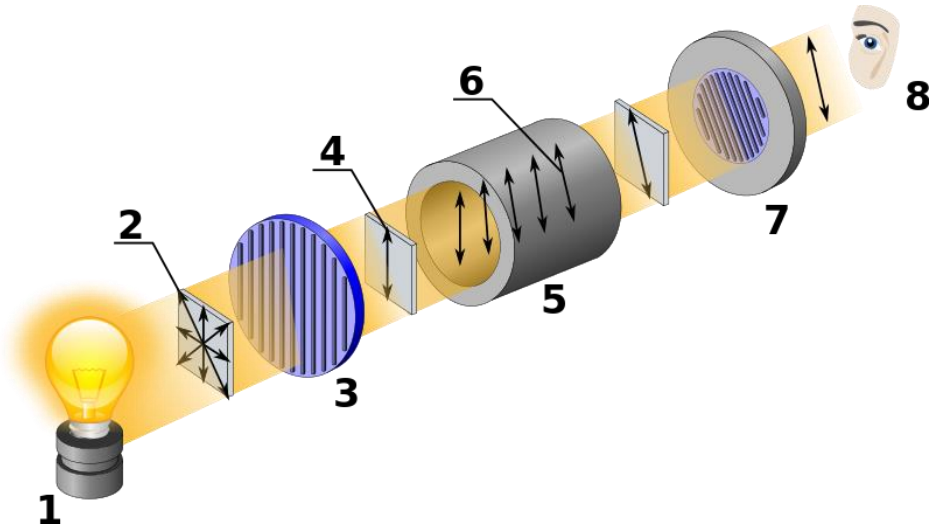
Wednesday 8th March - Tools for Materials Science - Challenge n° 9- 40'

Optical Active Materials

What does *optically active material* mean?



1. Light Source
2. Unpolarized light
3. Polarizer
4. Polarized light
5. **Optically active material**
6. Rotated polarized light with specific rotation
7. Movable analyser
8. Observer

Source: By Kaidor [CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0) or GFDL (http://www.gnu.org/copyleft/fdl.html)], via Wikimedia Commons-https://upload.wikimedia.org/wikipedia/commons/5/5d/Polarimeter_%28Optical_rotation%29.svg

Looking at the picture above you can see a schematization of what is ***polarized light***: the beam of white light oscillates lying on all the plans perpendicular to direction of propagation of the beam; then the beam goes through the polarizing filter, the light ***oscillates on only one definite plan*** (which is determined by the polarizer axis).
This plan is rotated, as shown in the above picture, by the action of the material that, exactly for this reason, is called *optically active.* We call analyzer the second polarizing filter because it allows us to see what has happened.

Introduction – 5'

On the desk you have a computer with a plastic sheet envelope on the lit screen, a roll of scotch tape and what seems to be a simple black plastic piece; the latter will act as "*analyzer*" because it actually is a polarizer.

1. Stick scotch pieces with different orientation, also superimposing, on the plastic sheet envelope.

Q1. How does the scotch appear if you look at it trough the polarizing filter?

Q2. Take a photo of this effect.

Scotch is an *optically active material. L*et's investigate this further.

Experience

You can see, next to you, a box with a covered front window and a lamp; this simulates the polarized light of the computer screen (the big black plastic piece covering the window is a polarizing filter). On the other side of the box there is a pipe through which you can watch the effect of a new optically active material, in fact now we're going to use cellophane for convenience.
You have at your disposal 4 layers of cellophane and a black analyzer on a structure that you can assemble and disassemble very easily. On the analyzer you can see two letters: **D** and **L** that indicate the positions in which respectively you see the minimum(*Dark*)/maximum light brightness.

Funded by EU under the Erasmus+ KA2 grant N° 2014-1-IT02-KA201-003604_1.

2. Set the analyzer on position D.

Q3. Do you really see total Darkness through the tube?

Q4.Can you explain why?

Keep the analyzer on **D.**

3. Put one cellophane sheet in the structure between window and analyzer and rotate it till the coloured arrow is on 0°. Now look through the tube.

Q5.What do you see?

4. Test one by one all the cellophane sheets.

Q6. Do you think they are all alike?

5. Now one of you should rotate the analyzer from 0° to 360° while somebody else will watch through the tube.

Q7. What do you see?

