

---

# Les verres de chalcogénures

ZHANG Xianghua

UMR 6226 CNRS-Université de Rennes I

Institut des Sciences Chimiques de Rennes

Equipe Verres et Céramiques

35042 Rennes, France

# Sommaire

---

- Qu'est-ce que les verres de chalcogénures?
- A quoi servent ces verres?
- Que sont les défis actuels?
- Et les perspectives?


# Sommaire

---

- **Qu'est-ce que les verre de chalcogénures?**
- A quoi servent ces verres?
- Que sont les défis actuels?
- Et les perspectives?

# Chalcogenide glasses

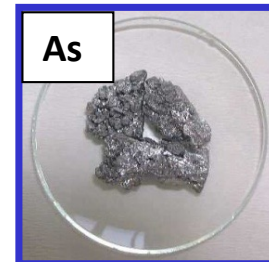
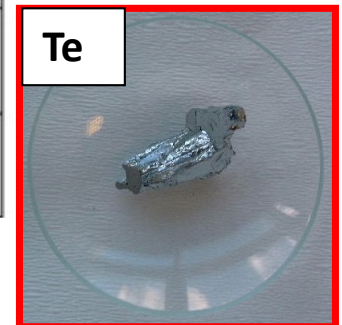
The Periodic Table of Elements



1 <b>H</b> Hydrogen 1.01																	2 <b>He</b> Helium 4.00	
3 <b>Li</b> Lithium 6.94	4 <b>Be</b> Beryllium 9.01																	10 <b>Ne</b> Neon 20.18
11 <b>Na</b> Sodium 22.99	12 <b>Mg</b> Magnesium 24.31																	18 <b>Ar</b> Argon 39.95
19 <b>K</b> Potassium 39.10	20 <b>Ca</b> Calcium 40.08	21 <b>Sc</b> Scandium 44.96	22 <b>Ti</b> Titanium 47.87	23 <b>V</b> Vanadium 50.94	24 <b>Cr</b> Chromium 52.00	25 <b>Mn</b> Manganese 54.94	26 <b>Fe</b> Iron 55.85	27 <b>Co</b> Cobalt 58.93	28 <b>Ni</b> Nickel 58.69	29 <b>Cu</b> Copper 63.55	30 <b>Zn</b> Zinc 65.38	31 <b>Ga</b> Gallium 69.72	32 <b>Ge</b> Germanium 72.64	33 <b>As</b> Arsenic 74.92	34 <b>Se</b> Selenium 78.96	35 <b>Br</b> Bromine 79.90	36 <b>Kr</b> Krypton 83.80	
37 <b>Rb</b> Rubidium 85.47	38 <b>Sr</b> Strontium 87.62	39 <b>Y</b> Yttrium 88.91	40 <b>Zr</b> Zirconium 91.22	41 <b>Nb</b> Niobium 92.91	42 <b>Mo</b> Molybdenum 95.94	43 <b>Tc</b> Technetium (98)	44 <b>Ru</b> Ruthenium 101.07	45 <b>Rh</b> Rhodium 102.91	46 <b>Pd</b> Palladium 106.42	47 <b>Ag</b> Silver 107.87	48 <b>Cd</b> Cadmium 112.41	49 <b>In</b> Indium 114.82	50 <b>Sn</b> Tin 118.71	51 <b>Sb</b> Antimony 121.76	52 <b>Te</b> Tellurium 127.60	53 <b>I</b> Iodine 126.91	54 <b>Xe</b> Xenon 131.29	
55 <b>Cs</b> Cesium 132.91	56 <b>Ba</b> Barium 137.33	57 <b>La</b> Lanthanum 138.91	72 <b>Hf</b> Hafnium 178.49	73 <b>Ta</b> Tantalum 180.95	74 <b>W</b> Tungsten 183.84	75 <b>Re</b> Rhenium 186.21	76 <b>Os</b> Osmium 190.23	77 <b>Ir</b> Iridium 192.22	78 <b>Pt</b> Platinum 195.08	79 <b>Au</b> Gold 196.97	80 <b>Hg</b> Mercury 200.59	81 <b>Tl</b> Thallium 204.38	82 <b>Pb</b> Lead 207.2	83 <b>Bi</b> Bismuth 208.98	84 <b>Po</b> Polonium (209)	85 <b>At</b> Astatine (210)	86 <b>Rn</b> Radon (222)	
87 <b>Fr</b> Francium (223)	88 <b>Ra</b> Radium (226)	89 <b>Ac</b> Actinium (227)	104 <b>Rf</b> Rutherfordium 178.49	105 <b>Db</b> Dubnium (262)	106 <b>Sg</b> Seaborgium (266)	107 <b>Bh</b> Bohrium (264)	108 <b>Hs</b> Hassium (269)	109 <b>Mt</b> Meitnerium (268)	110 <b>Ds</b> Darmstadtium (281)	111 <b>Rg</b> Roentgenium (272)	112 <b>Cn</b> Copernicium (285)							

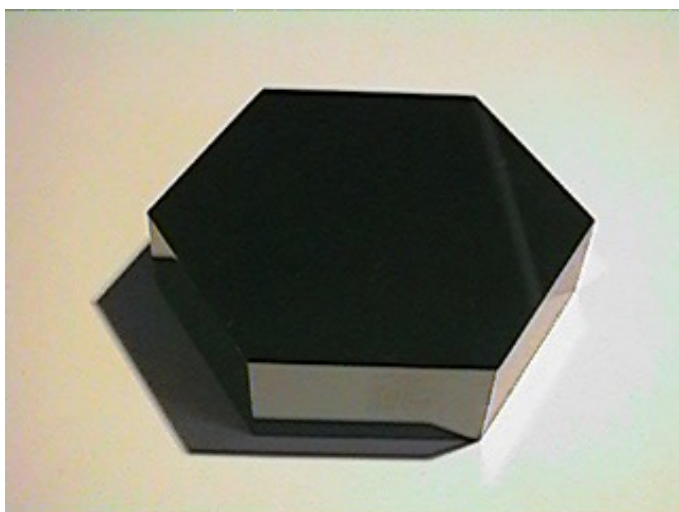
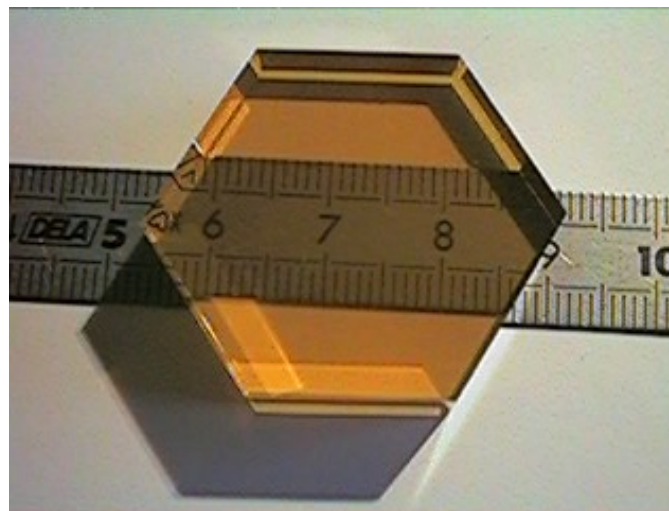
Legend for the periodic table:

- Li** — Element Symbol
- Lithium — Element Name
- 6.94 — Average Atomic Mass



# Chalcogenide glass samples

---

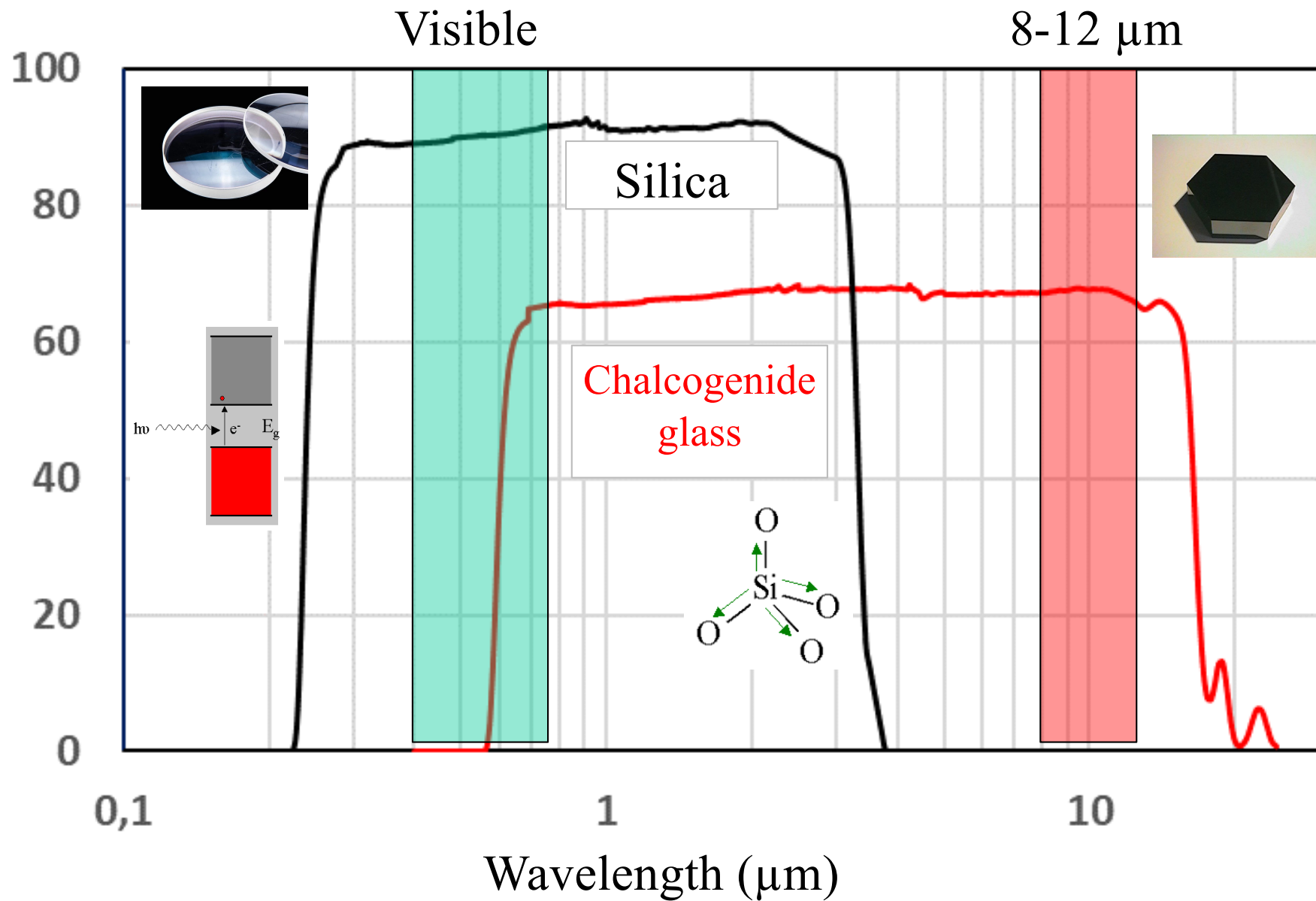


# Sommaire

---

- Qu'est-ce que les verres de chalcogénures?
- **A quoi servent ces verres?**
- Que sont les défis actuels?
- Et les perspectives?

