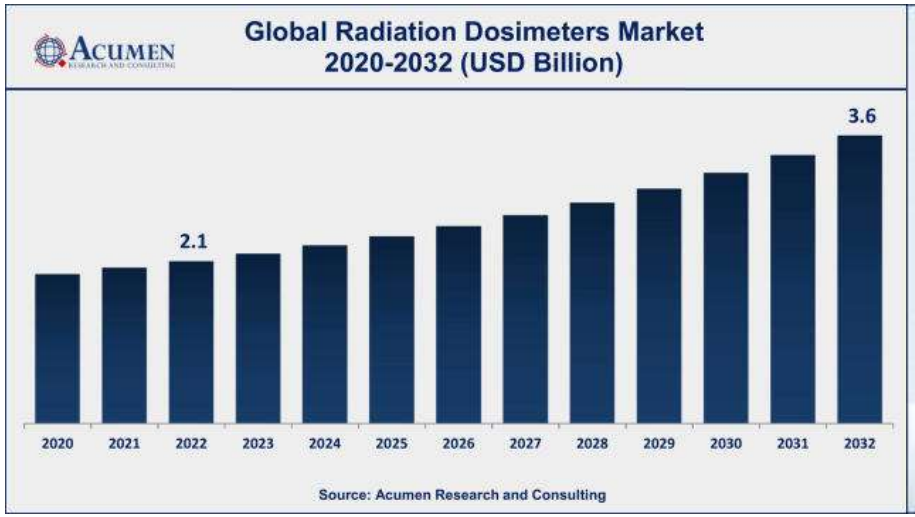
Raval Harshil Narendra, Tiwari Shree Prakash, Navan Ramesh Raju, Anil Kumar and V. RamgopalRao, "Method and device for determining ionizing radiation", United States Patent 8,536,885, Issue Date: 17 Sep 2013

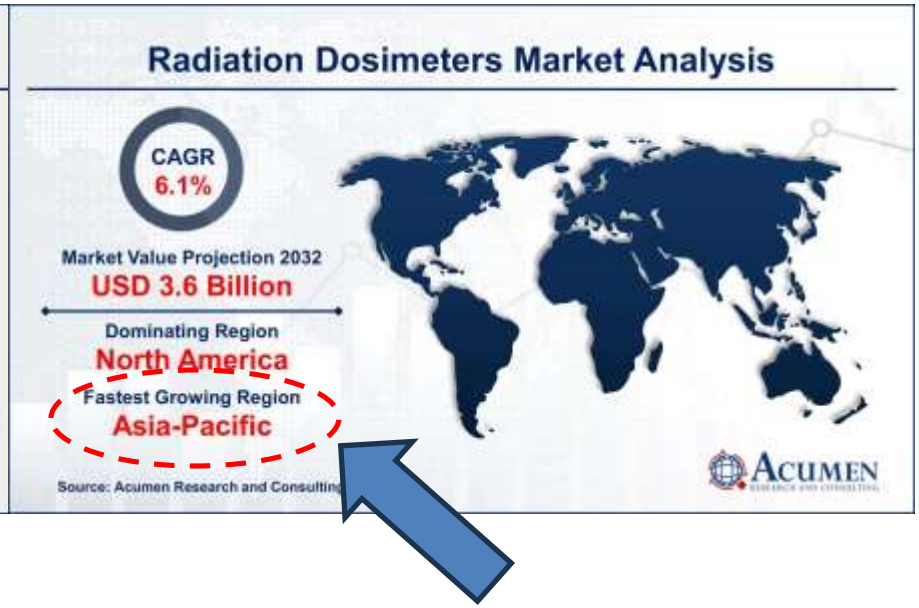
Introduction: Radiation Dosimeters for Medical Applications

A radiation dosimeter is a specialized device used to measure and record the amount of ionizing radiation exposure an individual or an object has received over a specific period.

In 2022, the market value of Global Radiation Dosimeters was USD 2.1 Billion, with projections suggesting a climb to USD 3.6 Billion by 2032.

The Asia-Pacific region is on the verge of experiencing significant growth, anticipating a CAGR exceeding 6.5% from 2023 to 2032, a reflection of the expanding industrial and healthcare sectors in this region.





https://www.acumenresearchandconsulting.com/radiation-dosimeters-market

Requirements of a Dosimeter:

In principle, any effect could be used as the basis for dose measurement if the relationship between the measured effect and absorbed dose can be determined:

- Be sufficiently **accurate across the range of doses** used in modeling and treatment in radiotherapy
- Be **sensitive** (**high signal for small dose** and not be subject to noise problems)
- Be **linear across the dose range**
- Be **independent of the dose rate**
- Response which is **independent of dose (can measure large/small doses equally well)**
- Have a **response that is independent of energy**
- Be small enough to have spatial resolution for use in high-dose gradients.

