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Next Generation Chalcogenide Glass for Active and Passive Applications

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The Future Photonics Hub
Industry Day and Exhibition
Tuesday 13 September 2016

Light

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With particular thanks to:

Kevin Huang
CVD and 2D

Khouler Khan
High Purity Glass

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2D and plasmonic devices

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Optoelectronic Devices

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Optical Fibre

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2D Materials and Devices

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Technical Support

Ed Weatherby
Laboratory Infrastructure

Andrea Ravagli
New Material Development

and Ghadah Alzaidy, *Solar Cells*

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Outline

- Chalcogenide Glass - Introduction
- Glass Manufacture – Improving Foundations
- Improving Materials – Building for the Future
- Device Challenges – Current and Planned

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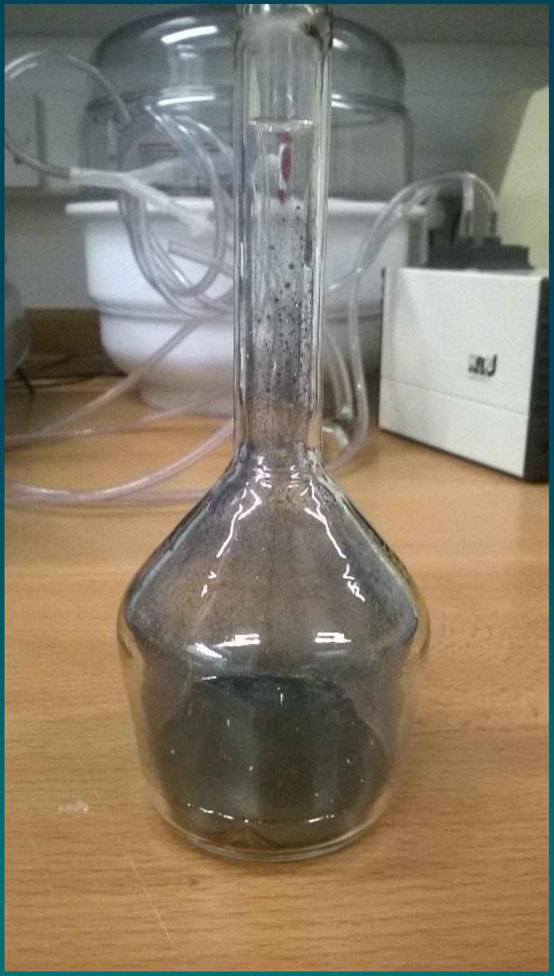
Chalcogenide Glass Manufacture

- First Produced in 1950’s
- Sealed Ampoule Techniques
- Driven by Defence Applications

Commercially Established

SCHOTT
glass made of ideas

umicore



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Why are they Interesting?

Initially – An IR Optical Material

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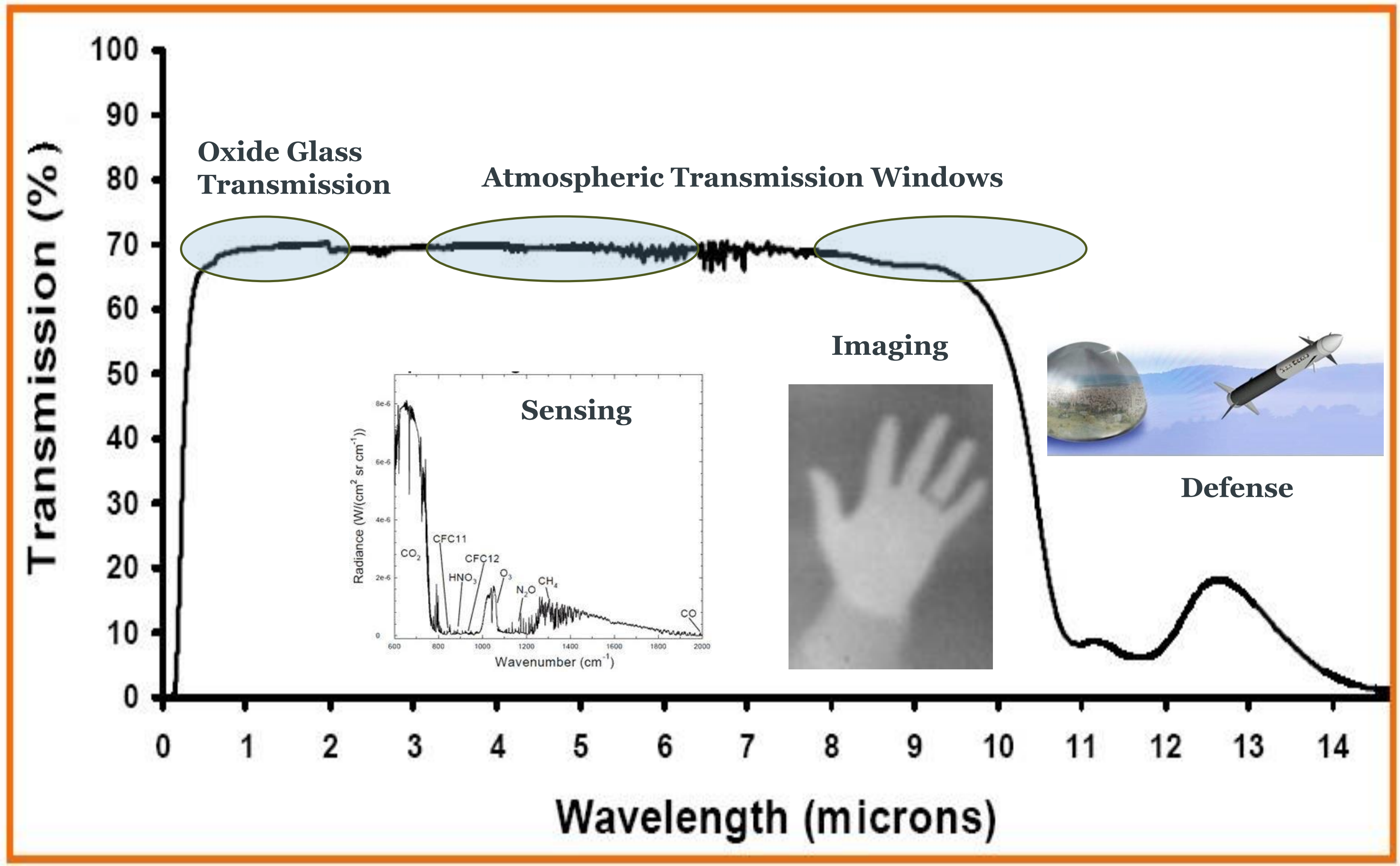

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Why more Materials Research?