# Transmission of different glasses





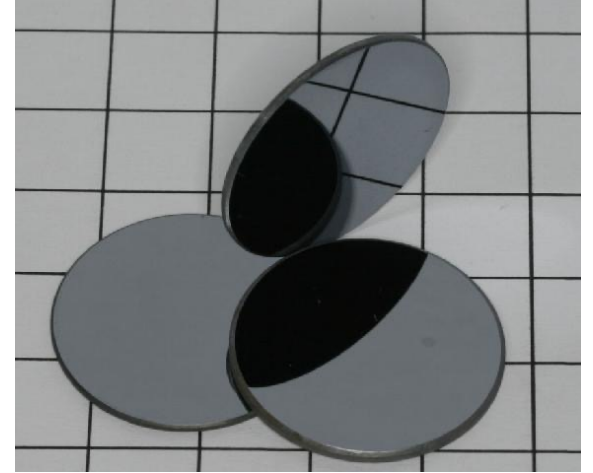
## Materials transparent between 8-12 $\mu\text{m}$



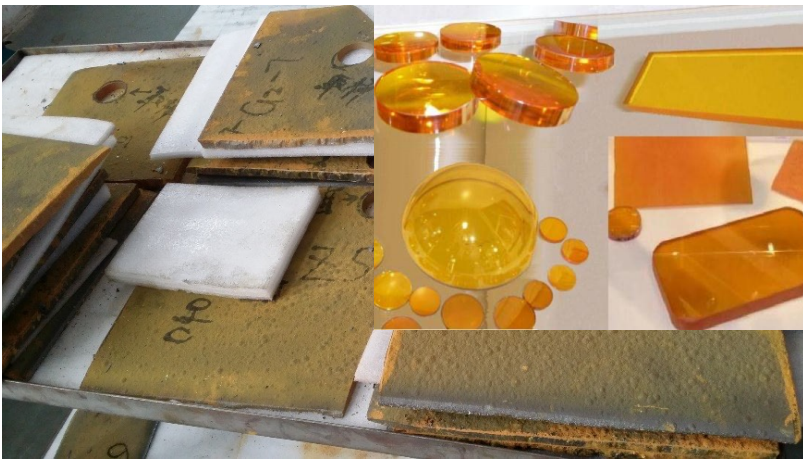
Diamond



Ge



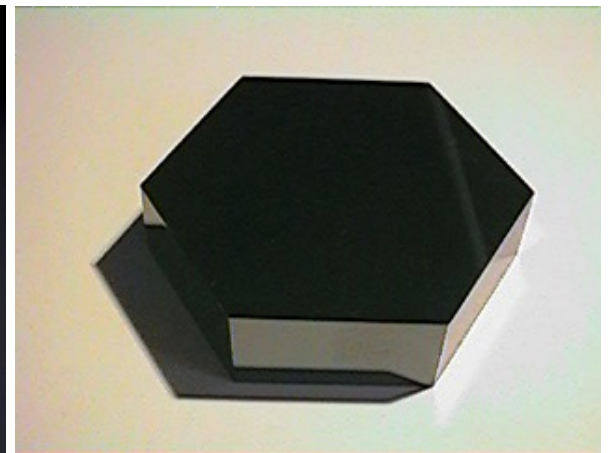
GaAs



ZnSe



Si

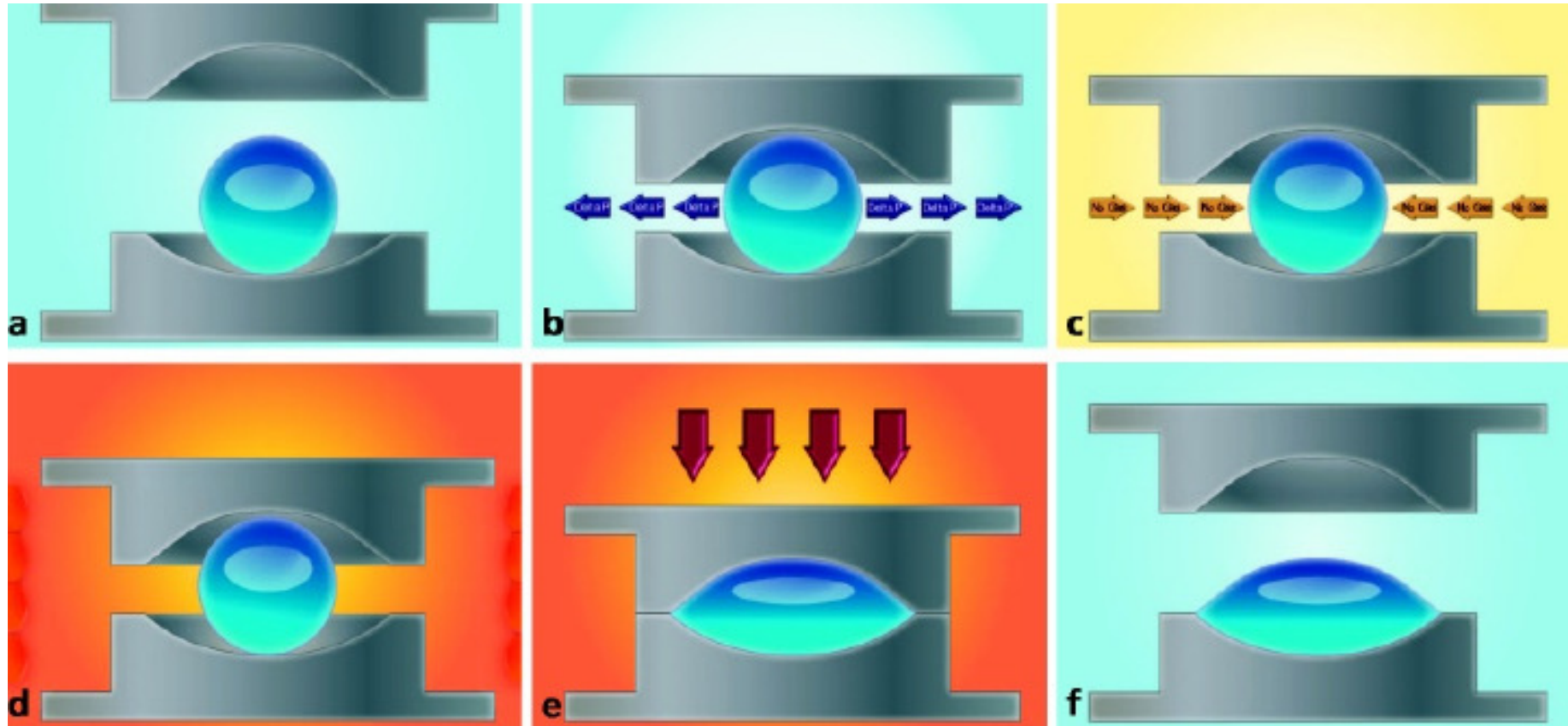


Chalcogenide glass



# Moulding of infrared glass optics

---

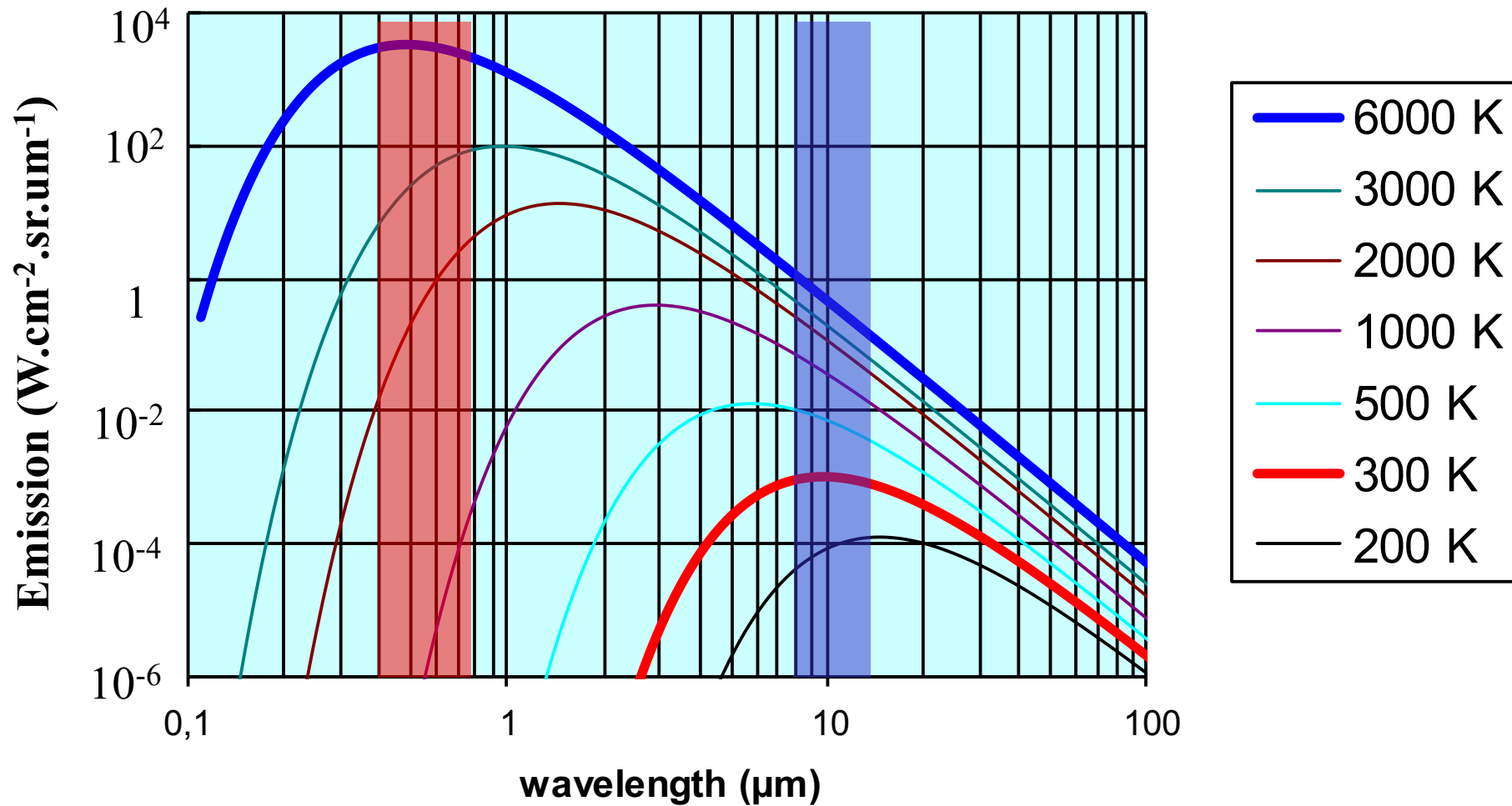
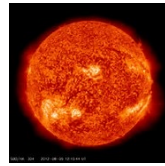


