Raman spectroscopy

Molecular Fingerprinting through Light

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Discovery

Sir C.V. Raman

- Discovered by Sir C.V. Raman in 1928.
- Inspired by the blue color of Mediterranean Sea.
- First Indian Nobel Prize in Science (1930)

C.V. Raman Indian physicist C.V. Raman photographed in 1930, the year he won the Nobel Prize for Physics.[1]

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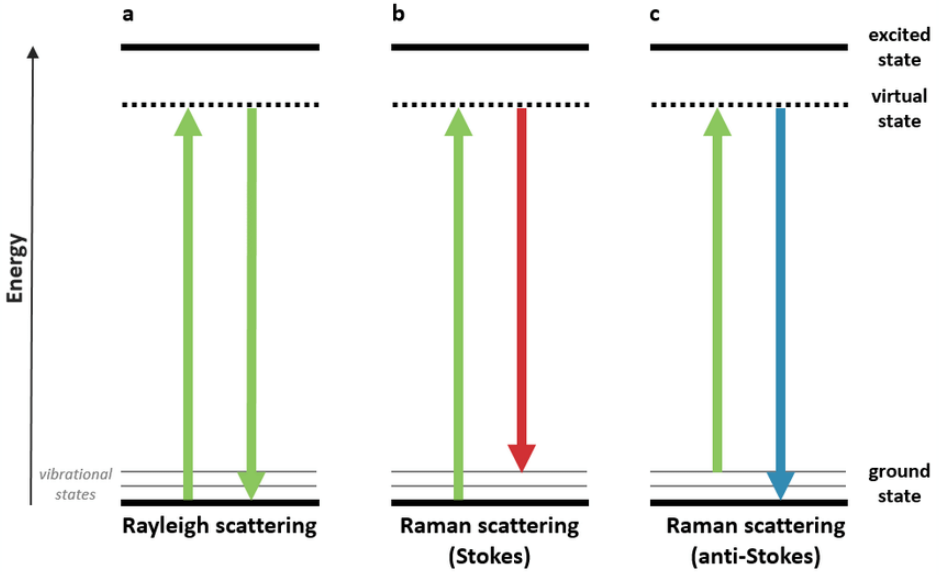
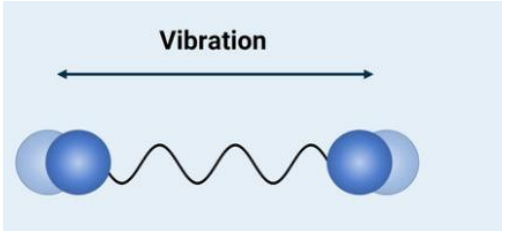
Basic Physics

- **Molecule vibration**
- **Rayleigh Scattering:** Elastic (no energy change).
- **Raman Scattering:** Inelastic (energy change).
- intense monochromatic light source
- Only 1 in 10 million photons undergoes Raman scattering.

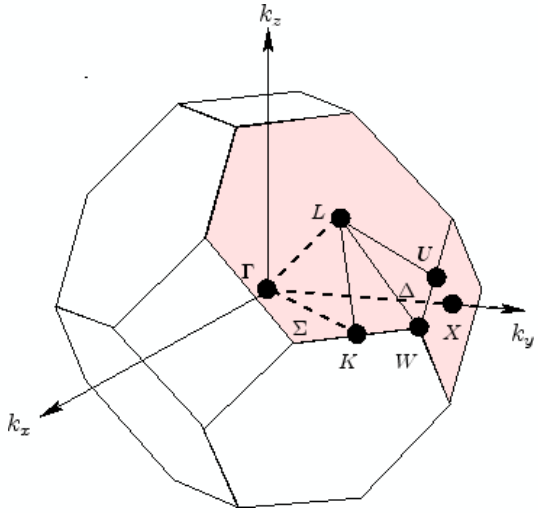
- Probing the Γ point



Schematic diagram of the energy transitions involved in Rayleigh scattering (a) and Raman scattering (b and c). [2]



Molecule vibration [6]



The Γ point [5]