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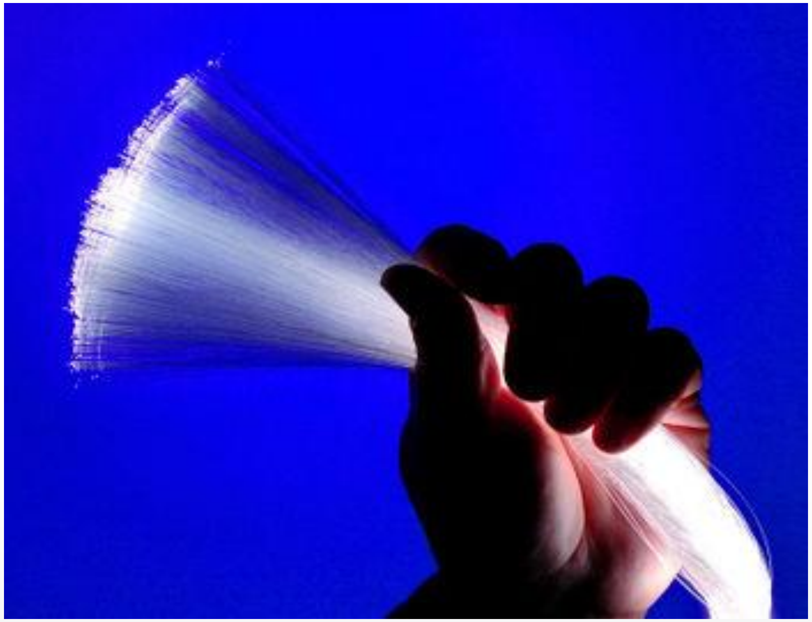
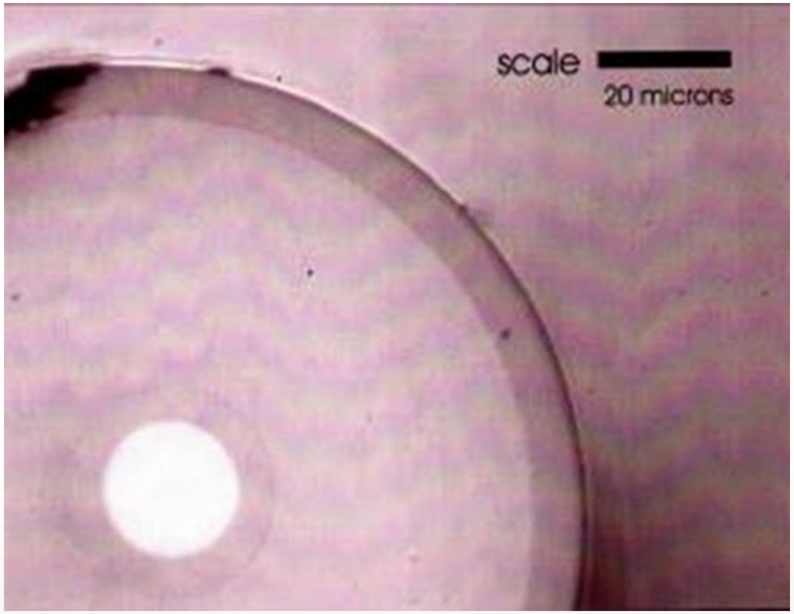
Glass Quality Far from Ideal



ORC Silica Fibre Fabrication
Typical Loss: < 0.2 dB/km



ORC Non-Silica Fibre Fabrication
Typical Loss: < 2 dB/m

Ten Thousand Times Higher Loss

A radical change in glass preparation is needed!

dstl

Ga:La:S Melt Quenching

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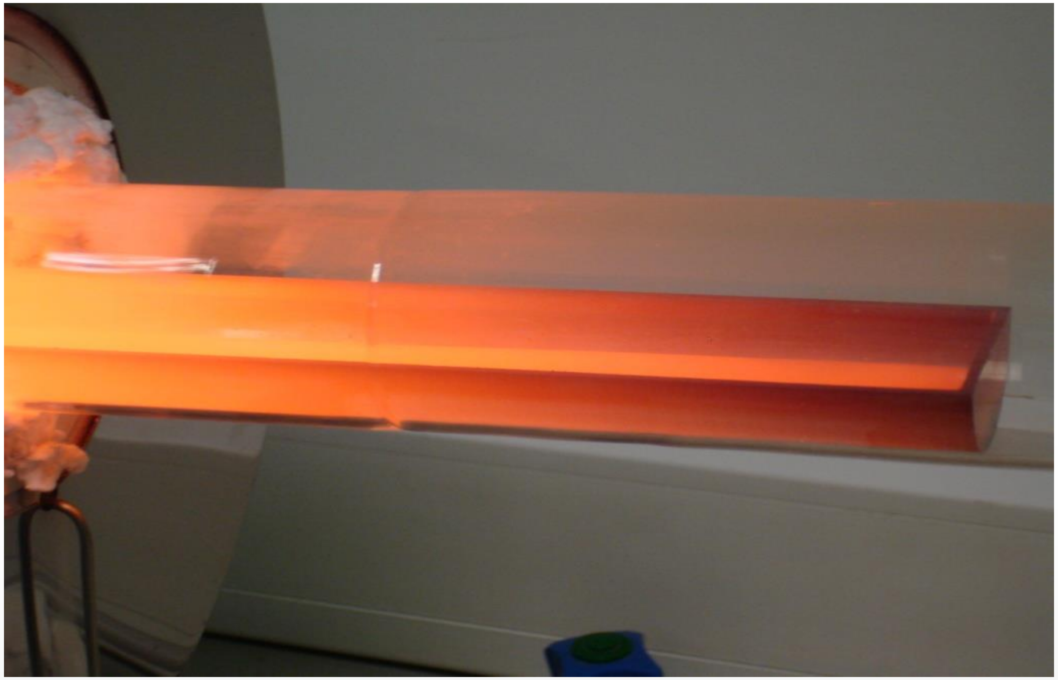

- Raw Materials batched in nitrogen purged glove box
- Sulphides melted in vitreous carbon crucibles
- Typically 24 hours at 1150°C in flowing argon
- Quenched to below glass transition temperature
- Annealed at 500°C, depending on ingot size

Focus on Glass Melt Facility

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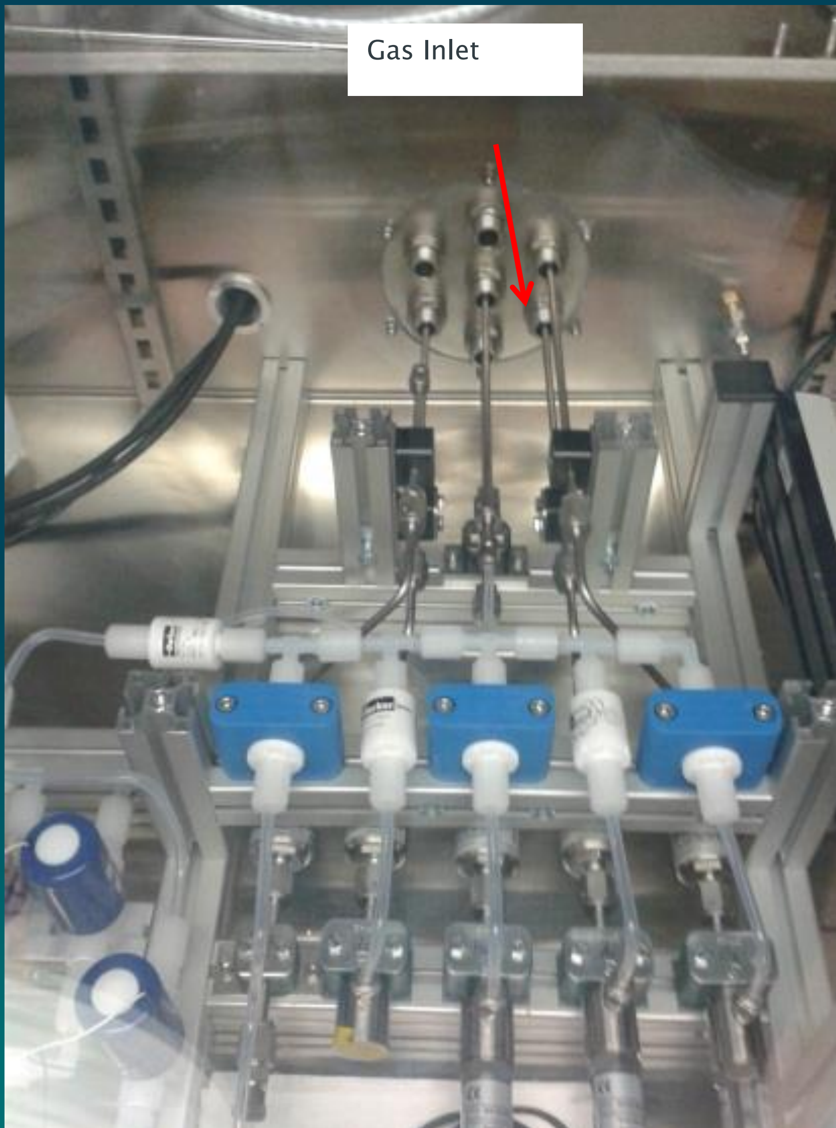
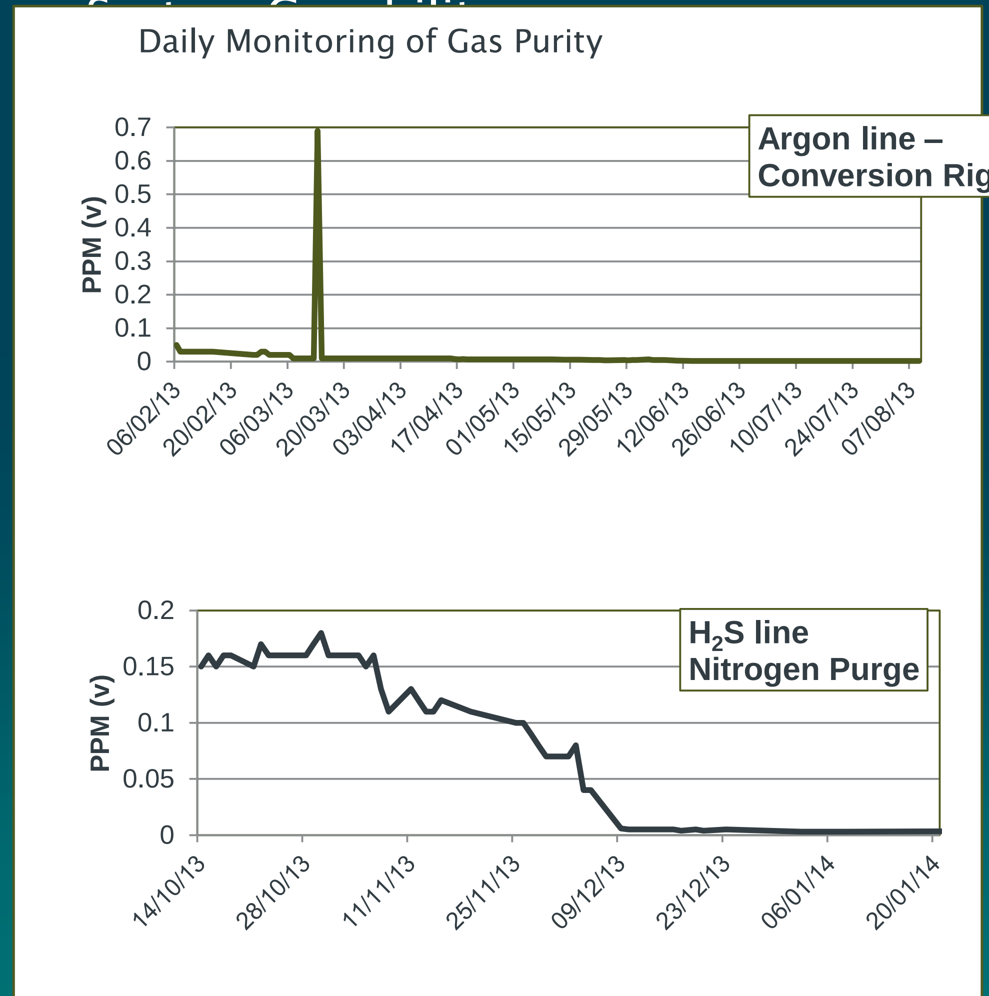