## Moulded optics in chalcogenide glasses

---

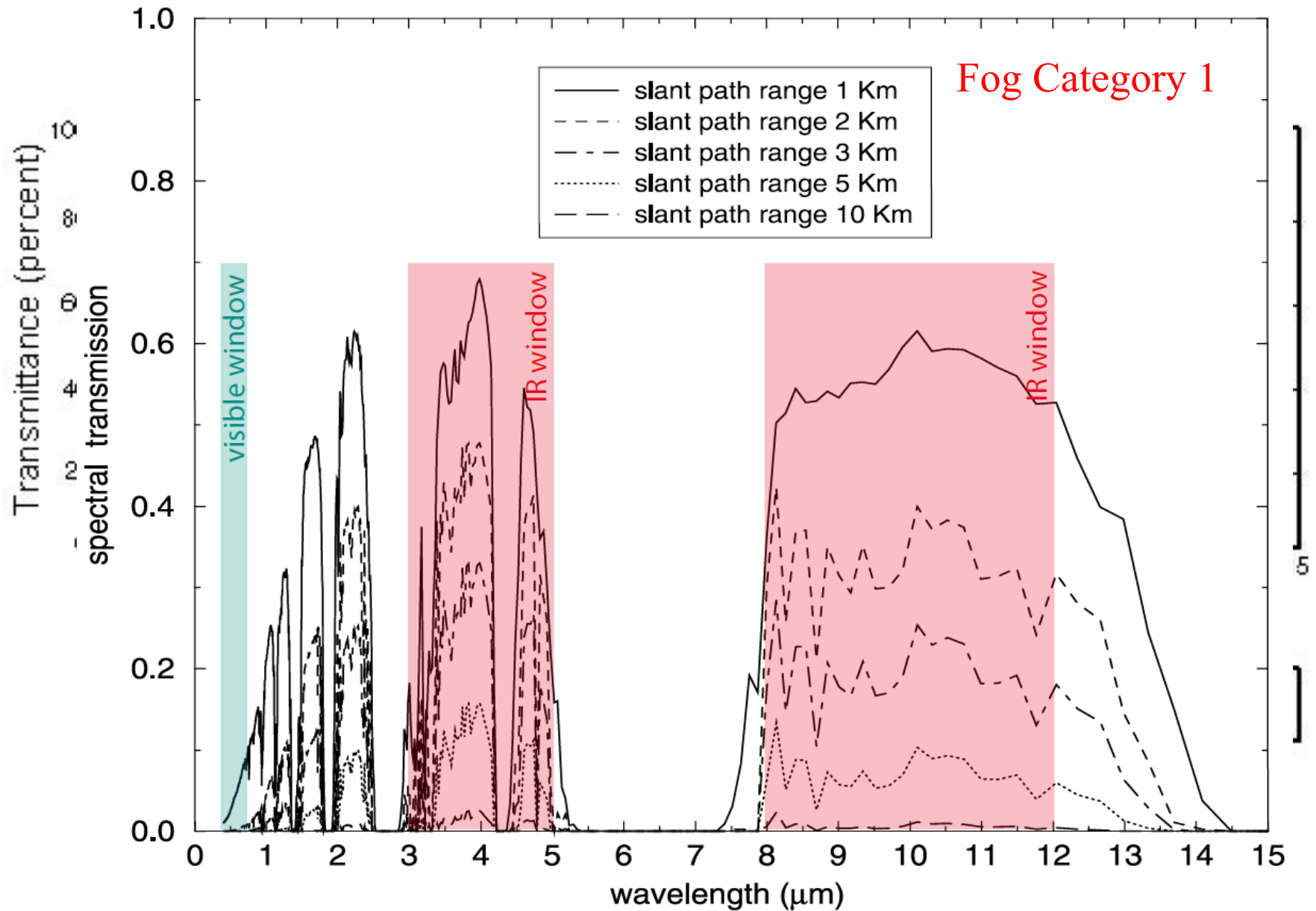


# Why 8-12 $\mu\text{m}$ is important



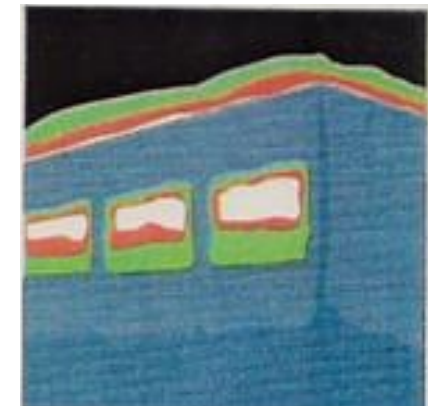
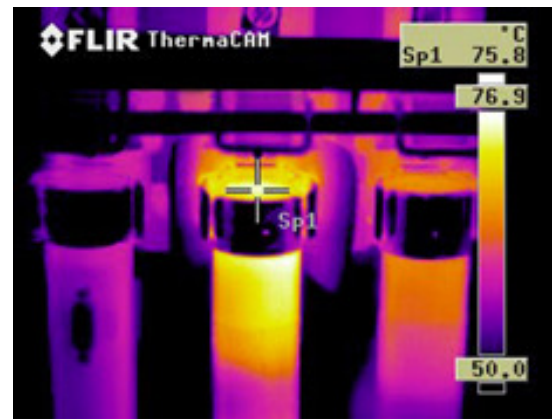
- Visible imaging uses reflection of external light source (sun, lighting...)
- Thermal imaging uses the emission of the objects