You have just verified the rotation of the plan of polarization (**Why can we say that?) .**

Let's examine which are the important parameters :

Keep the analyzer on L and the cellophane on 0°.

6. Use the same structure of the previous issues (1 layer of cellophane).

Q8. What colour is the light you see?

Since the polarizers axis are aligned, it means that your eyes are seeing only the light whose plan of polarization has not undergone rotation.

7. Rotate by 90° the analyzer.

Q9. What colour do you see now?

Q10. For what you answered in Q9 and what you have seen rotating the analyzer **can you say you have found a first dependence of the plan of polarization? Which one and why ?** (Remember that *different colour* corresponds to a *different wavelength* of the light)

Keep the analyzer on B and the cellophane on 0°.

8. Add one by one more cellophane layers.

Q11. What do you observe? [*Fill in the Table on the Answer sheet*]

Q12. What can you deduce about the second dependence of the rotation of the plan of polarization? [*Think also of the first experience with the scotch*]

OUTPUT WANTED: answers to Q1 … Q12

 Funded by EU under the Erasmus+ KA2 grant N° 2014-1-IT02-KA201-003604_1.

Answer sheet **GROUP N°_____**

Ch.9 --- OPTICAL ACTIVE MATERIALS

Q1

Q2: PICTURES [*Sent by Whatsapp to your group – See general instruction to share pictures or files*]

Q3

Q4

Q5

Q6

Q7

Q8

Q9

Q10

Q 11

Layers	Colour
1	
2	
3	
4	

Q12

 Funded by EU under the Erasmus+ KA2 grant N° 2014-1-IT02-KA201-003604_1.

Teacher's notes

Organizational notes:

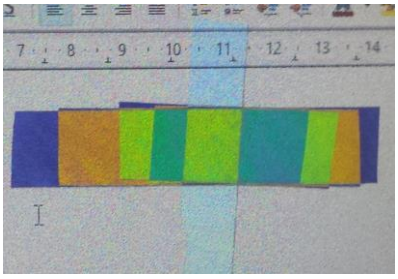
- Each student will keep a copy of the students' sheet but the group will collectively fill in the answer sheet and give it over to the teacher in charge at the end of the lab.

Correction grid

Question	Note	Max. score
Q1; Q3; Q6	See Key to Answer below	**1**
Q4; Q5; Q7; Q8; Q9; Q10; Q11; Q12	See Key to Answer below	**2**
Q2 Picture*		**1**

* **Pictures**: are the pictures meaningful? [*To evaluate the "meaningful" see also the "Picture Description" on the Answer Sheet*] Are they focusing on significant details or clearly showing the apparatus structure or the investigation results? Are they aesthetically beautiful?

Key to Answer



Q1. The scotch tape colours itself according to the thickness and the orientation with which it has been sticked.

Q2. See picture

Q3. Yes

Q4. Because the polarizer axis are perpendicular. From the first polarizer comes out linearly polarized light according to the polarizaton axis. We may say that light is oscillating on the YZ plane. Due to the second polarizer, whose polarization axis is perpendicular to the first one, light is polarized and should oscillate on xy plane; however in our experiment the light that reaches the second polaroid (analyzer) is already polarized with an oscillatiing plane which has no components in the direction of the polarization axis of the analyzer. Therefore light is totally blocked and doesn't reach our eye.

Q5. Now the light passes through the analyser

Q6. Yes

Q7. If you rotate the analyser , you can see different colours.
We can definitively agree on the fact that a rotation of the polarization plane occurred. This is proved by experimental evidence: the observer actually "sees" a portion of light when he should instead see total darkness. This means that there is at least one component of the plane on which the light oscillates - after coming out of the optically active material - which lies on the same direction of the polarization axis of the second polarizer and prevents total extinguishing. As we rotate the analyser we can clearly observe such phenomena. Rotation of the analyser actually means that we are selecting the light which is oscillating on a very definite and specific plane and we can see only this light, nothing else!
However what we actually see watching inside the pipe when we rotate the analyser is light of different colours, therefore we can deduce that the material (cellophane) has rotated the polarization plane of an angle which actually changes with the wavelength.