Market Constraints:

- **High cost** of advanced dosimetry equipment
- Limited availability of **skilled professionals** for radiation safety.

Reference: Radiotherapy in Practice **:**Physics for Clinical Oncology.

Current Technology:

S.NO	NAME	TYPE	• SPECIFICATION (RADIATION DETECTED : gamma, Weight:1-2kg)	Price:~50,000 INR
1	**Landlum** Ambient Dose Ion Chamber Survey Meter	Pressurized Ion chamber	• **MINIMUM READOUT** :0.1 µR/hr • Highly sensitive	
2	**Landlum** Ion-chamber survey meter	Air Ion chamber	• **MINIMUM READOUT**: 0.2 mR/hr	
3	**Originet** Detector ion chamber	Ion chamber	• **Range** : 10-1 to 107 mR/h	
4	**Originet** Environmental Lab	Ion chamber	• **Range** : 200 µR - 2 MR	
5	**Radcal** Therapy Qa Chamber	Ion chamber	• **Range** : 100 µR - 589 kR	

Reference: 1 . http://ludlums.com/products/survey-meters/ion-chambers
2. http://radcal.com/10x6-0-18-high-dose-rate-ion-chamber/
3. https://www.indiamart.com/originet-technologies-ltd/products.html#detector-ion-chamber

Specification of Organic Dosimeters under development

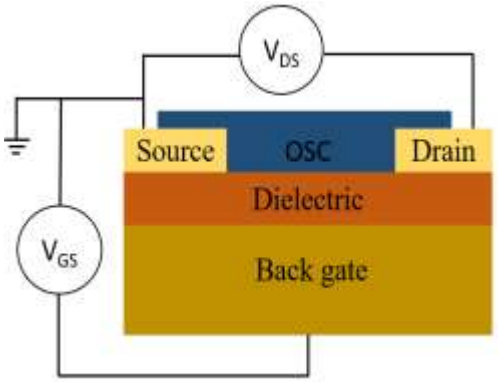
- Range:
- Total dose of 55-60 Gy is given in 25-30 cycles i.e. 1.5-2 Gy in one cycle.
- Hence required range is 3-4 Gy.
- Sensitivity:
- A minimum sensitivity in the range of 0.3 V/Gy.

1 Gray=100 rads

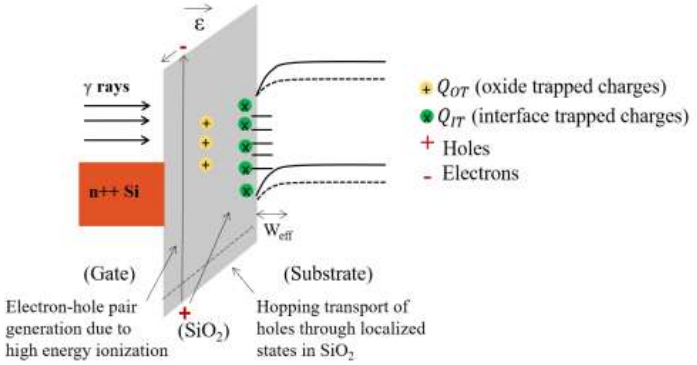
- Size:
- A size of 0.2mm x 0.2mm or smaller is desirable.
- Spatial Resolution requirement:
- CT scan has a spatial resolution of 0.5-0.625 mm. Therefore the boundary thickness of tumor a doctor can see on CT is at least 0.5 mm. So we would want to measure dose gradient across this boundary thickness, So a OFET dosimeter of size of size <=0.5mmx0.5mm is optimum. Since OFETs are flexible we can utilize this feature to have dose measurement over a patch of a body.
- Wireless: Desirable.
- Calibration: Ideally calibration free, but practically, simpler/automated calibration procedure.