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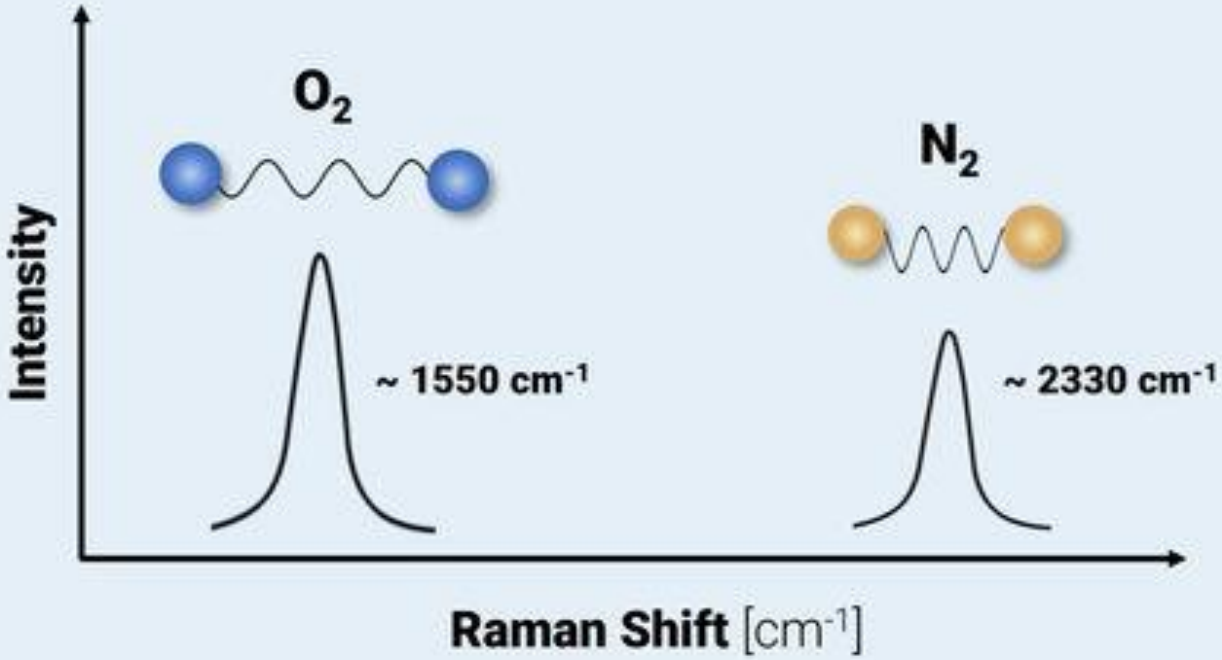
Example : Oxygen and Nitrogen



Molecule vibration [6]

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Quantitative Strain Mapping

Subhead, Franklin Gothic 20

- Every molecule vibrates differently.

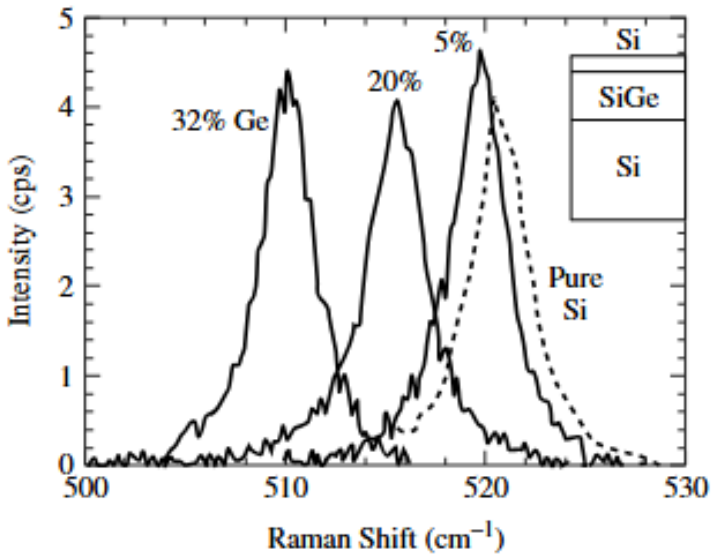
- The "shift" in light frequency is unique to specific chemical bonds.
- Linear Metrology:

$$\Delta\omega = b \bullet \epsilon$$

Δω: the Raman shift

b: strain-shift coefficient

Є: the strain



Raman spectra of Si and Si grown on SiGe grown on Si. The percentages represent the germanium content in the SiGe layer. Courtesy of M. Canonico, Freescale Semiconductor [3]

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The Pros and Cons of Raman Spectroscopy

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Advantages:

- In-situ Capable
- Depth Profiling
- Strain Sensitivity
- Non-destructive & Non-contact.

disadvantages:

- Limited Sensitivity
- Laser Induced Damage
- Surface Selection

[4]

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Conclusion

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- **The Physical Mechanism:** inelastic scattering of light
- **“good tool for strain”:**
  Red-shift = Tensile Strain (increases electron mobility in Si).
  Blue-shift = Compressive Strain (increases hole mobility in SiGe/PMOS).

•**Non-Destructive Metrology:** Raman offers a "best of both worlds" approach: it provides chemical and structural data like a TEM, but it is **non-contact** and requires **zero sample preparation**, making it ideal for in-line monitoring of wafers.

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Thank You

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Appendix

[1] The Editors of Encyclopedia Britannica. “C.V. Raman | Indian Physicist.” Encyclopædia Britannica, 17 Nov. 2018, www.britannica.com/biography/C-V-Raman.
[2] Raman spectroscopy and coherent anti-Stokes Raman scattering imaging: prospective tools for monitoring skeletal cells and skeletal regeneration - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Schematic-diagram-of-the-energy-transitions-involved-in-Rayleigh-scattering-a-and-Raman_fig4_302963558 [accessed 4 Apr 2026]
[3] Schroder, D. K. (2006). *Semiconductor material and device characterization* (3rd ed.). IEEE Xplore. https://doi.org/10.1002/0471749095
[4] meadow. ″Advantages and Disadvantages of Raman - SlideServe.″ *SlideServe*, 18 July 2014, www.slideserve.com/meadow/advantages-and-disadvantages-of-raman. Accessed 5 Apr. 2026.
[5] ″3.2 Structure of Relaxed Si.″ *Tuwien.ac.at*, 2024, www.iue.tuwien.ac.at/phd/dhar/node18.html.
[6] ″Guide to Raman Spectroscopy.″ *Bruker.com*, 2025, www.bruker.com/en/products-and-solutions/raman-spectroscopy/raman-basics/what-is-raman-spectroscopy.html.