

A. PARRETTA

CORSO DI OTTICA APPLICATA

A.A. 2011-2012

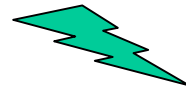
RIFLETTOMETRO ROSE

PROPRIETA' OTTICHE DI CELLE SOLARI E MODULI FV

A. Parretta, A. Sarno, H. Yakubu

“Non-destructive optical characterization of photovoltaic modules by an integrating sphere. Part I: Mono-Si modules”

Optics Communications 161 (1999) 297–309

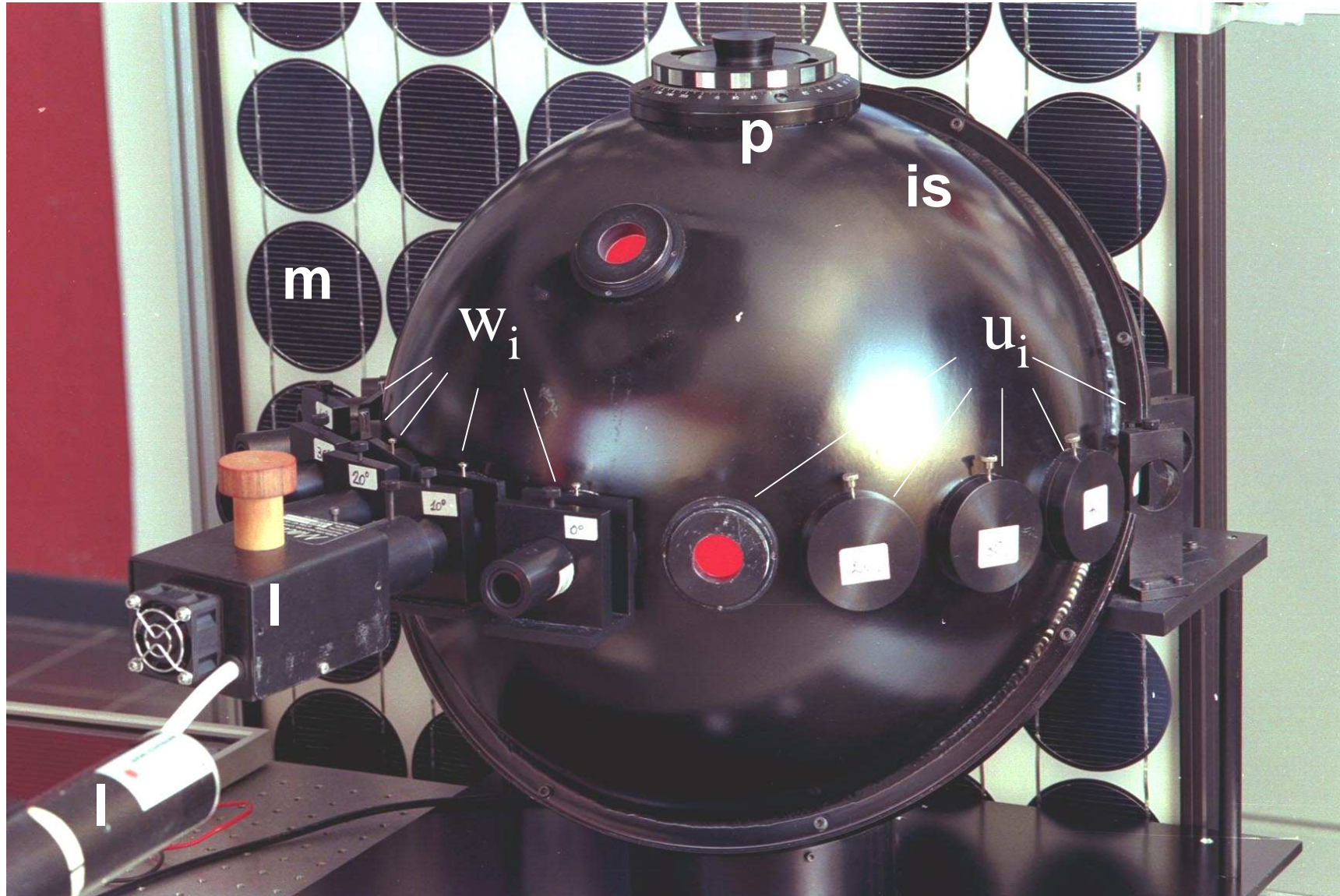