Emerging Technologies:

1. OFETs: Organic Field-Effect Transistors for GAMMA radiation detection

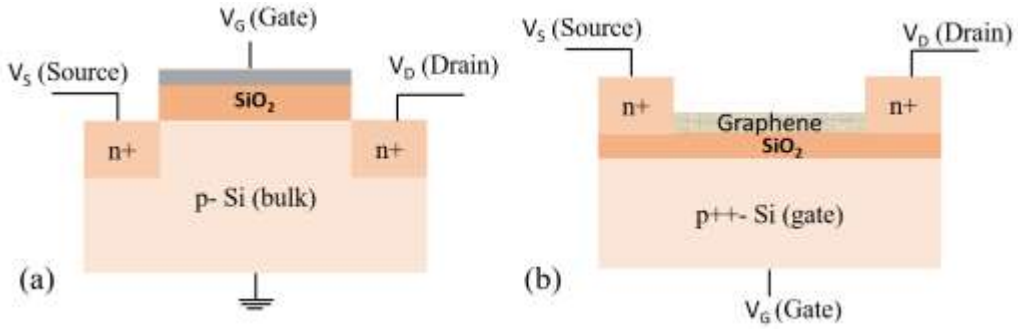


OFET's channel conductivity can be tuned by varying gate voltage like the Si-MOSFET.

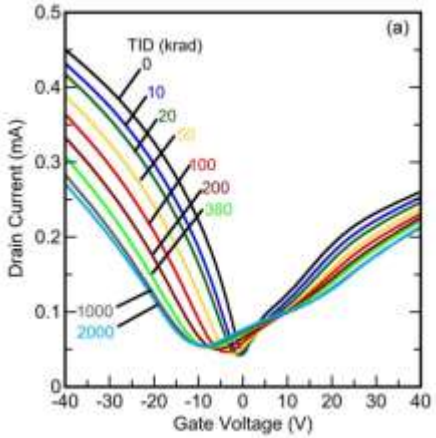


Energy band diagram MOSFET vertically showing the generation and subsequent trapping of carriers inside oxide and at the interface of Si and SiO_2 interface.

2. GFETs: Graphene Field-Effect Transistors for GAMMA radiation detection



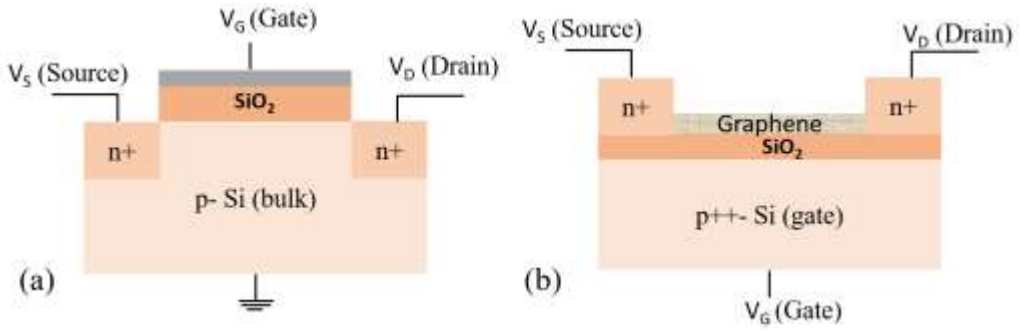
A typical schematic of (a) n-channel Si-MOSFET, (b) Bottom-gated graphene FET (GFET).



Effect of radiation on Graphene FETs.

Emerging Technologies:

2. GFETs: Graphene Field-Effect Transistors for GAMMA radiation detection



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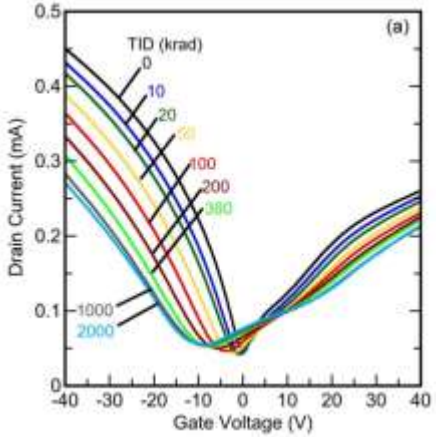

Effect of radiation on Graphene FETs.

Comparison of key parameters of different Graphene FETs for Gamma Irradiation

Material	tox (nm)	Transistor source	Vg (V) during radiation	Sensitivity (ΔV_{DP}/kGy) (mV/Gy)	Fading /time response	Advantage	Disadvantage	Ref
Si	-	Commercial, p-channel (3N163)	0	24	Yes	Low operating voltage	Fading	[33]
Si	400	Commercial, Tyndall National Institute, Cork, Ireland	0	41	Yes	Low operating voltage	Fading	[32]
Si	-	Commercial, p-channel (3N163)	0	28	No	Low operating voltage	Fading	[34]
Si	-	Commercial, p-channel (ZVP3306)	0	4.5	No	Low operating voltage	Fading, low sensitivity	[34]
SLG	300	Fabricated	+5V	0.4	No	Better mobility	High operating voltage	[25]
SLG	300	Fabricated	0	0.33	No	Better mobility	High operating voltage	[26]
SLG	**300**	**Fabricated**	**0**	**~1**	**Yes**	**Good sensitivity, high mobility, less fading**	**High operating voltage**	**This work**

Sonam Jain, Ashwini Gajarushi, Ankur Gupta, V. Ramgopal Rao, “A Passive Gamma Radiation Dosimeter using Graphene Field-effect Transistor", IEEE Sensors Journal, Vol. 20, No. 6, 2938-2944, 2019.