Gas Purification



Current Glass Purity

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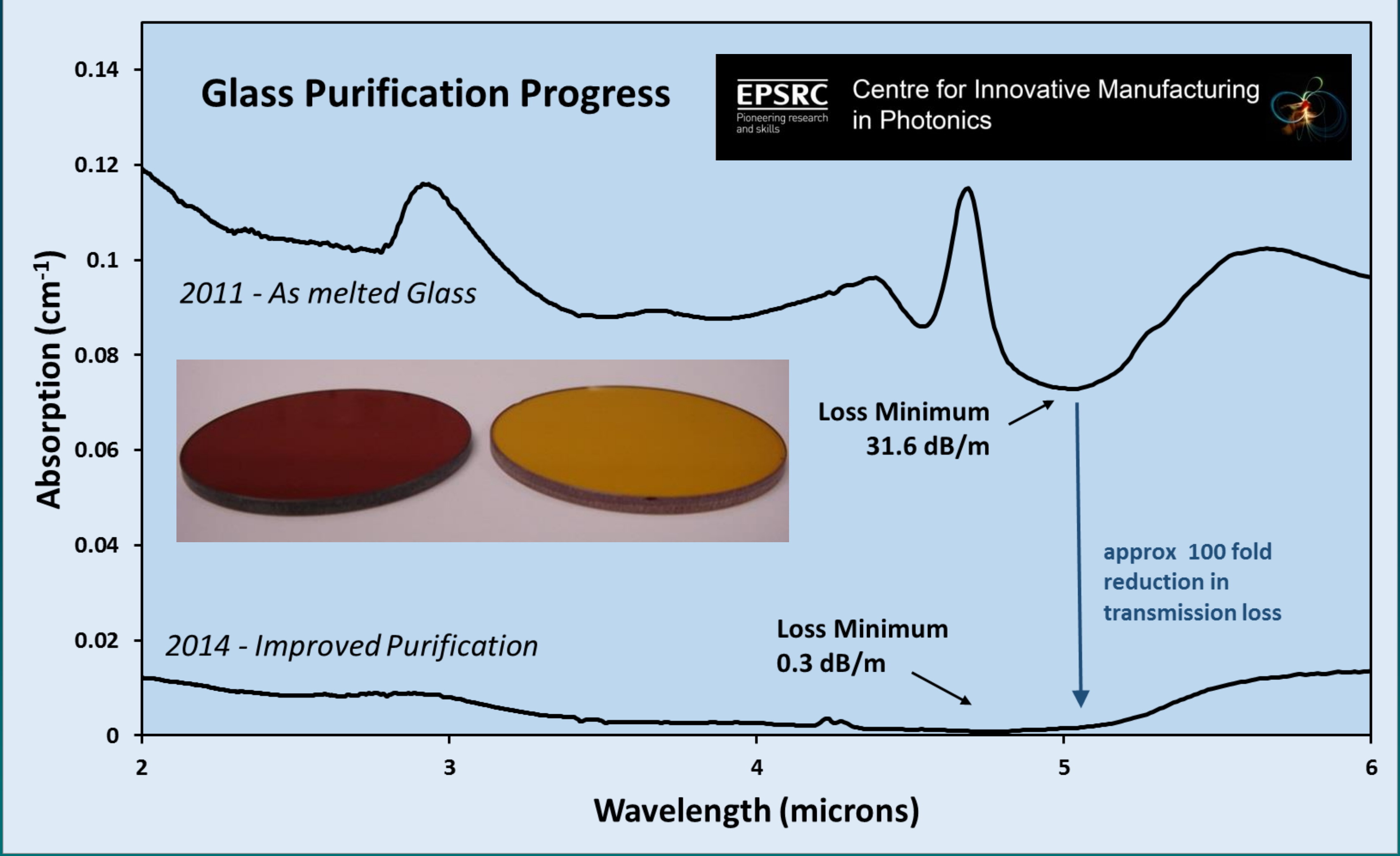