Q8. Green

Q9. Pink

 Funded by EU under the Erasmus+ KA2 grant N° 2014-1-IT02-KA201-003604_1.

Q10. Yes.The dependence is related to the wavelength of the light. Because I see different colours with different angles, it means that the inclination of the polarization plane depends on light wavelength.

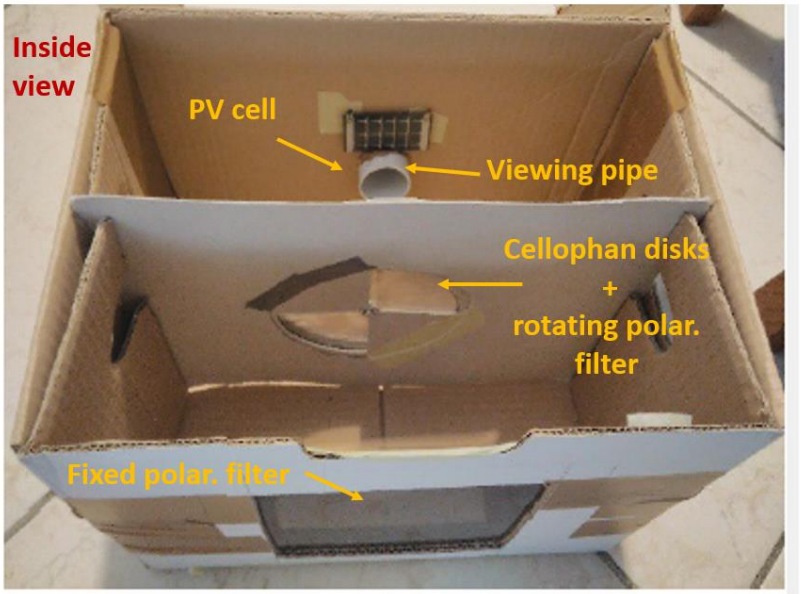
Layers	Colour
1	pink/yellow
2	Almost the same
3	Light green
4	Green

Q12. The polarization plane depends also on the thickness of the optically active material.

How to build the apparatus

It's common knowledge that sheets of clear cellophane sellotape sticked in layers and at different angles produce fascinating effects when interposed between polarized light (such as the one coming from a laptop screen) and a second polarizer (analyser).Some artists even took advantage of this creating Polarized Art.
The colours moreover change upon rotation of the strips.
In this activity the idea was to have a systematic study of these colours alternatively varying the involved parameters (number of layers, orientation of the strips related to each other, rotation of the strips system as a whole in front of the polarized light. The following equipment made from scratch, cheap and easily reproducible, was devised to easily separate and study the effects of the single variables.

We used a box (something like the ikea cardboard boxes (0.80 euros).What's is important is that you can open and close the lid quite easily. Insert a pipe for visual observation on one side and cut out a window on the other one. The window will be closed with a polarizing filter sheet and through it you will shine the lamp light. So what you obtain INSIDE the box is polarized light which will be harvested by the PV (PhotoVoltaic) cell fixed just over the pipe. The PV cell acts as "colorimeter ". We used a type which harvests well in diffused low light.