A. Parretta

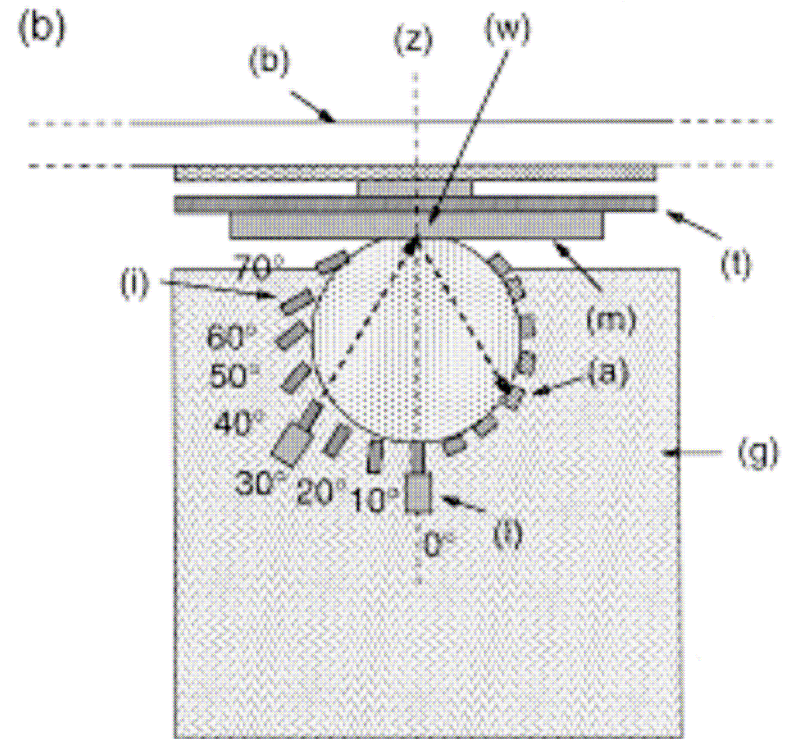
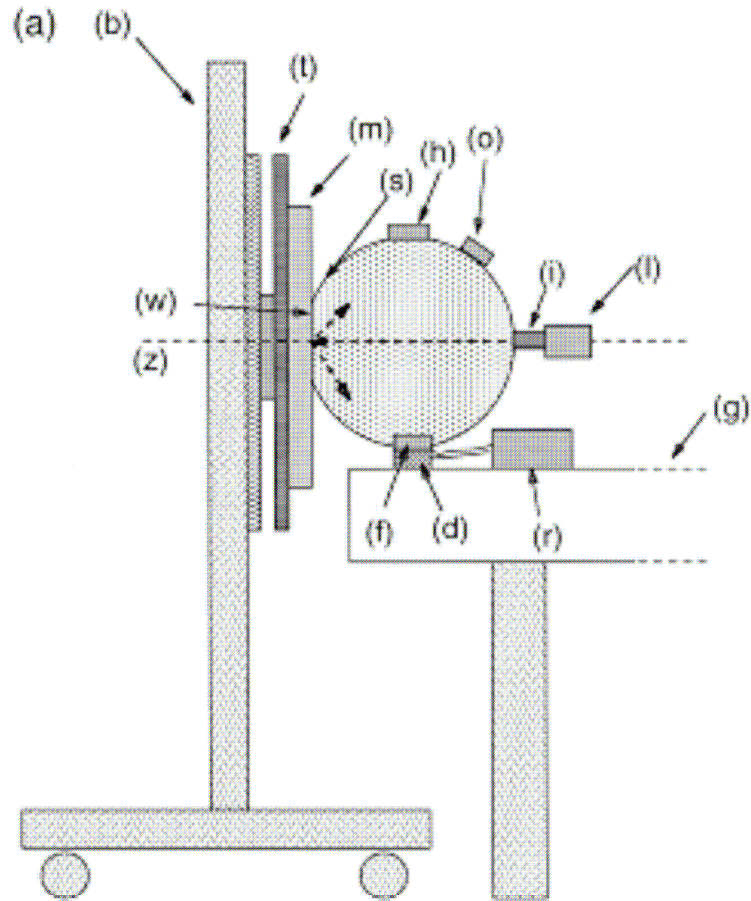
“Dispositivo per la esecuzione non distruttiva di misure di riflettanza spettrale, globale, speculare e diffusa, ad angolo di incidenza variabile, nonchè di trasmittanza, per celle solari e moduli fotovoltaici”

Brevetto It., Application N. RM 97 A 000676, 5 November 1997.