# The atmosphere should be transparent for imaging



# Why infrared is useful

Visible 0.4-0.75  $\mu\text{m}$

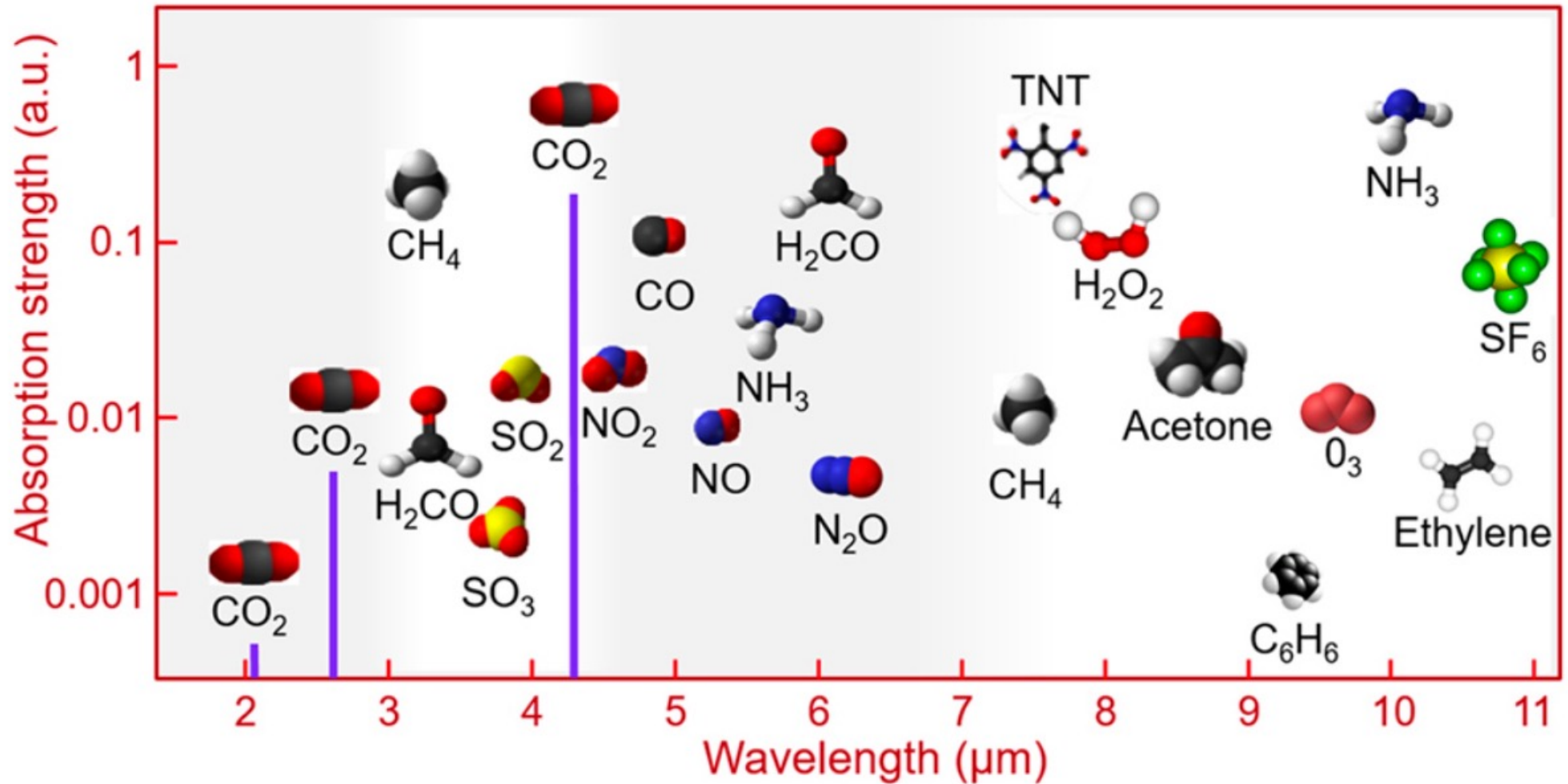


Infrared 8-12  $\mu\text{m}$



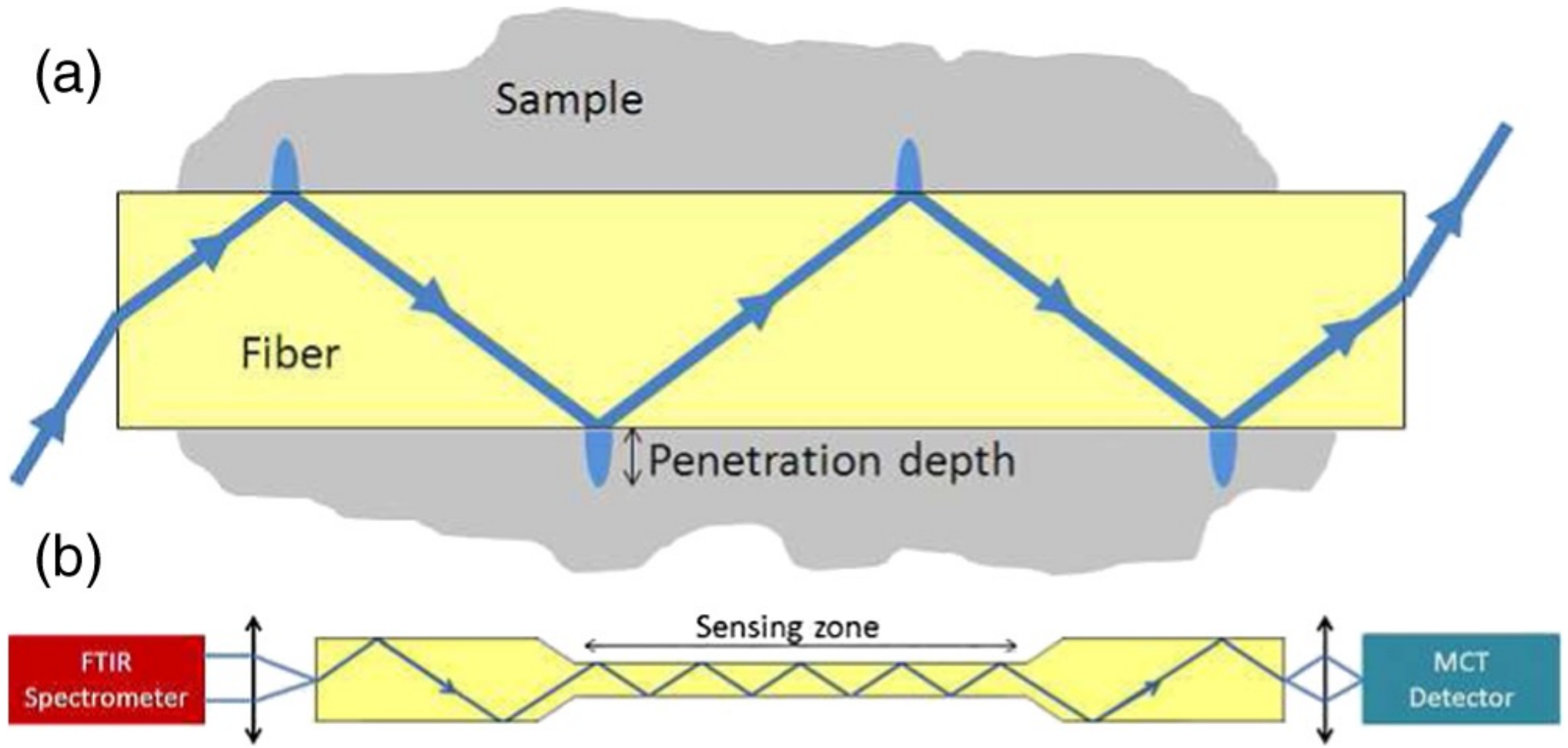
# Infrared fibre for chemical sensing

## Finger print absorption

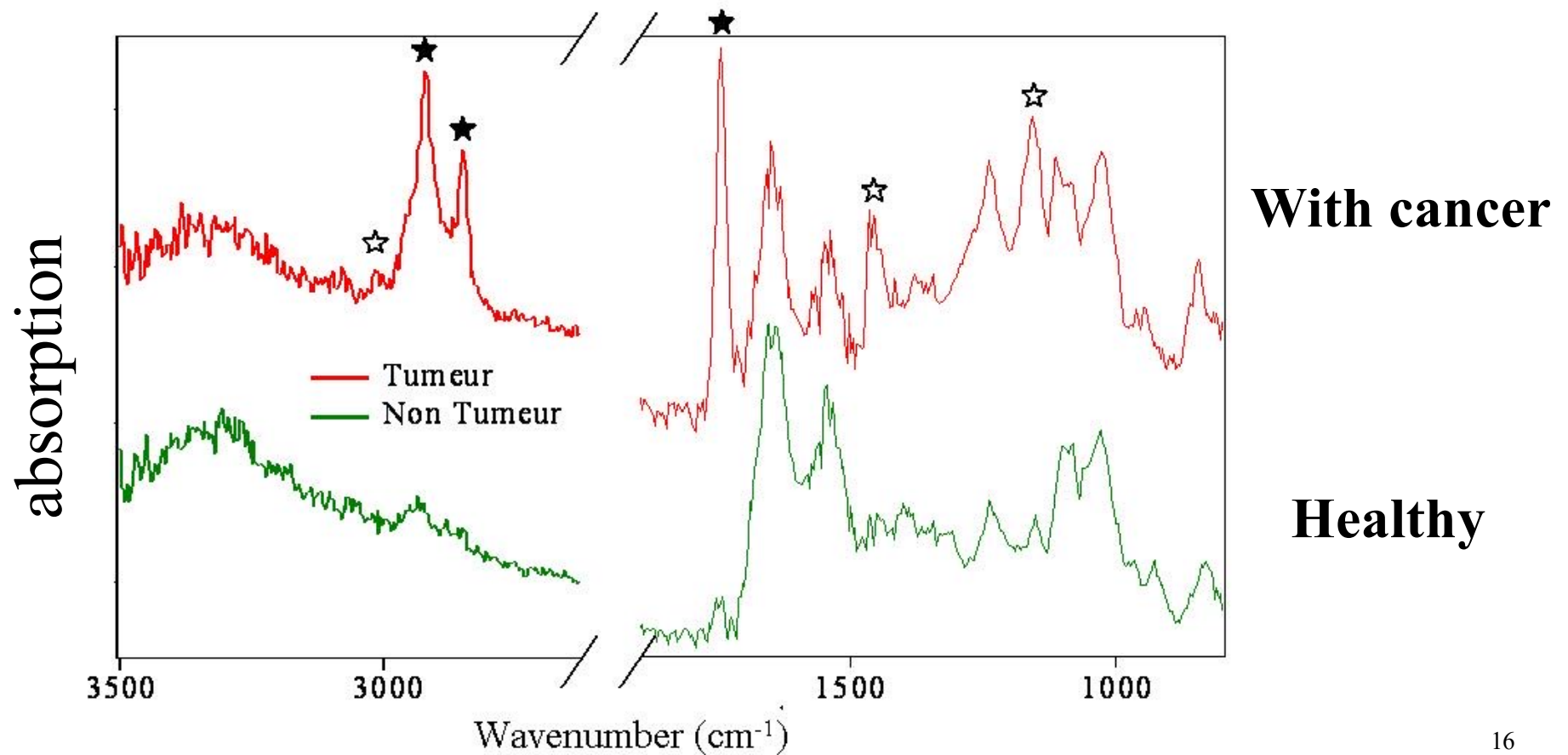
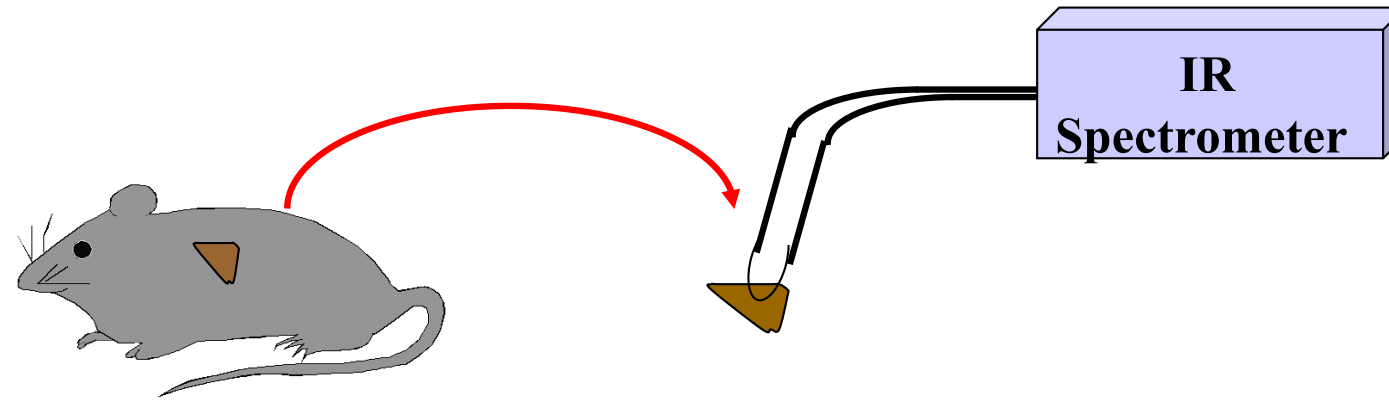