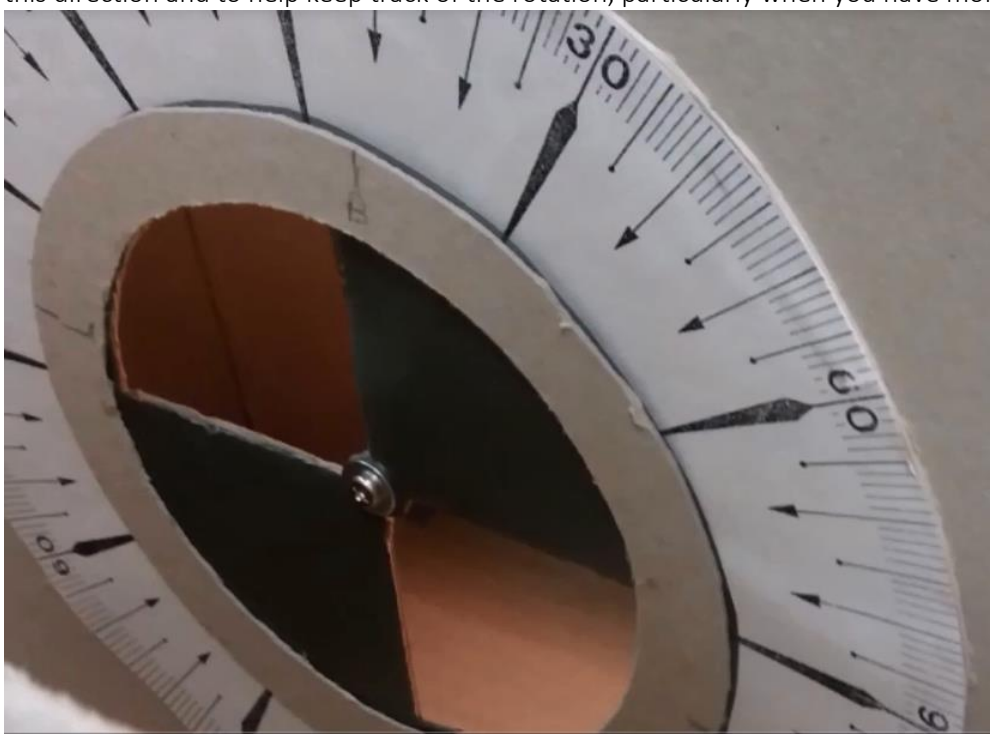


A cardboard sheet has been put vertically in the middle of the box. On the sheet a circle has been drawn right in the middle, split into four quarters two of which have been cut out (the reason of the two quarters left is to

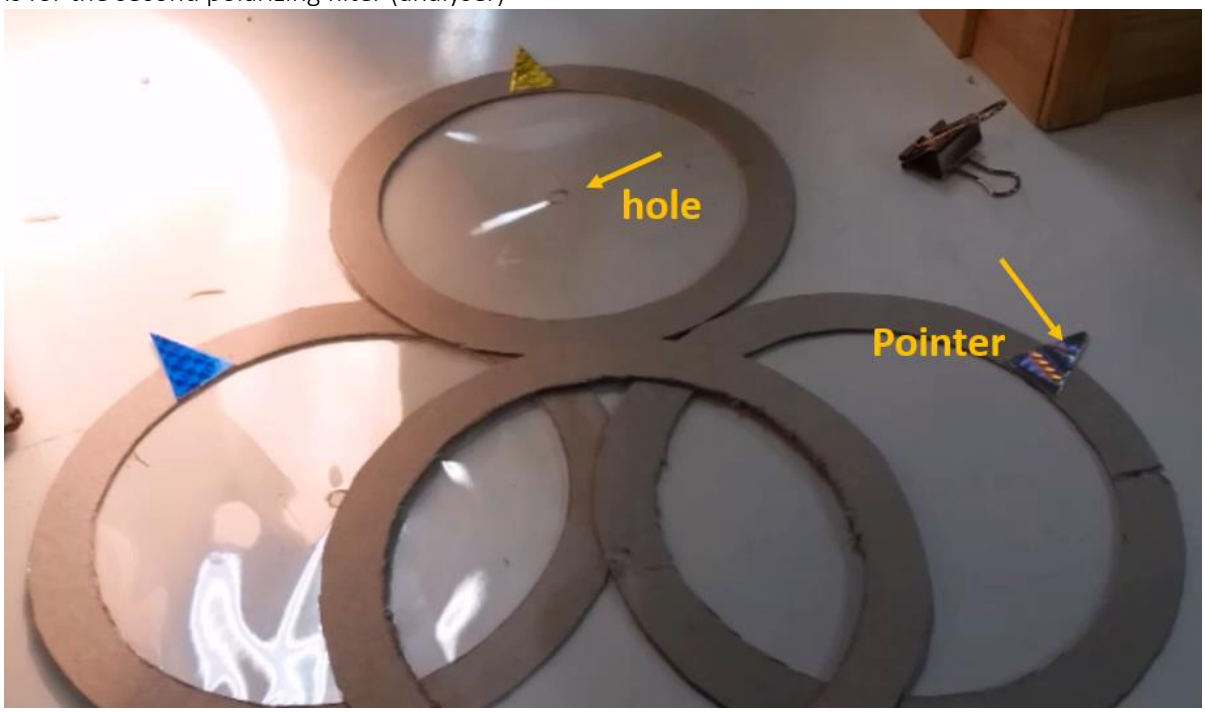
 Funded by EU under the Erasmus+ KA2 grant N° 2014-1-IT02-KA201-003604_1.

create a structure on which you can mount with a screw the circular disks which should however be free to rotate.