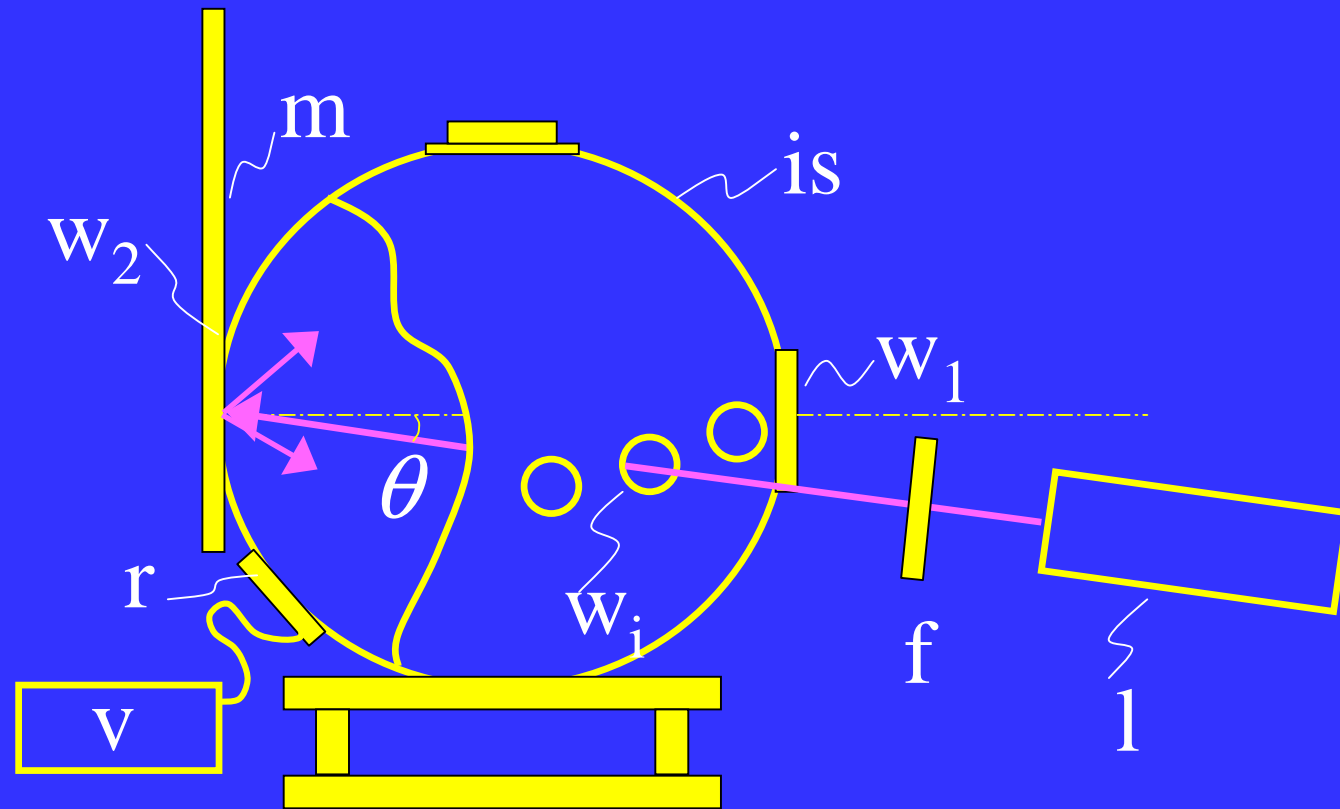
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Misure di R vs. θ , λ su su campioni di larga area
(moduli FV, vetri, lenti di Fresnel).