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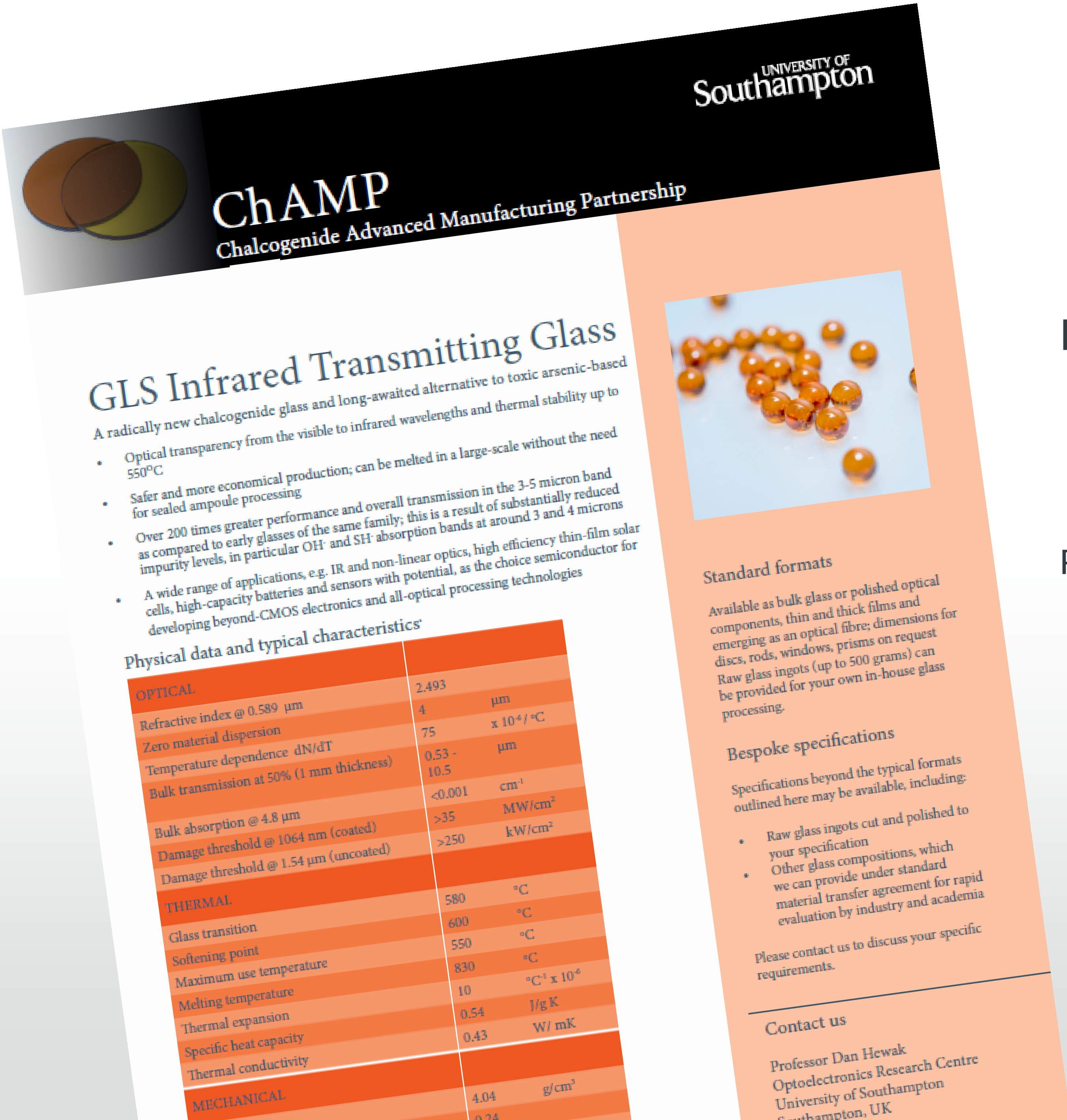

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ChAMP
Chalcogenide Advanced Manufacturing Partnership

GLS Infrared Transmitting Glass

A radically new chalcogenide glass and long-awaited alternative to toxic arsenic-based

- Optical transparency from the visible to infrared wavelengths and thermal stability up to 550°C
- Safer and more economical production; can be melted in a large-scale without the need for sealed ampoule processing
- Over 200 times greater performance and overall transmission in the 3-5 micron band as compared to early glasses of the same family; this is a result of substantially reduced impurity levels, in particular OH^- and SH^- absorption bands at around 3 and 4 microns
- A wide range of applications, e.g. IR and non-linear optics, high efficiency thin-film solar cells, high-capacity batteries and sensors with potential, as the choice semiconductor for developing beyond-CMOS electronics and all-optical processing technologies

Physical data and typical characteristics*

OPTICAL		
Refractive index @ 0.589 µm	2.493	
Zero material dispersion	4	µm
Temperature dependence dN/dT	75	$x\ 10^{-6}$ / °C
Bulk transmission at 50% (1 mm thickness)	0.53 - 10.5	µm
Bulk absorption @ 4.8 µm	<0.001	cm^{-1}
Damage threshold @ 1064 nm (coated)	>35	MW/cm^2
Damage threshold @ 1.54 µm (uncoated)	>250	kW/cm^2
THERMAL		
Glass transition	580	°C
Softening point	600	°C
Maximum use temperature	550	°C
Melting temperature	830	°C
Thermal expansion	10	$°C^{-1}\ x\ 10^{-6}$
Specific heat capacity	0.54	J/g K
Thermal conductivity	0.43	W/ mK
MECHANICAL		
	4.04	g/cm^3
	0.24	

Standard formats

Available as bulk glass or polished optical components, thin and thick films and emerging as an optical fibre; dimensions for discs, rods, windows, prisms on request. Raw glass ingots (up to 500 grams) can be provided for your own in-house glass processing.

Bespoke specifications

Specifications beyond the typical formats outlined here may be available, including:

- Raw glass ingots cut and polished to your specification
- Other glass compositions, which we can provide under standard material transfer agreement for rapid evaluation by industry and academia

Please contact us to discuss your specific requirements.

Contact us

Professor Dan Hewak
Optoelectronics Research Centre
University of Southampton
Southampton, UK

Physical Data and Characteristics

Pick up a copy of our brochure

Corrosion resistance

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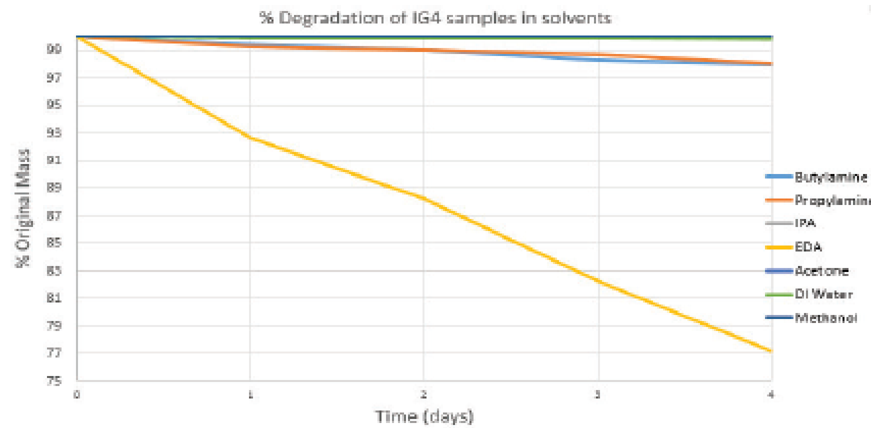
Chemical vulnerability weakness for previous chalcogenides

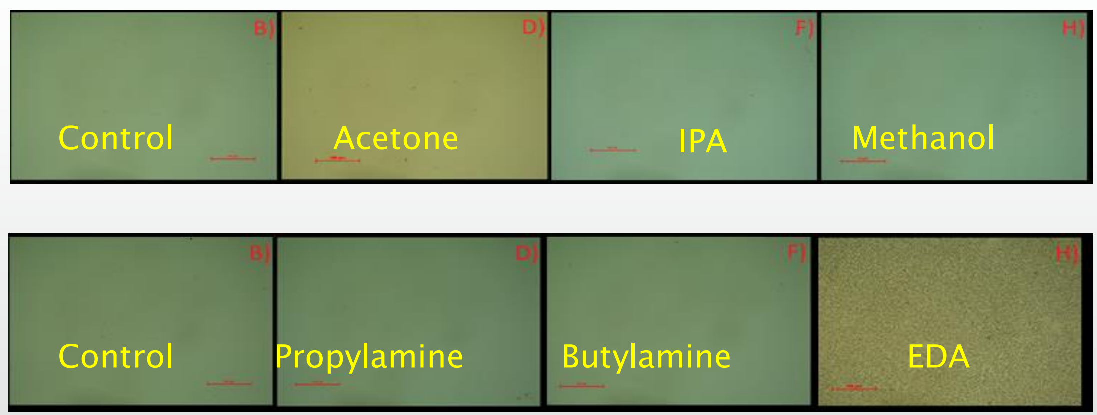
IG4 (Ge:As:Se) 4 day 23% mass loss in ethylenediamine (EDA)