Dosimeter Technologies Comparison:

Mater-ial	tox (nm)	Transistor source	Vg (V) during radiation	Sensitivity (ΔV_{DP}/kGy) (mV/Gy)	Fading /time response	Advantage	Disadvantage	Ref
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Low-Cost Sensor Platforms and Systems

- A Low Cost Cardiac Diagnostic System *(Medical doctors)*
- A Vapour Phase Explosive Detection System *(Security Agencies - PSA)*
  - NEMS Platform
  - Vibration Energy harvesting for sensors
- Soil Moisture & NPK Sensors for Agricultural applications *(Farmers)*
- Organic Dosimeters *(medical doctors)*
- Summary

Prototypes/Products from CENs

A soil moisture sensor node

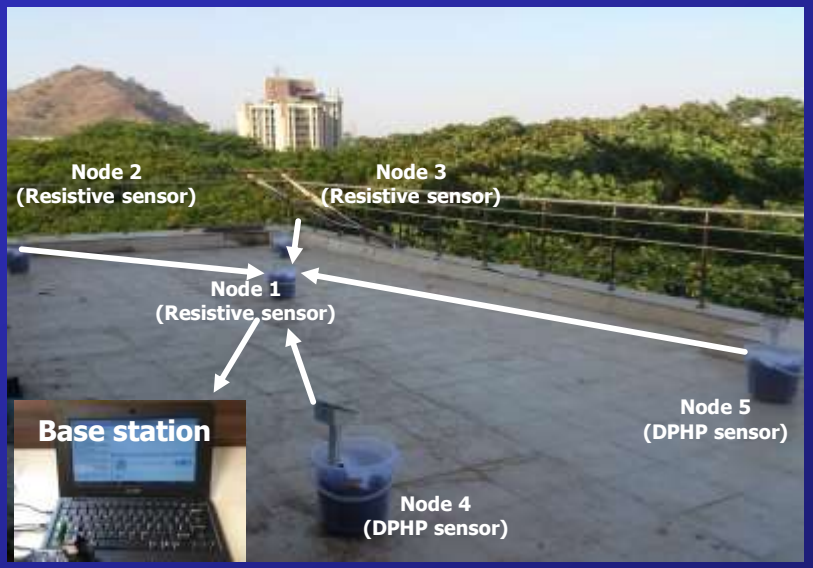
An electronic Nose platform

An explosive sensor prototype from NanoSniff

Soil moisture wireless sensor network

Developed prototype

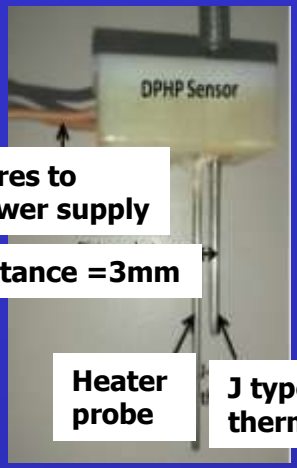
Prototype deployed in soil



Deployment of soil moisture wireless sensor nodes

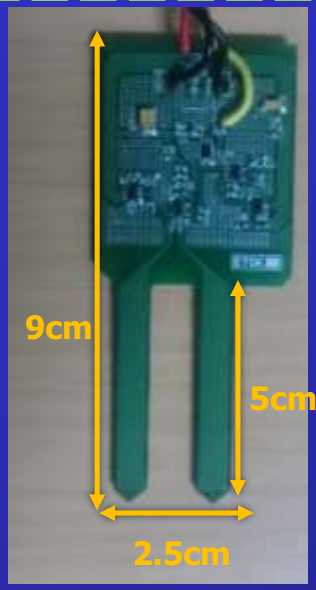
Can be replaced with any of the developed soil moisture sensor

Sensors for Agricultural Sensors Deigned & developed in the CEN @ IITB

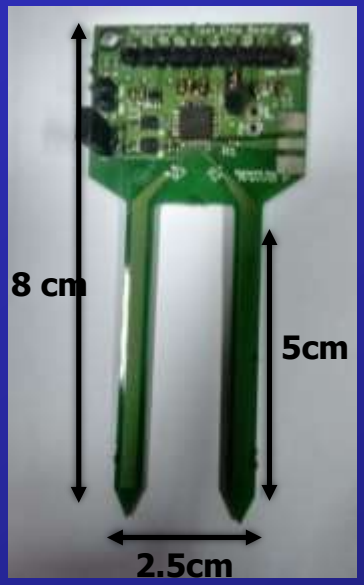


DPHP sensor (Heater probe of DPHP sensor is fabricated by Prof. Ananthasuresh and team, IISc)