CATEGORIE DEI MODULI AL SILICIO MONOCRISTALLINO

Table 1

Categories of the tested mono-Si modules, in relation to their front structure. The reference to the glass is made only for the top surface. The table contains also the type of spot of the specularly reflected beam and the average equivalent refractive index, n_{eq}

Category	Front structure	Reflectance spot	n_{eq}
A	Flat-glass/text-Si	dot	≈ 3.0
B	Flat-glass/ARC/text-Si	dot	≈ 2.5
C	Flat-glass/ARC/flat-Si	dot	≈ 2.5
D	Text-glass/text-Si	fractal	≈ 3.0
E	Text-glass/ARC/flat-Si	fractal	≈ 3.0
F	Text-glass/ARC/text-Si	fractal	≈ 3.0

LISTA DEI MODULI MONO-SI

Table 2

List of the tested mono-Si modules. It shows the year of fabrication, the category (see also Table 1), the total reflectance, the absolute diffuse reflectance and the relative diffuse reflectance

N	Type	Year	Category	Glass back surface	R_{tot} (%)	R_{diff} (%)	R_{diff}^{rel} (%)
1	BP Solar BP585	1994/1995	B	textured	4.3 ± 0.2	0.3 ± 0.2	8 ± 4
2	Italsolar 36MSCE	1988	A	flat	7.1 ± 0.2	3.3 ± 0.2	46 ± 4
3	Italsolar 36MSCE	1988	A	flat	6.2 ± 0.2	2.7 ± 0.1	$43. \pm 3$
4	Ansaldo, prototype	1986	E	textured	5.3 ± 0.4	1.7 ± 0.2	31 ± 6
5	Helios HT5563	1988	A	flat	6.6 ± 0.2	3.1 ± 0.2	46 ± 4
6	Helios B5033	1988/1989	D	textured	6.2 ± 0.1	3.5 ± 0.2	57 ± 3
7	AEG MQ10	1989	C	?	4.1 ± 0.1	0.2 ± 0.1	4 ± 1
8	Pragma S24P3	1985	E	textured	7.7 ± 0.1	4.3 ± 0.1	56 ± 3
9	Helios S347	1991	D	textured	6.3 ± 0.1	2.9 ± 0.1	46 ± 3
10	Helios S161	1991	D	textured	6.3 ± 0.2	2.9 ± 0.2	47 ± 4
11	Helios H50	1993/1994	D	textured	8.4 ± 0.6	4.9 ± 0.1	58 ± 6
12	Ansaldo AP38HD	1986	E	textured	4.9 ± 0.6	1.6 ± 0.2	33 ± 7
13	Arco Solar M55	1990/1991	F	?	5.0 ± 0.5	1.7 ± 0.3	33 ± 8
14	ENEA/HT/Lamel	1986	D	textured	6.2 ± 0.3	3.4 ± 0.2	55 ± 6
15	Helios, prototype	1988	D	textured	7.4 ± 0.3	4.5 ± 0.1	61 ± 4
16	Ansaldo, prototype	1986	E	textured	3.9 ± 0.2	0.6 ± 0.1	14 ± 3
17	SNES S22.12	1983	B	?	3.7 ± 0.2	0.5 ± 0.2	13 ± 6
18	Italsolar 36MSCE	1988	A	flat	6.9 ± 0.2	3.1 ± 0.1	45 ± 3
19	Italsolar 36MSCE	1988	A	flat	6.6 ± 0.1	2.5 ± 0.1	39 ± 2
20	Italsolar 36MSCE	1988	A	flat	6.0 ± 0.1	2.9 ± 0.1	49 ± 3
21	Italsolar 36MSCE	1988	A	flat	6.4 ± 0.1	2.8 ± 0.1	45 ± 3

EFFETTO DELLA GRIGLIA SULLE MISURE DI RIFLETTANZA IN LUCE BIANCA

Riflettanza della regione otticamente attiva:

$$R_{oa}(\theta) = [\underline{R}(\theta) - R_g(\theta) \cdot S_g] / S_{oa}$$

$$S_{ill} = S_{oa} + S_g = 1$$

Riflettanza della griglia:

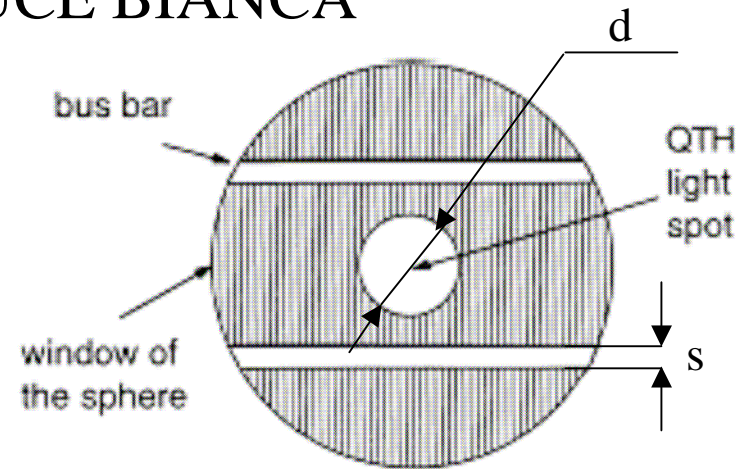
$$R_g(\theta) \approx R_g(0) = [\underline{R}'(0)(\pi d^2 / 4) - \underline{R}(0) \cdot (\pi d^2 / 4 - sd)] / (sd)$$