- GLS surface after **1 month** exposure to

Cleaning Agents

Amine Solvents



- Significantly improved chemical resistance

20X image surface

Many Properties
= Many Applications

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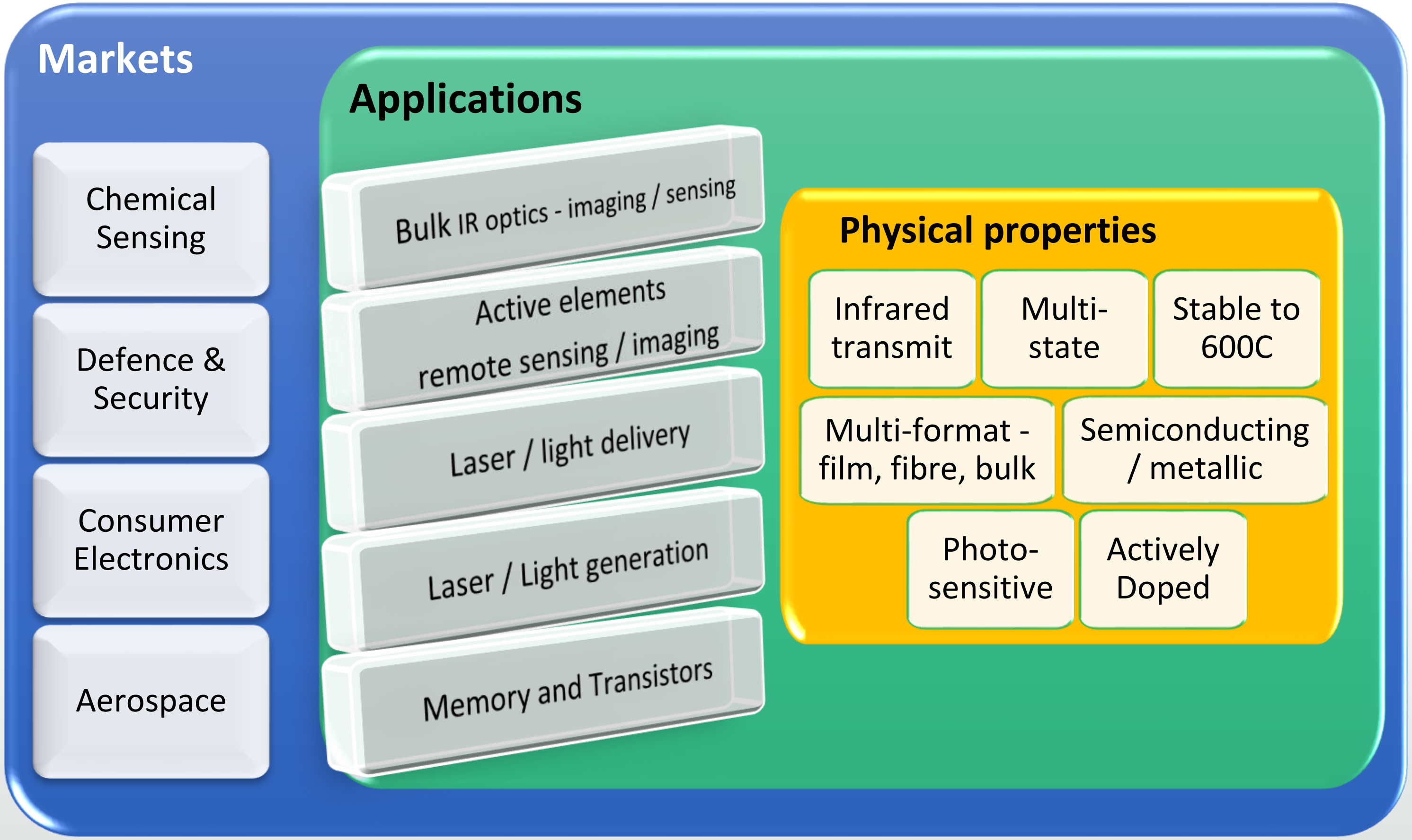

Chalcogenide content of systems will increase

slide courtesy of John Lincoln

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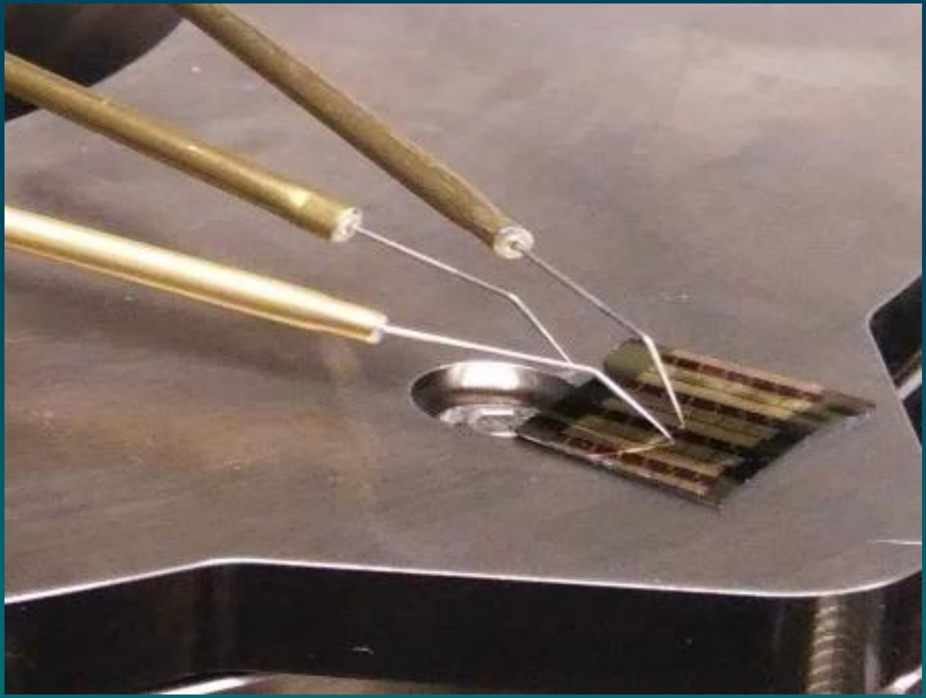
Emerging Devices

Demonstrated and Challenges:



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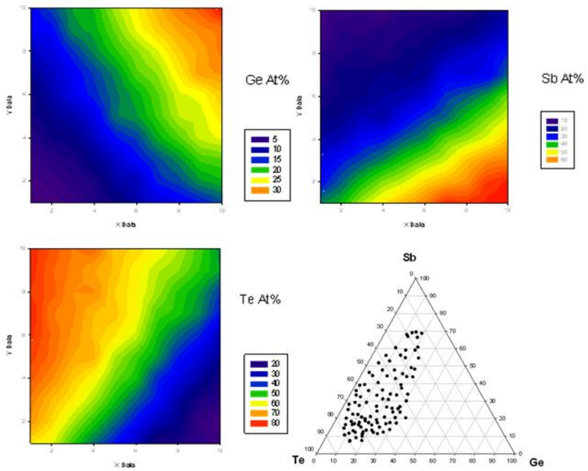
Glass Optimization (The Hard Way!)

Glass Optimization (The Efficient Way!)