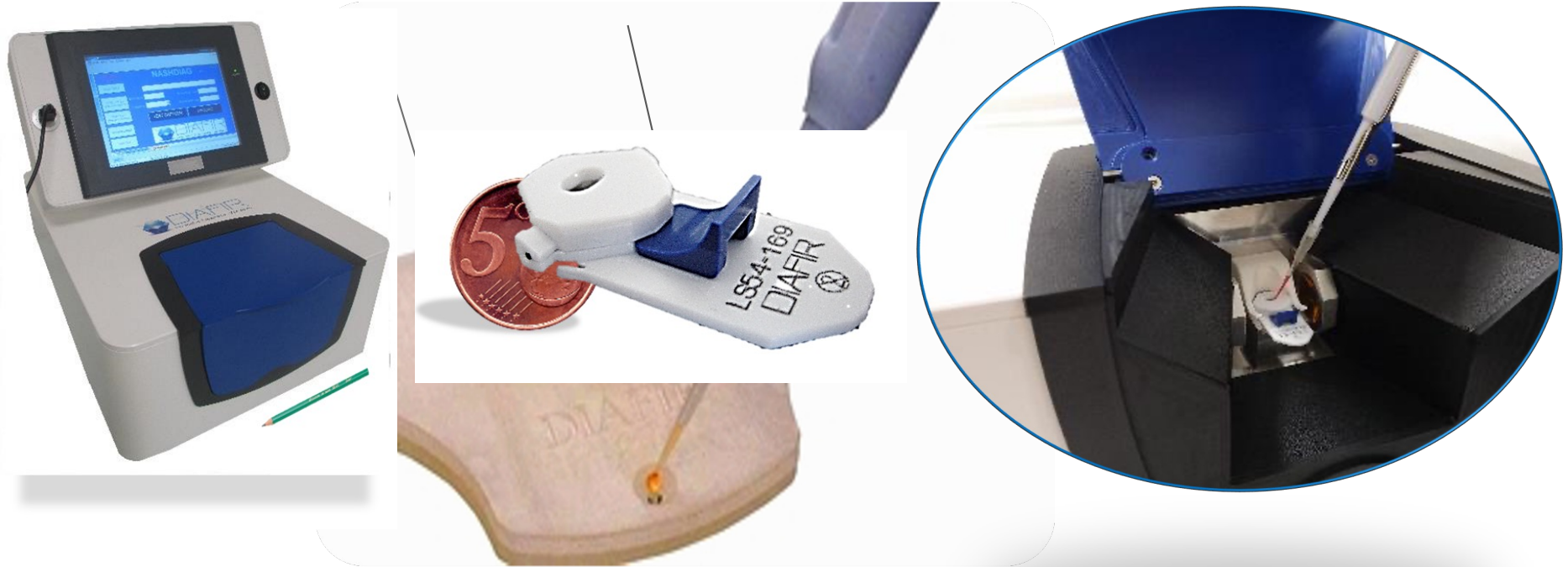
# Fiber evanescent wave spectroscopy



# chalcogenide glass fibers for biologic sensing



# Commercial Products

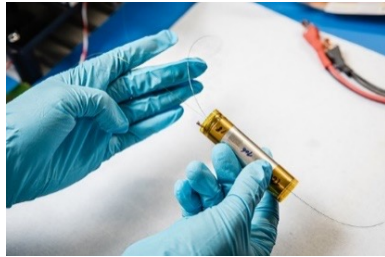


Non alcoholic SteatoHepatitis (NASH): a metabolic liver disease, a complication of Non Alcoholic Fatty Liver Disease

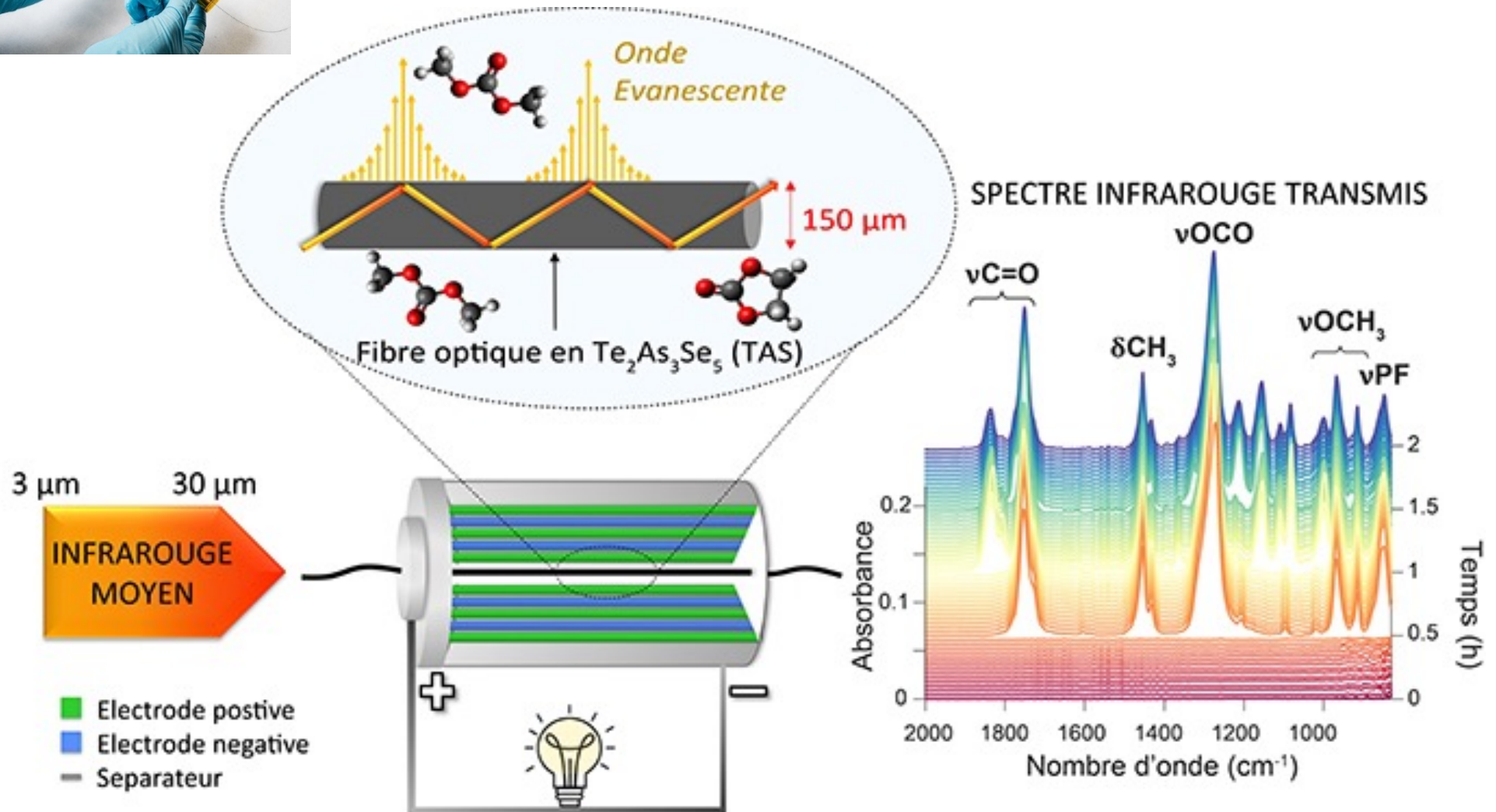
- ✓ Fast measurement (<10 min)
- ✓ Operator independent result
- ✓ Uses only 7µl for minimally invasive procedures

Website: [www.diafir.com](http://www.diafir.com)

# Fibre de chalcogénure pour « voir » dans les batteries commerciales



Collaboration groupe du Prof. Tarascon  
*Nature Energy* (2022)