Trasmittanza assoluta:

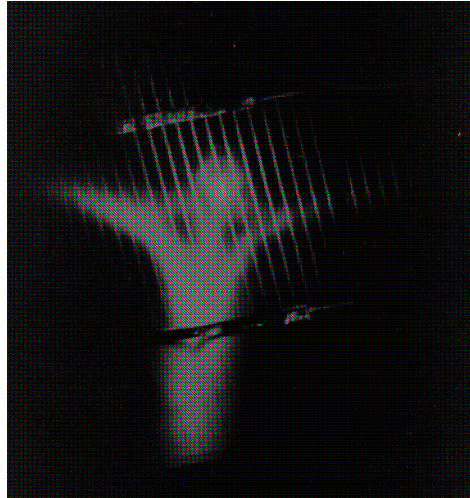
$$T_{oa}(\theta) = \left\{ 1 - \underline{R}(\theta) - S_g [1 - R_g(0)] - (1 - S_g) A_{oa}(\theta) \right\} / [1 - S_g]$$

Trasmittanza relativa (rispetto a STC):

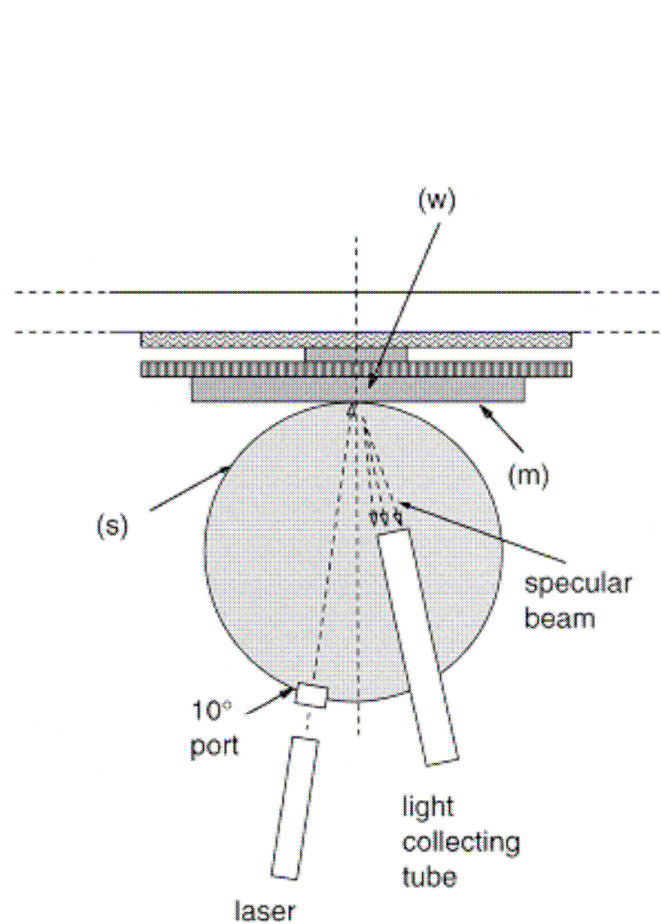
$$\tau_{oa}(\theta) = T_{oa}(\theta) / T_{oa}(0)$$