Four circular frames have been cut out of strong cardboard sheet. Cellophane disks have been cut and glued to them. A tiny hole for the screw has been made in the centre of each cellophane disk. It is extremely important that all cellophane disks are initially oriented along the same direction (cellophane is NOT isotropic- there's a privileged polarizing axis exactly as with polarizing filters with a small difference: the different effect on different wavelengths). The small coloured arrows are stuck there in order to remind in each disk which is this direction and to help keep track of the rotation, particularly when you have more disks at the same time.



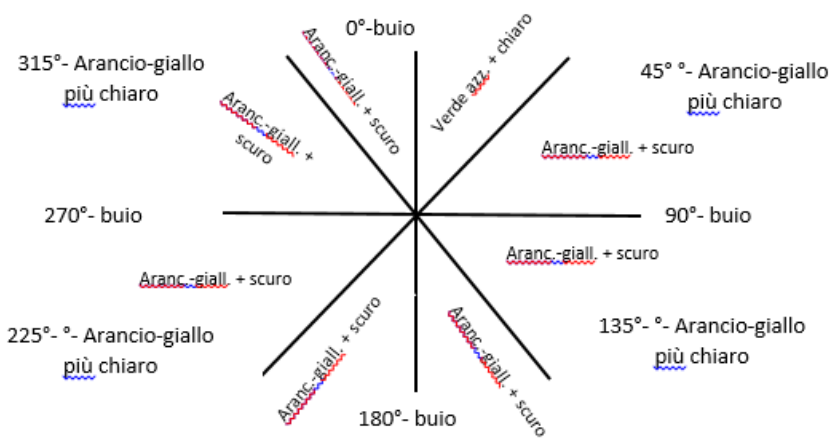
The cellophane disks are only three since, as it can easily be proved with clear sellotape stripes, the fourth strip provides the same effect - in terms of polarized light- as no strip (quarter wave-plate effect).The fourth is for the second polarizing filter (analyser)



 Funded by EU under the Erasmus+ KA2 grant N° 2014-1-IT02-KA201-003604_1.

The complete results may be found in the lab report of one of the students see Colours_of_Rotating_cellophane_stud_research_IT.pdf.
Below soma samples of the results obtained.

^ ± 1°	V ±0,01V	colore
0°	2,16	Verdino 
25°	2,10	Verdino più chiaro del precedente, ovvero con maggior componente di luce bianca.
45°	2,07	Luce normale (bianca)
60°	2,05	Poco arancione 
90°	2,09	Arancione 
115°	2,16	Poco arancione
135°	2,18	Luce normale (bianca)
150°	2,17	Verdino
180°	2,15	Verde-azzurro 
215°	2,05	Verdino
225°	2,08	Luce normale (bianca)
250°	2,06	Arancione
270°	2,08	-Arancione più intenso del precedente
315°	2,17	Luce normale (bianca)



 Funded by EU under the Erasmus+ KA2 grant N° 2014-1-IT02-KA201-003604_1.

MoM Resources

- FCh6_TEACH_EN_circular_polarization.pdf
- Colours_of_Rotating_cellophane_stud_research_IT.pdf
- MoM_intermobility_Experiments_overview.mp4

References

- https://en.wikipedia.org/wiki/Optical_rotation

Acknowledgments

- Special thanks to Nicola Bicocchi (MoM student) and Alice Biolchini (Physics Teacher student hosted at IIS Cavazzi in preservice/jobshadowing experience) who worked together in designing this activity and the related equipment, testing and results analysis.
- Thanks to Powerfilm Solar for donating the PV cell www.powerfilmsolar.com

Co-funded by the Erasmus+ Programme of the European Union

This project has received funding from the European Union's Erasmus + Programme for Education under KA2 grant 2014-1-IT02-KA201-003604. The European Commission support for the production of these didactical materials does not constitute an endorsement of the contents which reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