Measures rise in the temperature



Capacitive sensor designed using discrete components



Capacitive sensor designed using custom ASIC (VCO chip)

TDR sensor

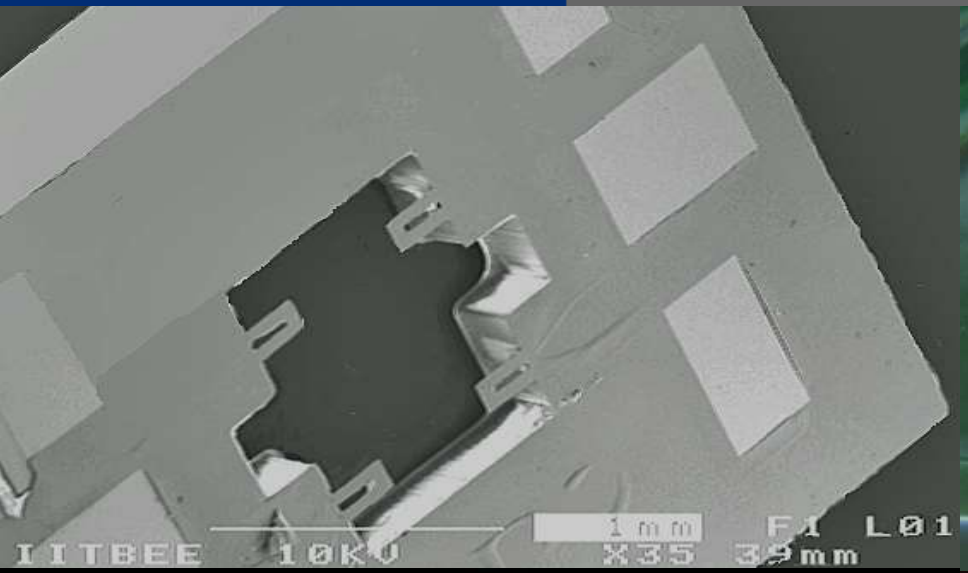
Measures dielectric constant

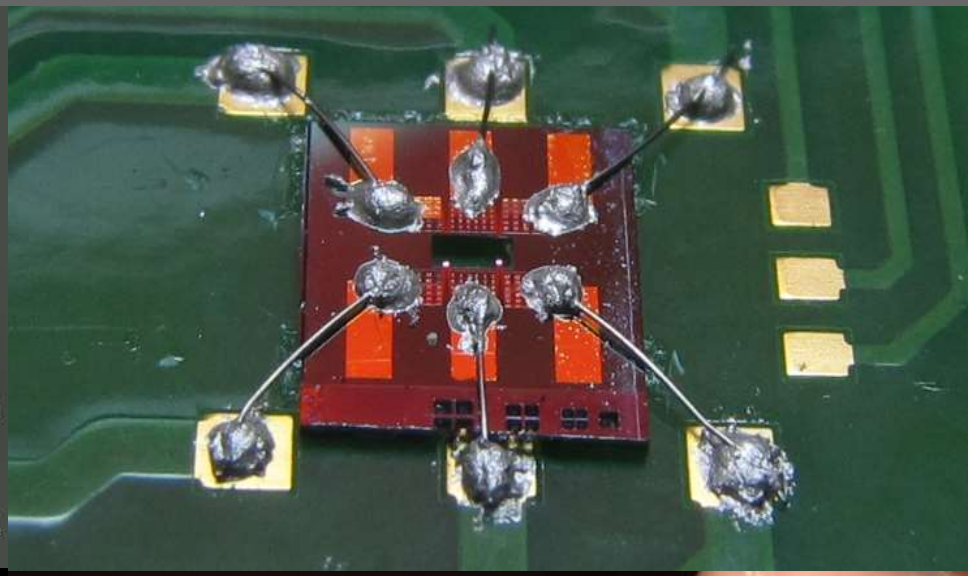
- The custom CMOS chip and all circuits are designed, developed and tested at IIT-Bombay.