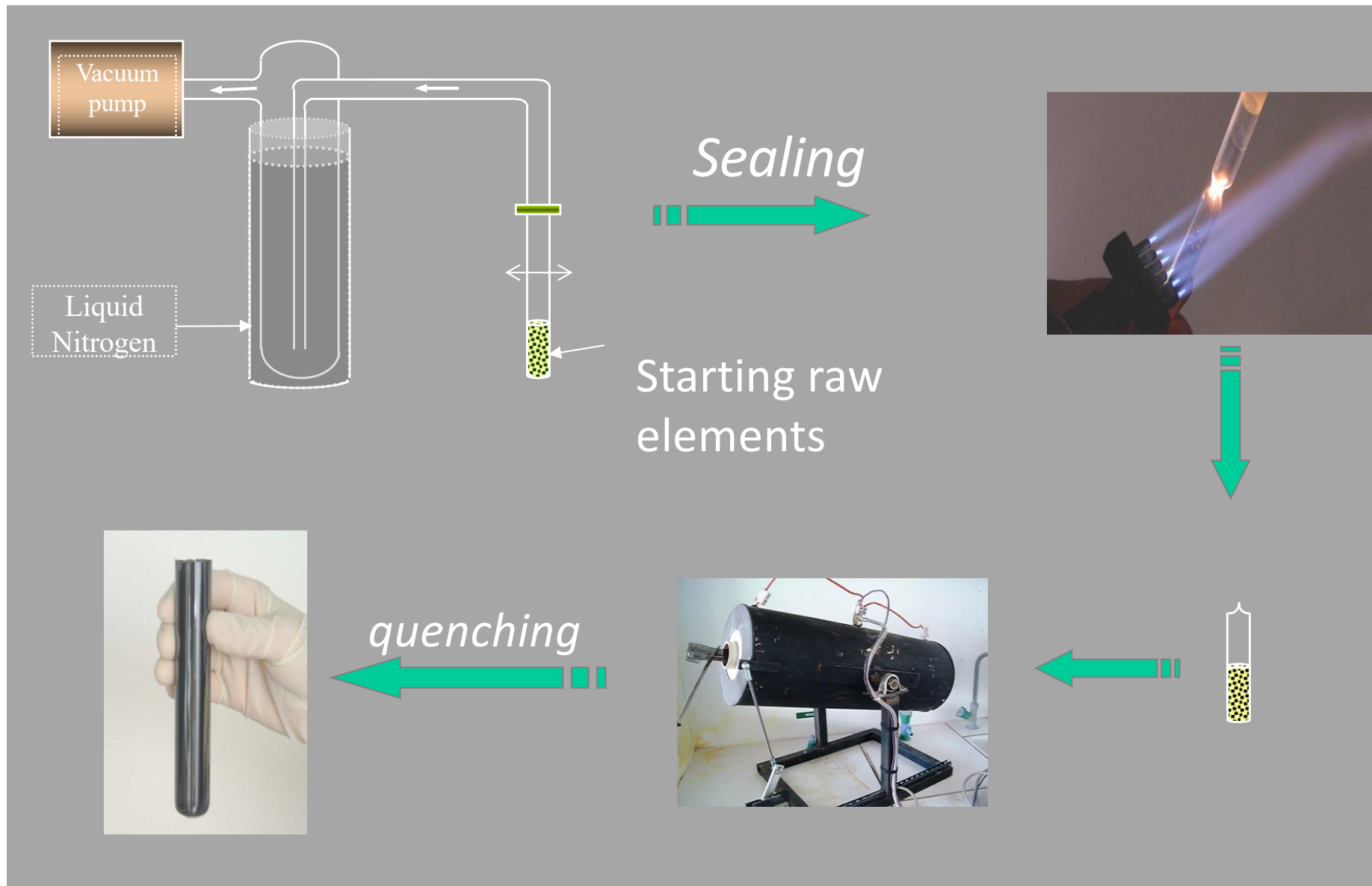
# Sommaire

---

- Qu'est-ce que les verres de chalcogénures?
- A quoi servent ces verres?
- **Que sont les défis actuels?**
- Et les perspectives?