High Throughput Material Discovery

Brian Hayden
Jaffar Saleh Subaie

ilika accelerated materials innovation

Phase Change Memory

High Throughput Screening Chip

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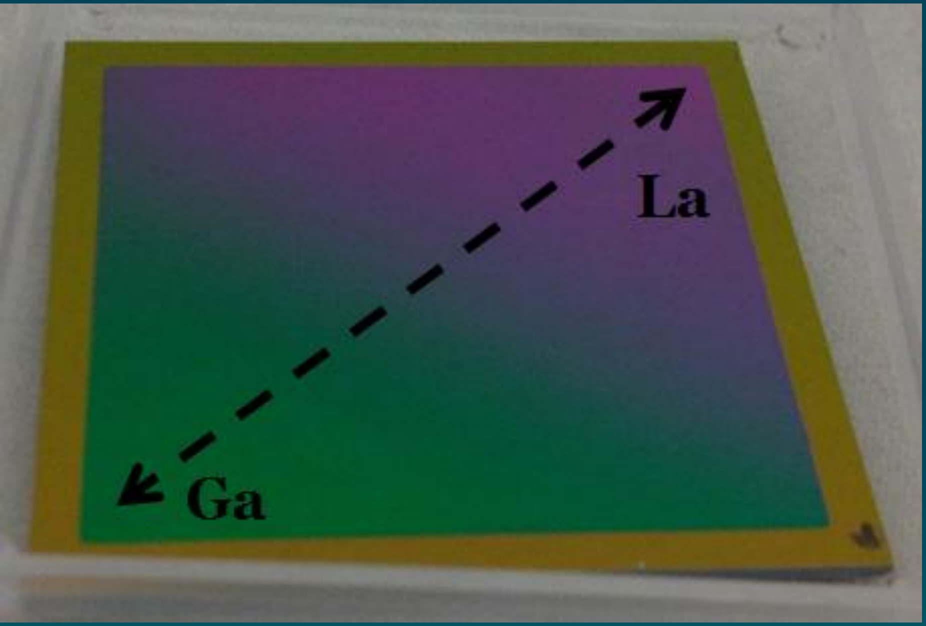
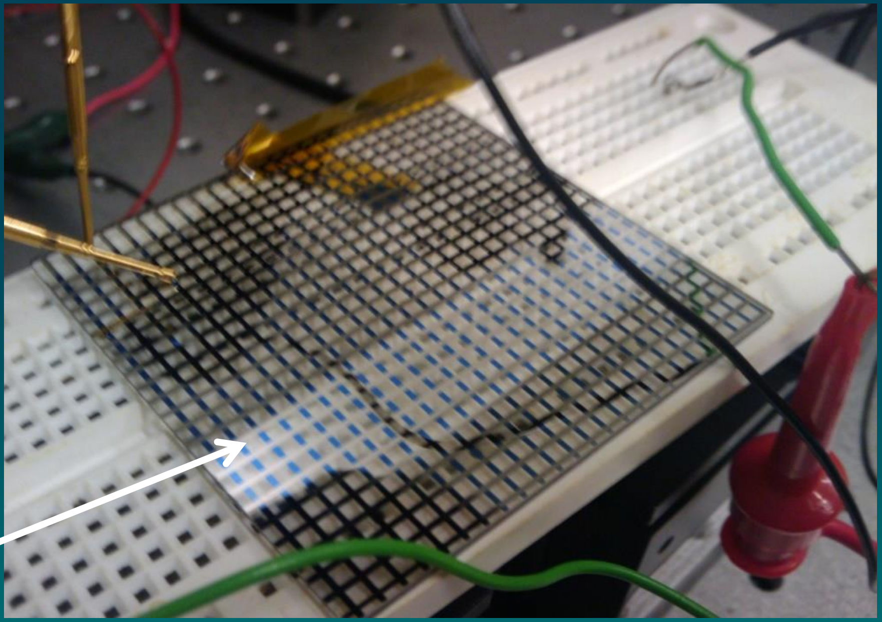


90% of Compositional Space



625 unique devices

B.Gholipour, Novel Chalcogenide Optoelectronic and Nanophotonic Information Storage and Processing Devices, PhD Thesis - May 2012

Optimum Composition GLS Switch

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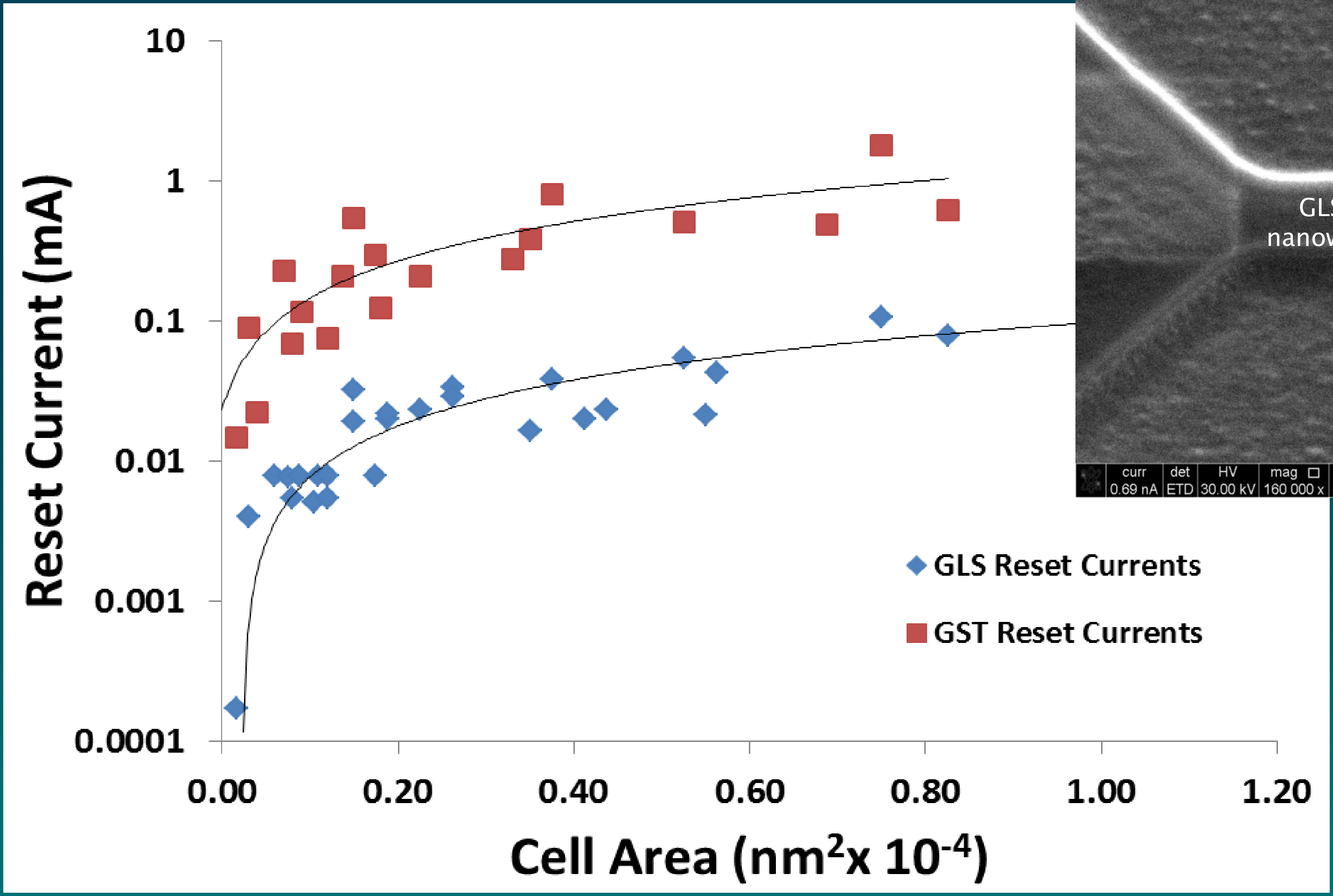