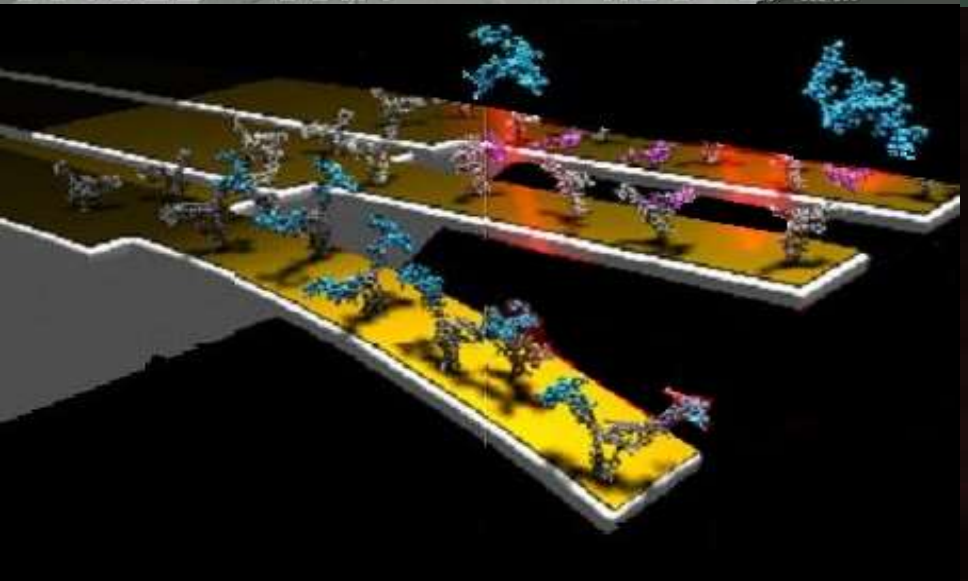
- Angel Funded by Priaas investments, R&D Funding by ICICI SPREAD
- 17 people currently employed in NanoSniff including 5 Ph.D.s
- Three Products: ***OmniCant™***, ***Explosive Detector***, ***iSens***
- OmniCant launched in Q2-2012
- Setting up of manufacturing facilities

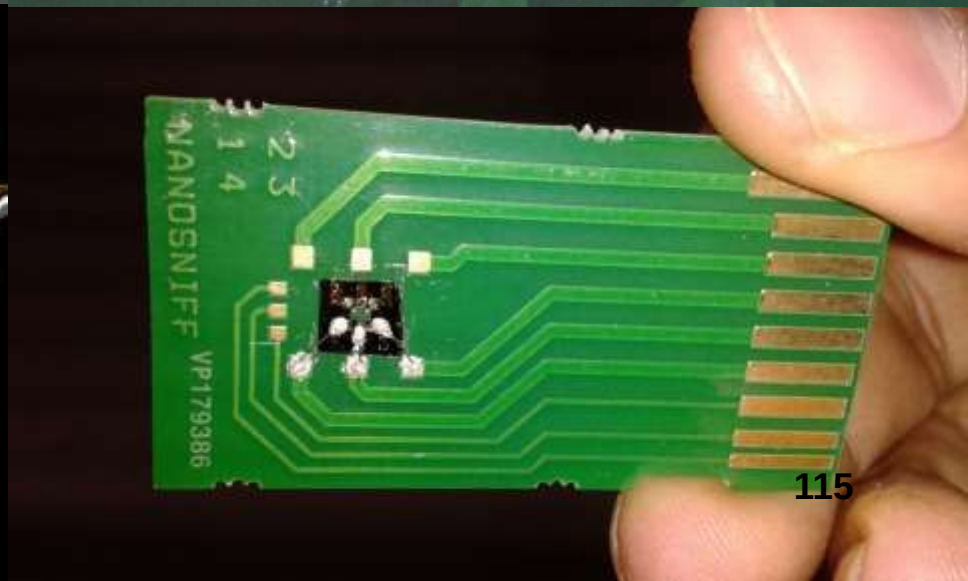
- ISA Technovation award in 2012 for the "Most Promising Startup Company Award - hosted by the Indian Semiconductor Association
- Won the Grand Challenges Canada's Stars in Global Health – Round 4
- Received the BIRAC grant from DBT