# Chalcogenide glass synthesis





# Chalcogenide glass industrial production

---

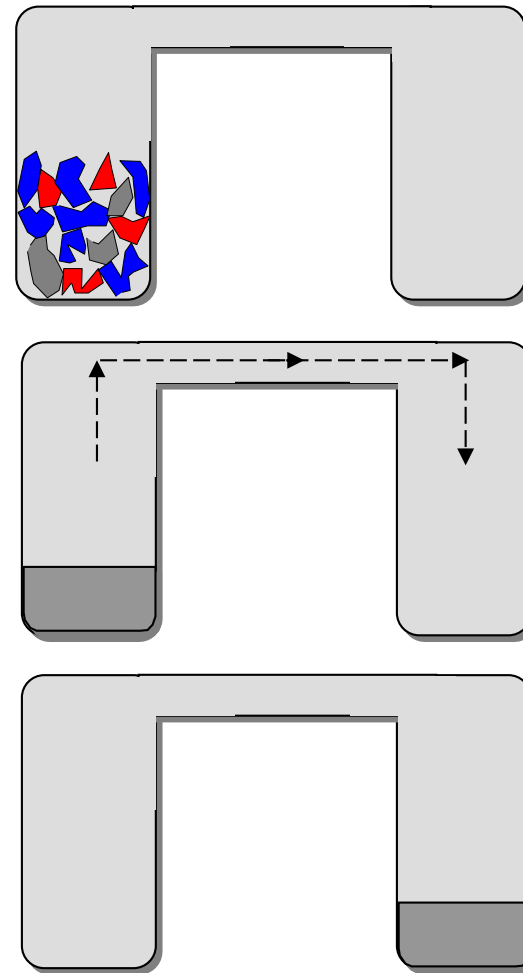
Raw materials, sealed under vacuum



Reaction et distillation



Homogenisation, cooling and annealing



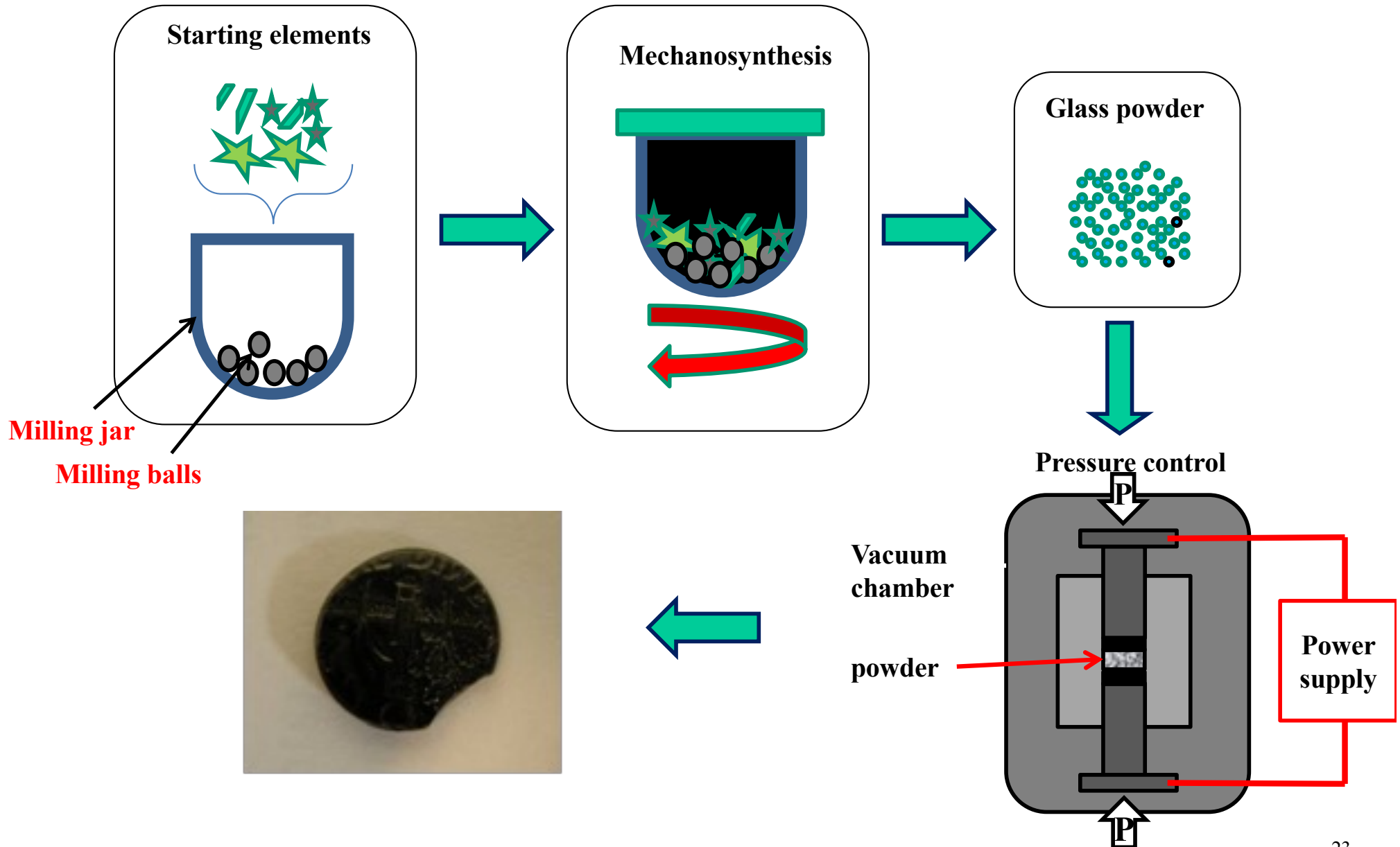
# Chalcogenide glass ingots

---

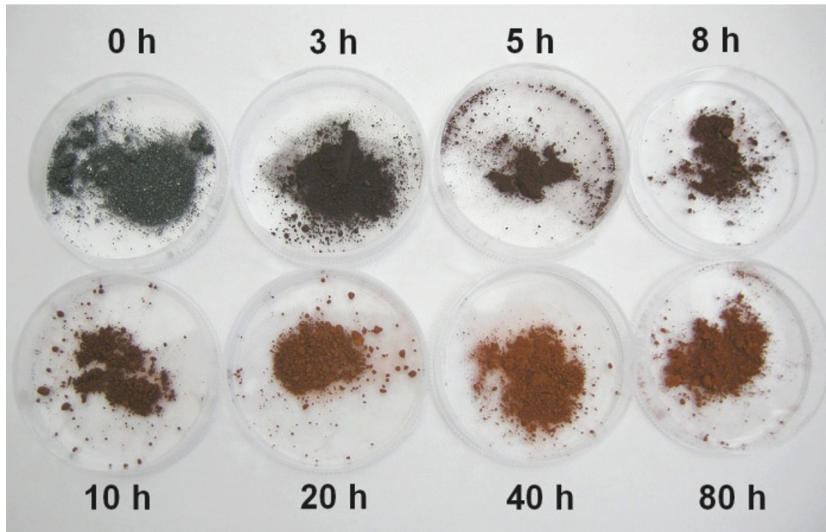
---

# New method for fabricating IR optics

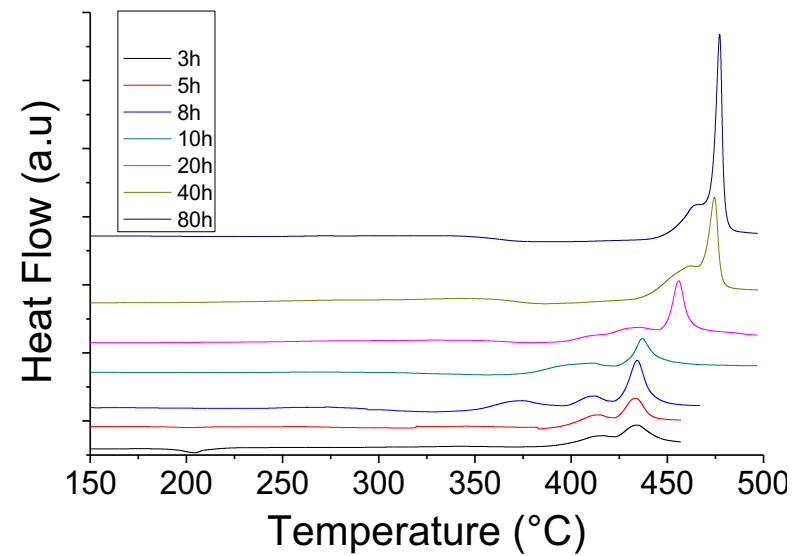
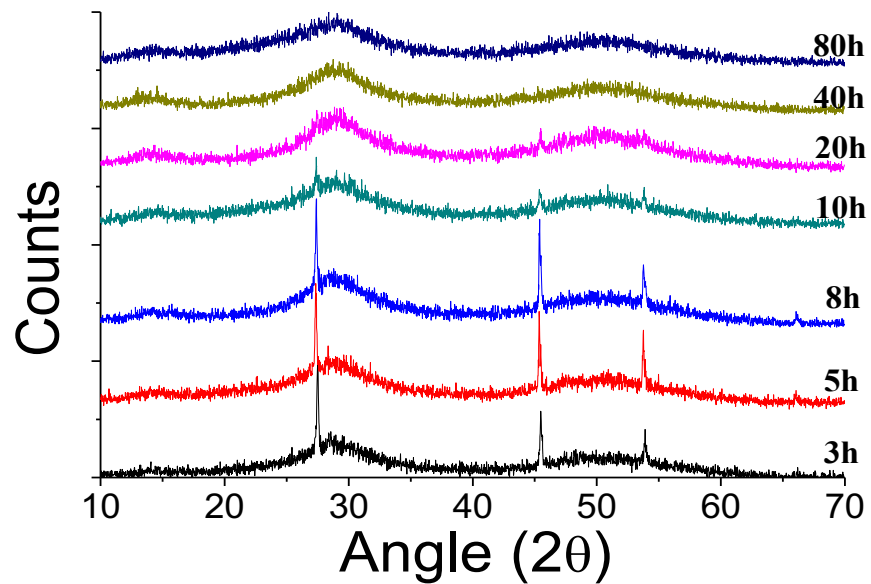
using mechanical energy instead of thermal energy to induce chemical reaction



# Example of $80\text{GeSe}_2\text{-}20\text{Ga}_2\text{Se}_3$



Progressive amorphisation  
of Ge, Ga, Se

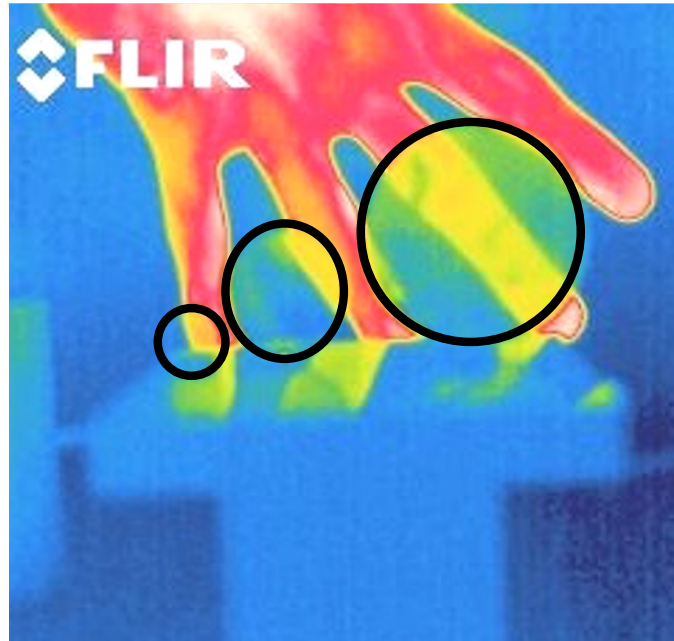


# Fast sintered glass from powder

---

Powder sintered **2 minutes at 390°C** ( $T_g+40^\circ\text{C}$ ), 50MPa

*visible*



*Thermal camera  
8-12 $\mu\text{m}$*

Densification > 99%

**More choice of compositions**

**Compatible with continuous process**

# Sommaire

---

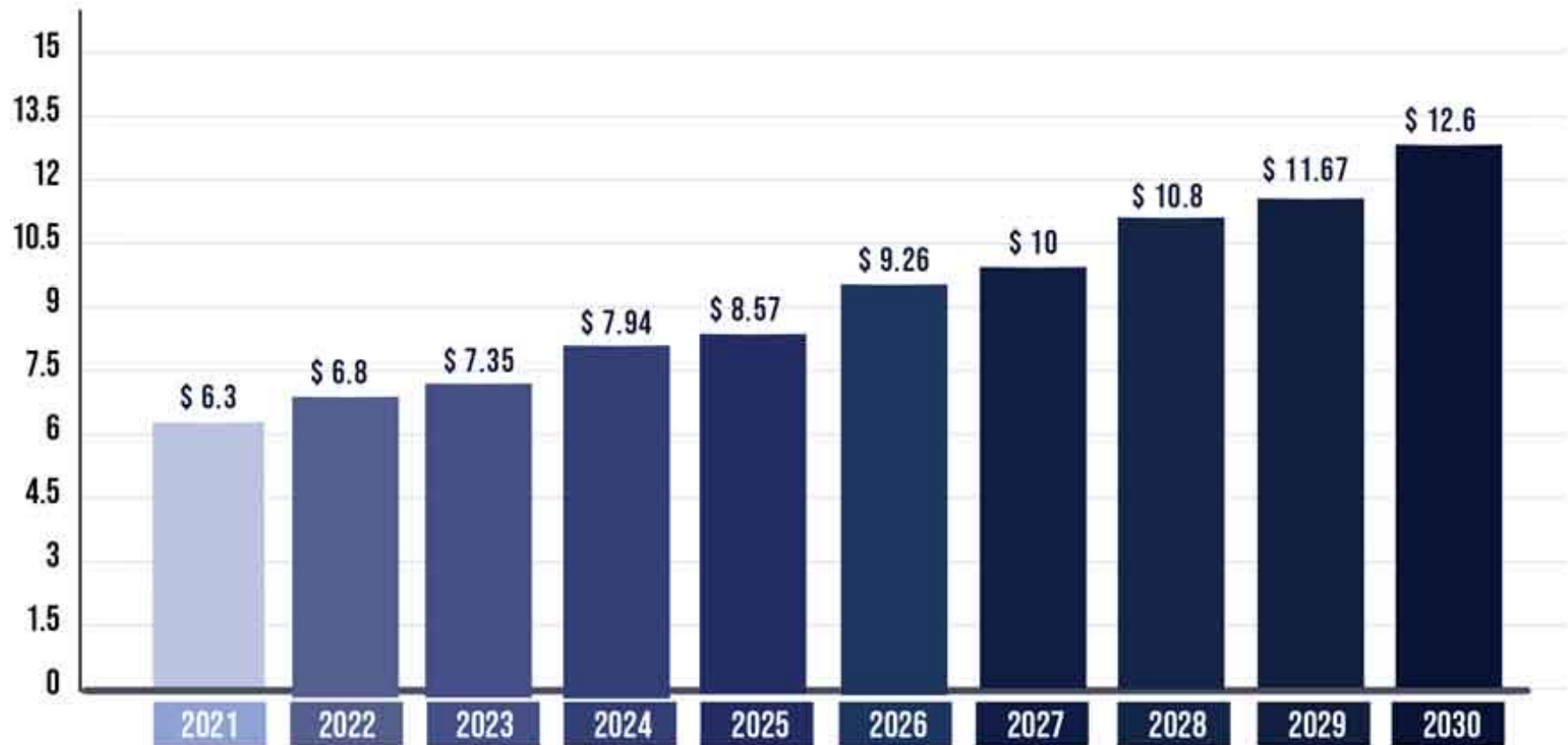
- Qu'est-ce que les verre de chalcogénures?
- A quoi servent ces verres?
- Que sont les défis actuels?
- **Et les perspectives?**



# Thermal Imaging – A growing market



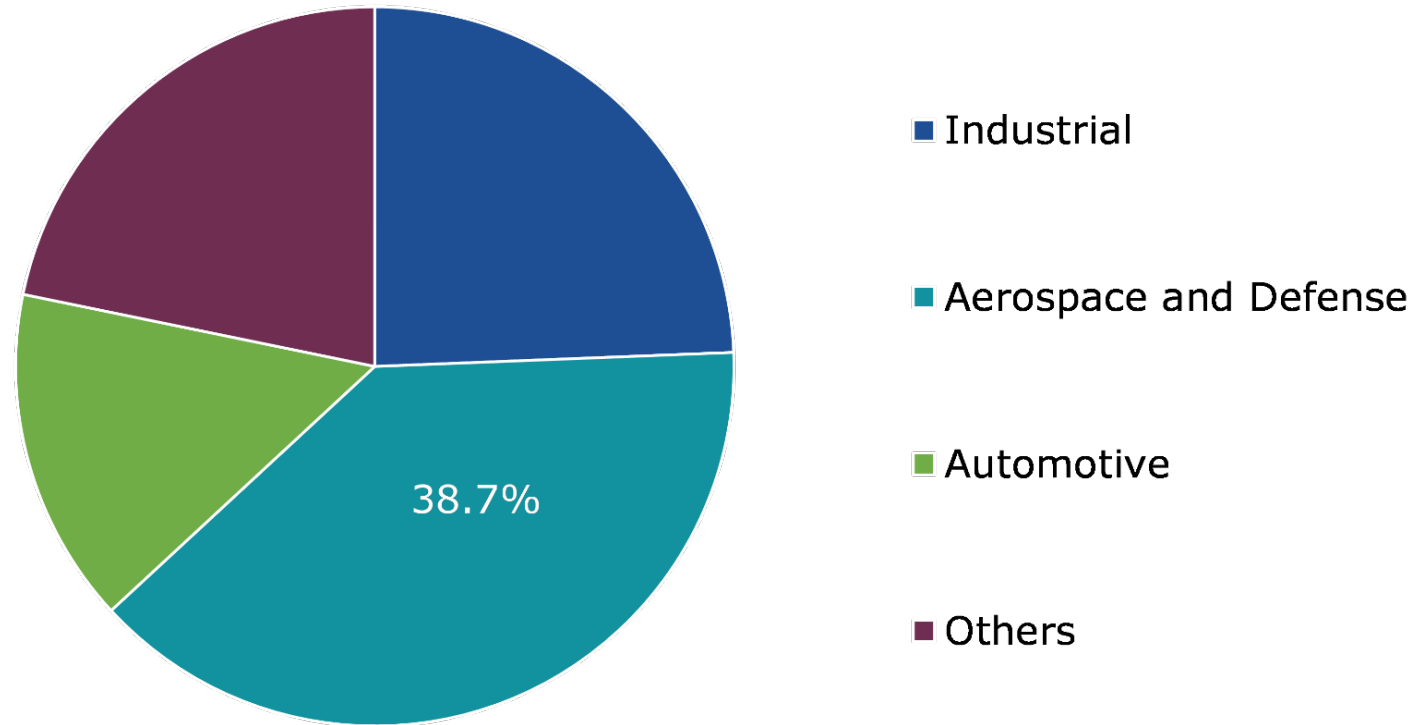
THERMAL IMAGING MARKET SIZE, 2021 TO 2030 (USD BILLION)