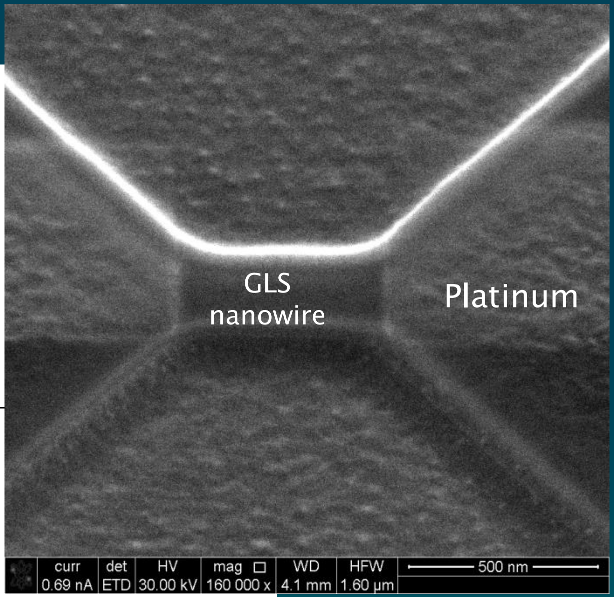

Chalcogenide P/N Junction

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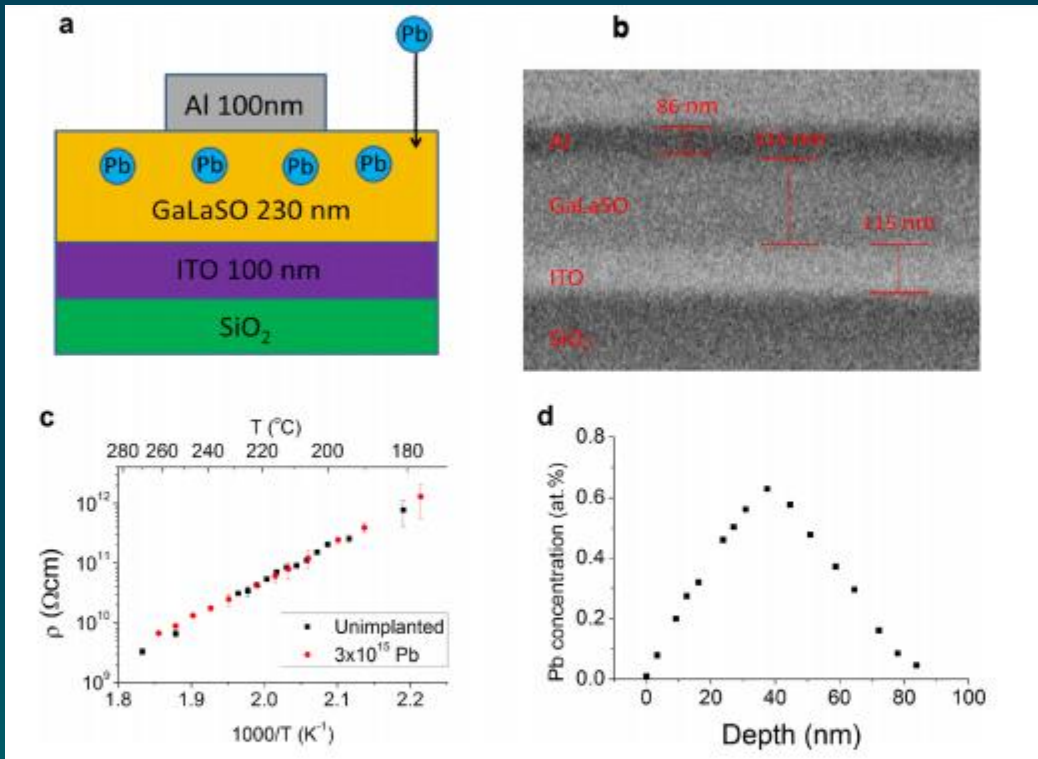

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Modifying chalcogenides through non-equilibrium doping via ion implantation

(collaboration with Richard Curry, University of Surrey)

Thermoelectric Devices

Waste Heat ⇨ Electrical Power

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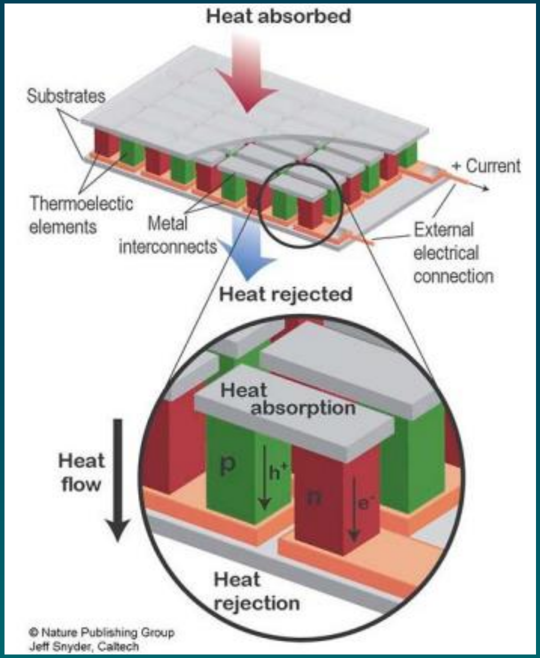
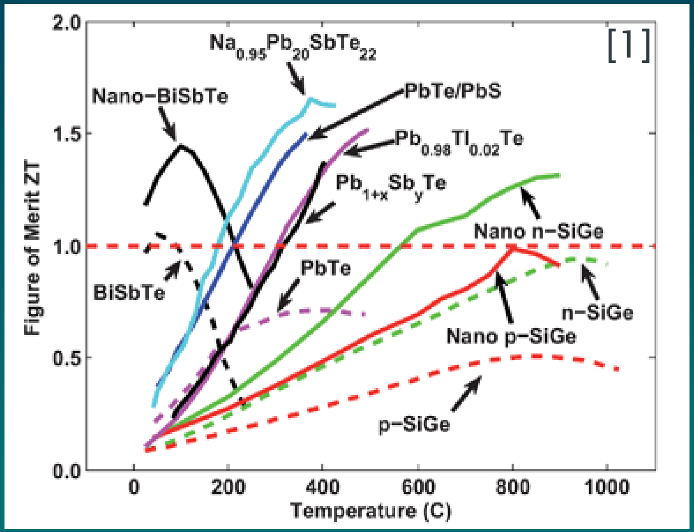


Classical bulk TE

$$ZT = \frac{S^2 T}{\rho\lambda}$$

Figure of merit (*ZT*) depends on Seebeck coefficient S, thermal conductivity λ, and electrical resistivity ρ.



Research directions:

- Thin film TE
- Nanostructuring
- Novel design of TE

Thermoelectric Device Fabrication

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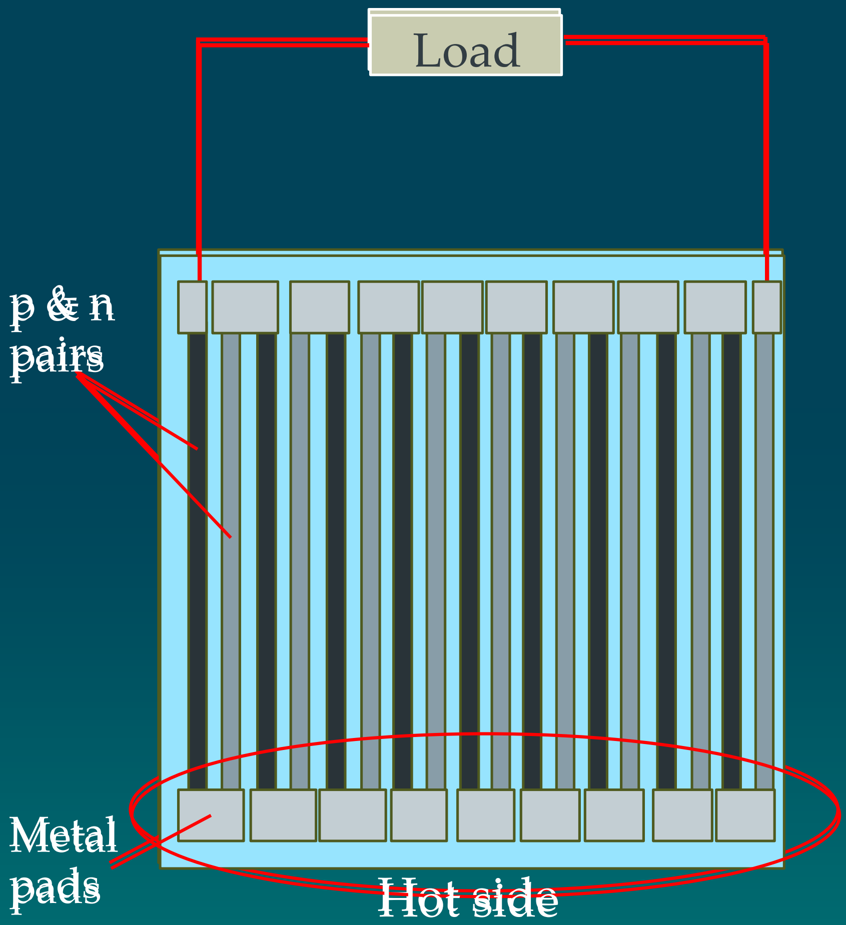

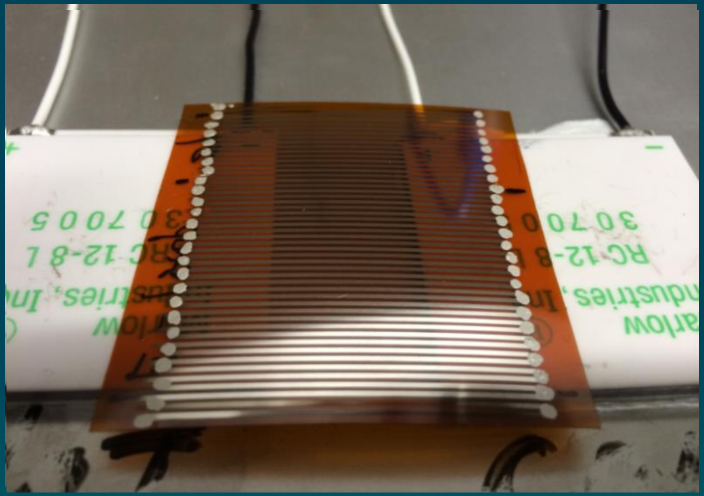

Schematic and real device image of TFTE on PI substrate

(collaboration with Harish Baskharim, University of Oxford)