Packaged Piezo-Cantilevers





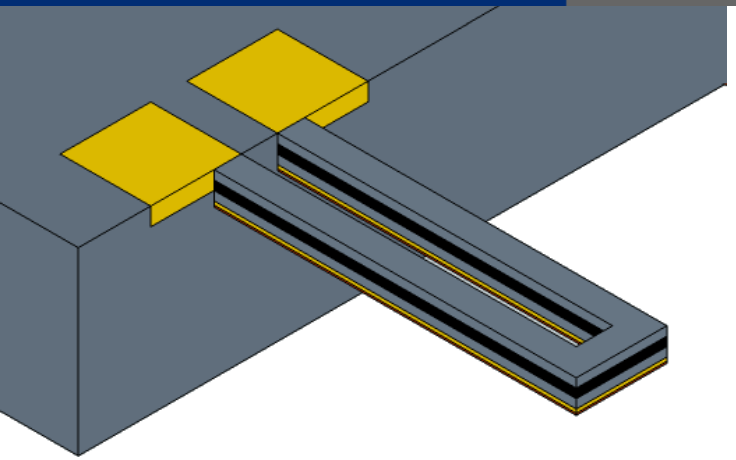


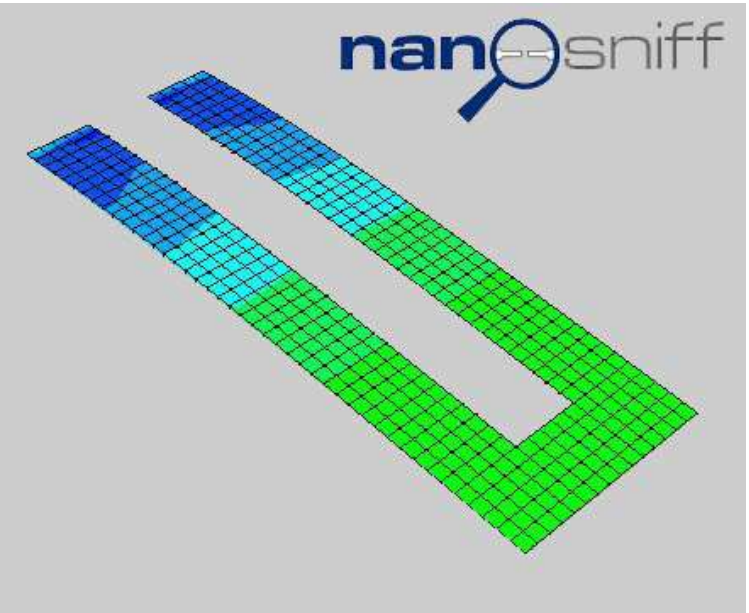


OmniCant™

- Customized Cantilevers
  - Silicon, Oxide, Polymer
  - Integrated Micro-fluidics
  - Chemical Coating Services
  - Hands-on Training
- Cantilever Instrumentation
  - Gaseous & Liquid Phase
  - Multi-channel Data Acquisition
  - Integrated Vapor Generator
  - Real time monitoring & recording

Handheld Systems





- Applications
  - Explosive Detection
  - Medical Diagnosis
  - Detection of Hazardous Gases

SOILSENS

HOME ABOUT SOLUTIONS CONTACT LOGIN

PROXIMAL SOILSENS TECHNOLOGIES

SoilSenS gives the solutions for optimized irrigation for agriculture.
Our aim is to make the agriculture sector, profitable and sustainable by improving the crop yield through efficient usage of water