Source: [www.precedenceresearch.com](http://www.precedenceresearch.com)

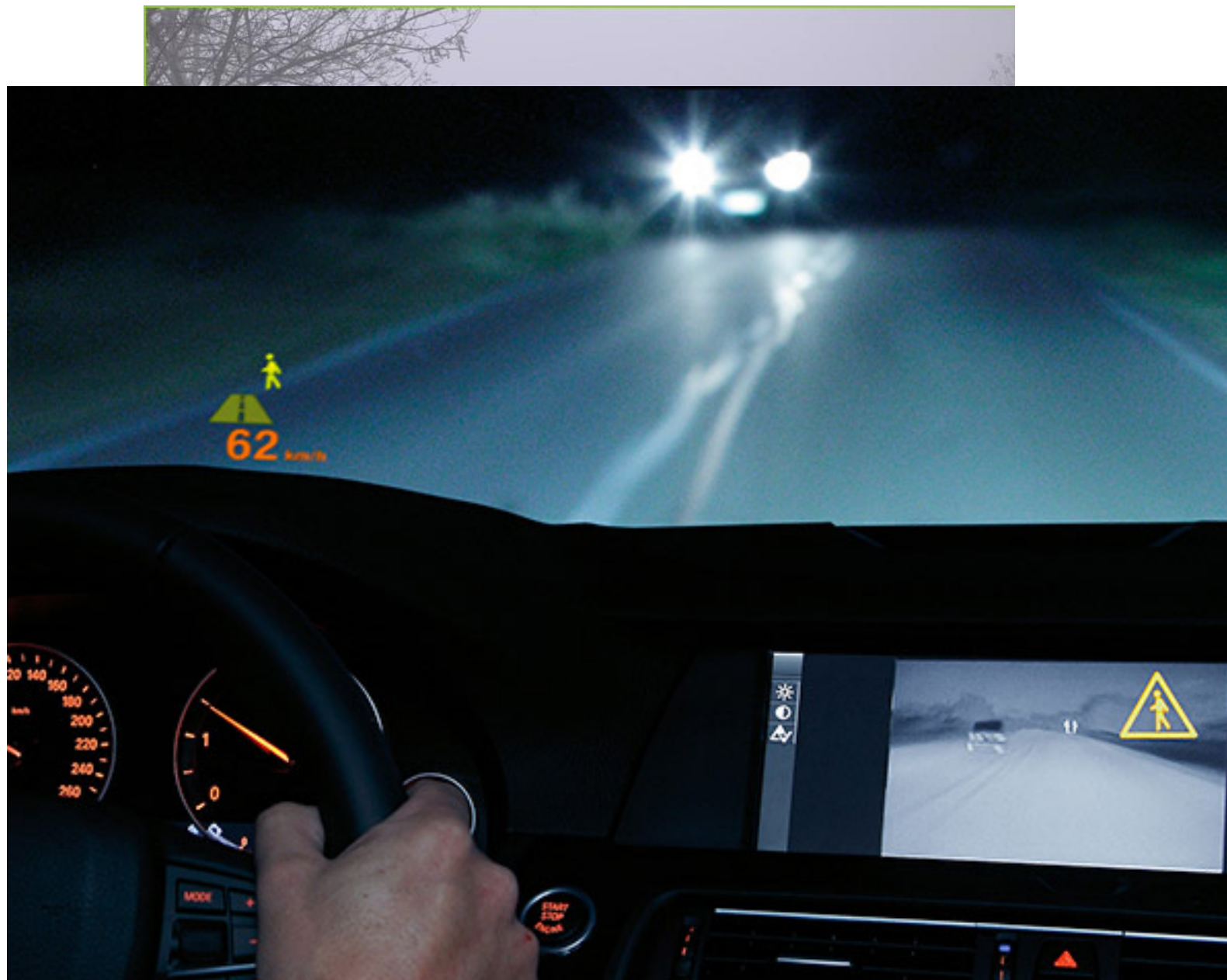
# Thermal Camera Market Share, by End-use Industry, 2021

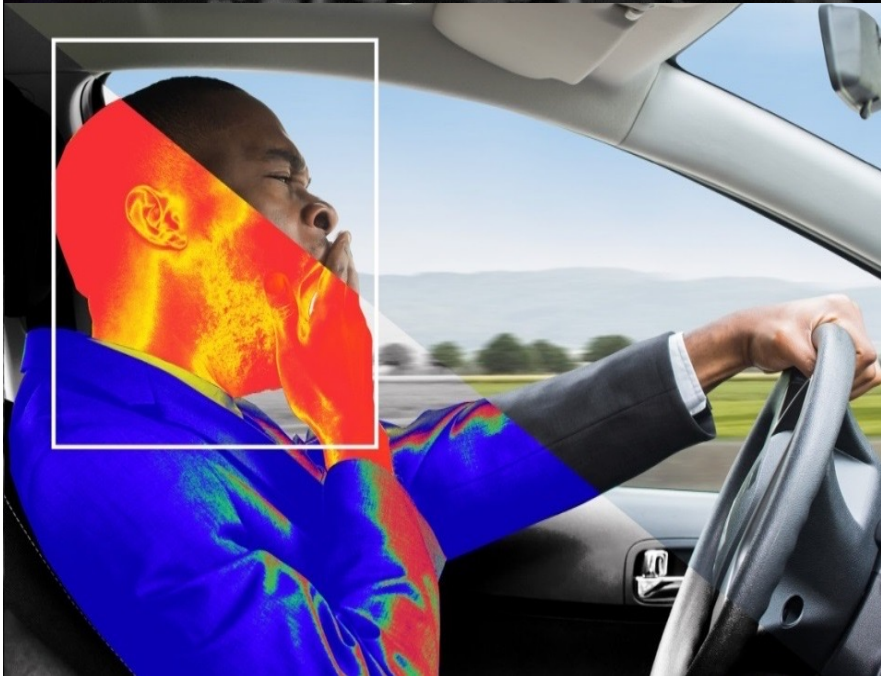
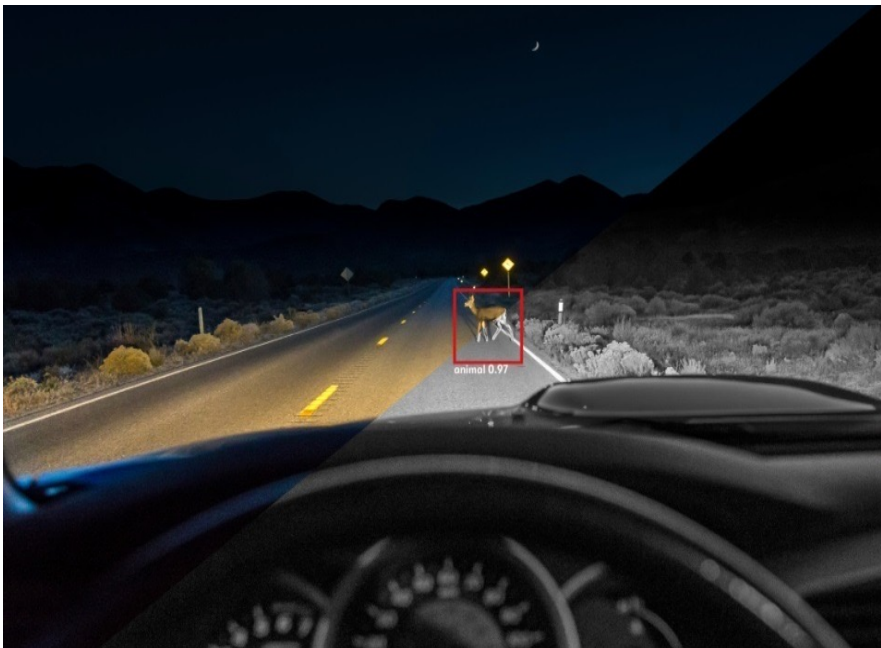
---



Source: Research Dive Analysis

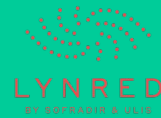
# Advantage of IR camera for driving assistance





# HELIAUS

2019-2022



Follow the project on:

[www.helious.eu](http://www.helious.eu)



**Heliaus** thermal vision augmented awareness





# The road to integration into smartphones

(Source: Uncooled Infrared Imaging Technology and Market Trends 2016 report, August 2016, Yole Développement)



**STEP I (2014): plug-in**



**STEP II (2016):  
Professional smartphone**



**STEP III: Consumer  
smartphone with integrated IR**



©2016 - August 2016 - www.yole.fr

# Perspectives d'analyses chimiques et biologiques

---

- L'infrarouge moyen présente des avantages uniques
  - Sélectivité
  - Sensibilité
  - Déportée
- Nombreux besoins plus au moins identifiés/urgents
  - Collaborations avec les utilisateurs
  - Développer des composants appropriés



# Résumé

---

- Qu'est-ce que les verres de chalcogénures?
  - Verres contenant au moins un élément de chalcogène
- A quoi servent ces verres?
  - Application infrarouge au delà de 2  $\mu\text{m}$
- Que sont les défis actuels
  - Baisser le coût pour application imagerie thermique
  - Développer des solutions d'analyse avec les utilisateurs
- Et les perspectives?
  - Beaucoup d'applications grand public à développer
  - Les composants clés en verre de chalcogénure

# Remerciements

---