3D Photonic Bandgap Structures

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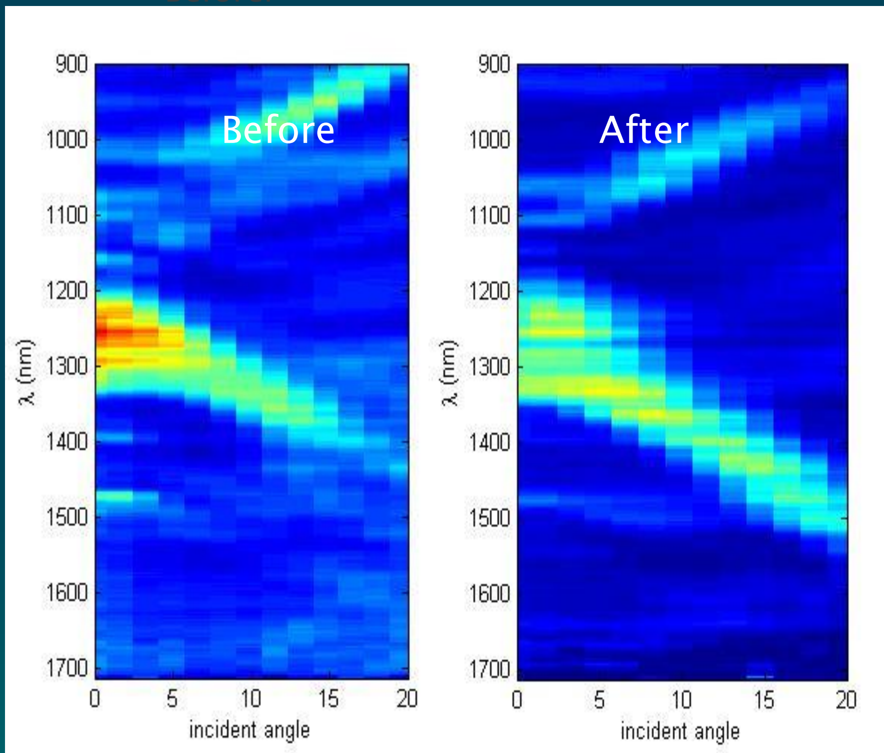
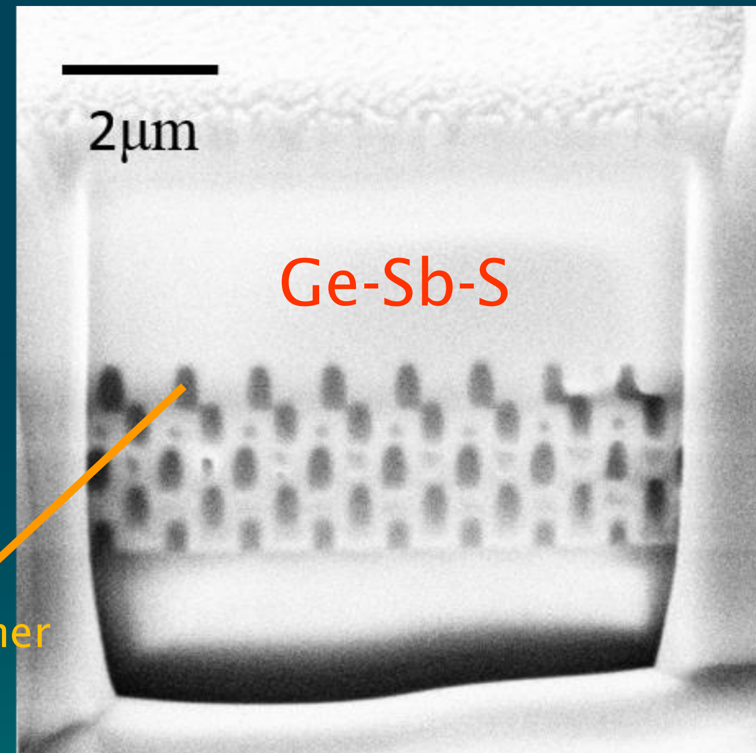
Backfill with Ge-Sb-S by CVD

Before:

(a)



b)



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(a) woodpile structure template before backfill process;
(b) SEM image fabricated by FIB showing the quality of in-filling

Collaboration with John Rarity, University of Bristol)

2D Emerging Materials

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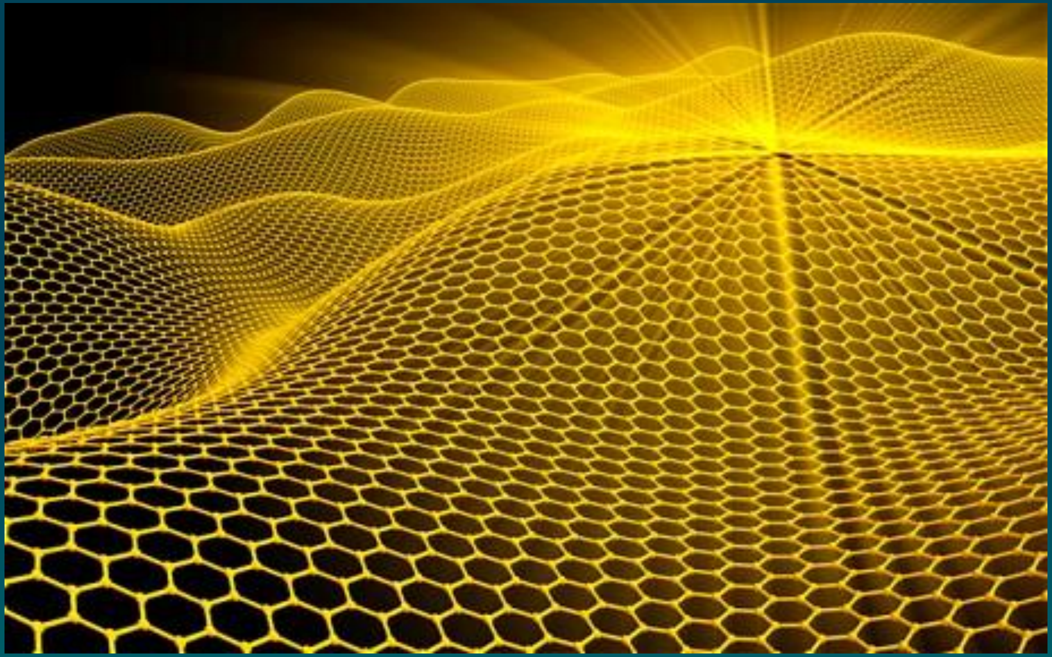
Applications and Challenges:



There remain hundreds of layered materials that could still yield monolayers

Summary

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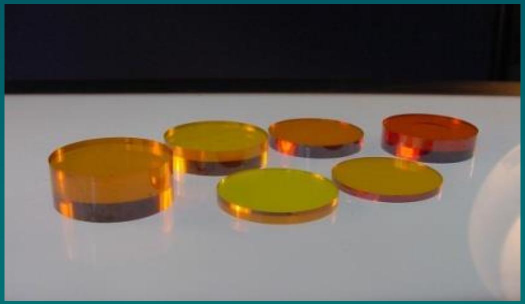
- Chalcogenide glass clearly has broad reaching potential
- With long term funding radical changes in their processing and applications were enabled
- The fascinating application space ensures the future of these materials.
- If you'd like some glass or thin films, please ask!



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EP/J00278X/1	FLITES : Fibre-Laser Imaging of gas Turbine Exhaust Species (ORC)
EP/I019065/1	Chalcogenide optoelectronic platform for next-generation optoelectronics
EP/H02607X/1	EPSRC Centre for Innovative Manufacturing in Photonics
EP/G060363/1	ChAMP – Chalcogenide Advanced Manufacturing Partnership

More details at http://chalcogenides.net

Light