OUR PILOTS

go4fresh.in
Nature grows, we deliver

SULA

Coromandel

ESSAR

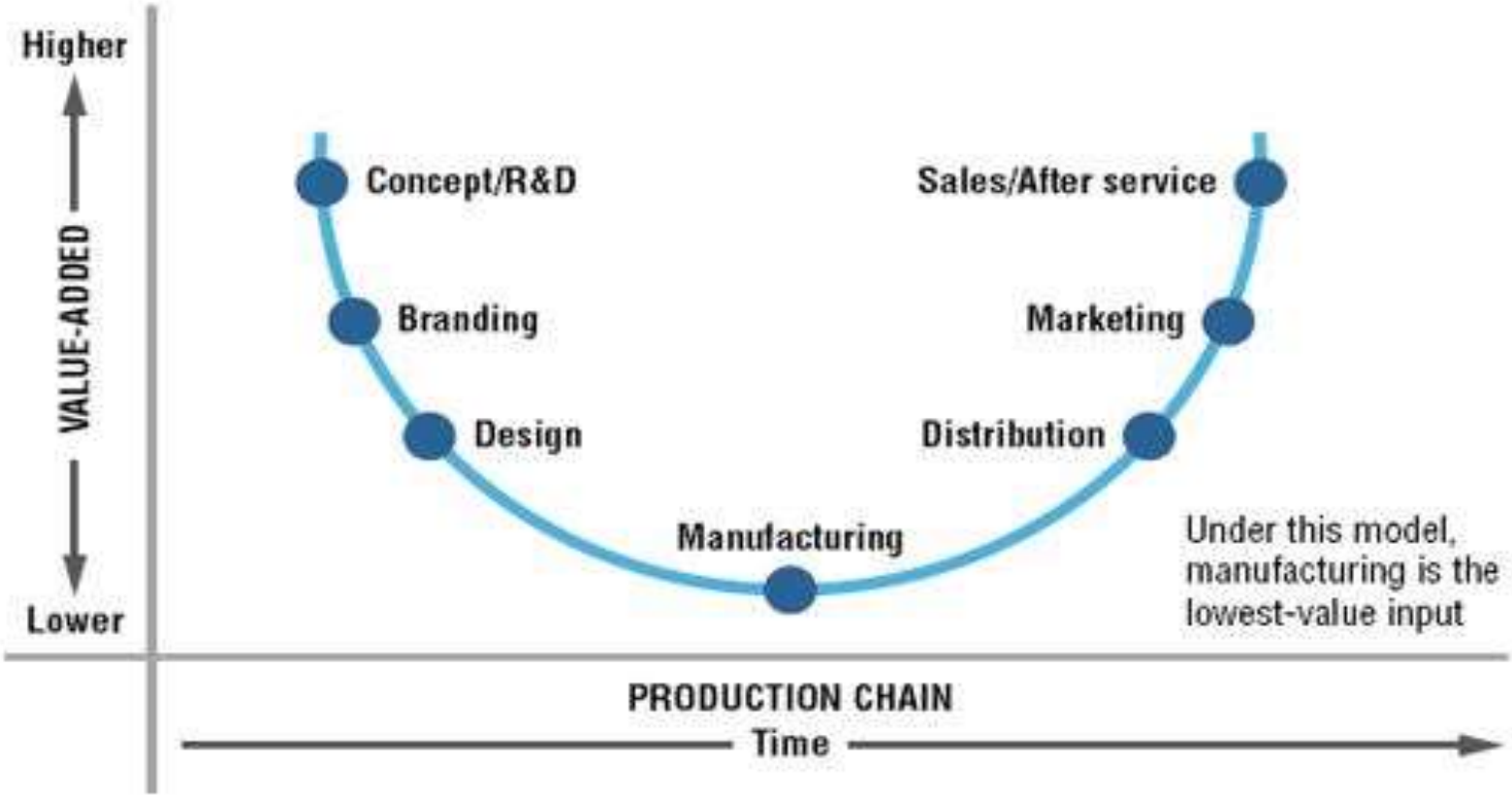
Mahindra

Products

INDIA = OPPORTUNITIES

- Strengthening academia-startup-industry collaboration is the key
- Address the bottom of the pyramid – most of MNC products get diverted to the market that reaches only about 100 million of India's 1.3 billion population (M4L4M)
- R&D in academic institutions is primarily driven by North American and European models. There is a need to innovate in areas where there is domestic demand. Focus on a systems approach.
- Local R&D for product development is absolutely essential for reducing the costs and for taking care of the needs of the people in India – be it for agriculture or security or healthcare applications.
- It is possible to do high quality research in academic insitutions in India now, and yet make it relevant to India's needs.
- Multiple Govt. of India initiatives for startups – TIH, BIRAC, TDB etc.

The Smile Curve



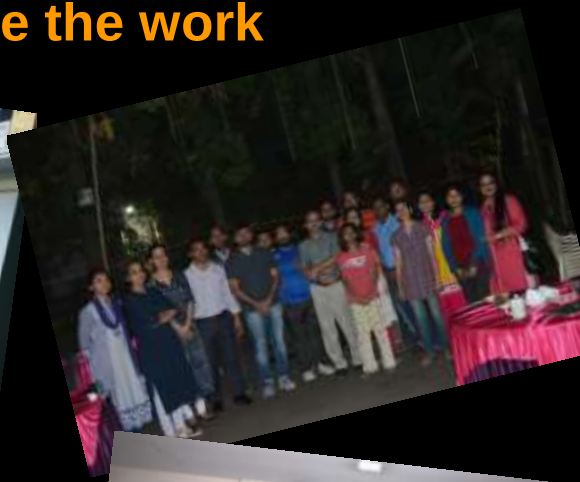
Source: The Smiling Curve: Stan Shih.

Rungi, A. & Del Prete, The smile curve at the firm level: Where value is added along supply chains, Economics Lett. 164, 38-42 (2018)

Brand	Current Market Cap [July 2024]
Microsoft	$3.394 T
	$3.323 T
NVIDIA.	$3.057 T
Alphabet	$2.269 T
amazon	$2.052 T
أرامكو السعودية saudi aramco	$1.817 T
Meta	$1.280 T

Acknowledgment: All the students who have done the work













Thank you.

Thank you.