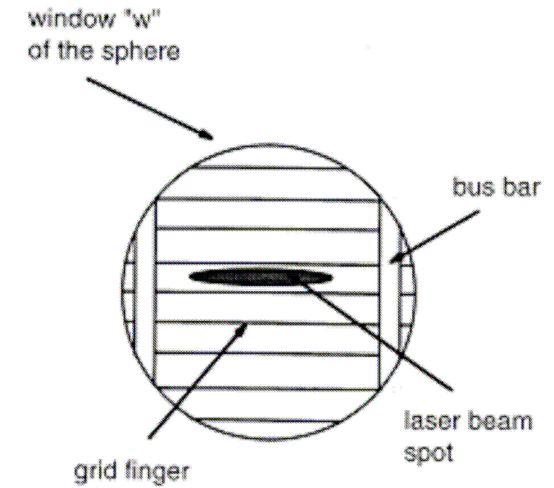
CARATTERIZZAZIONE CON FASCIO LASER



Riflessione da Silicio
testurizzato



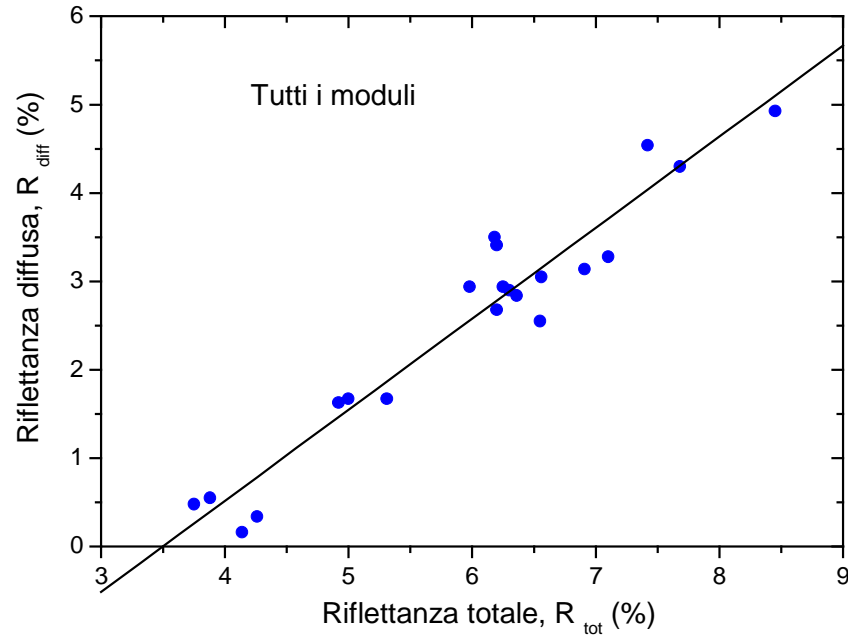
Misura della riflettanza diffusa



Caratterizzazione della regione
otticamente attiva

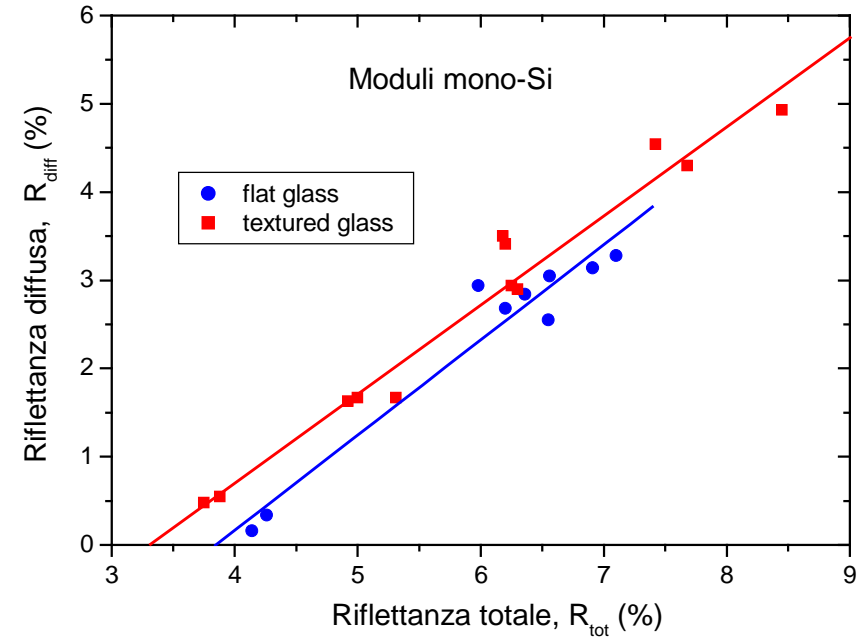
MISURE DI RIFLETTANZA CON FASCIO LASER

($\lambda = 633 \text{ nm}$, $\theta = 10^\circ$)



$$R_{tot} = 3.5 + R_{diff} (\%)$$

(Tutti i moduli)



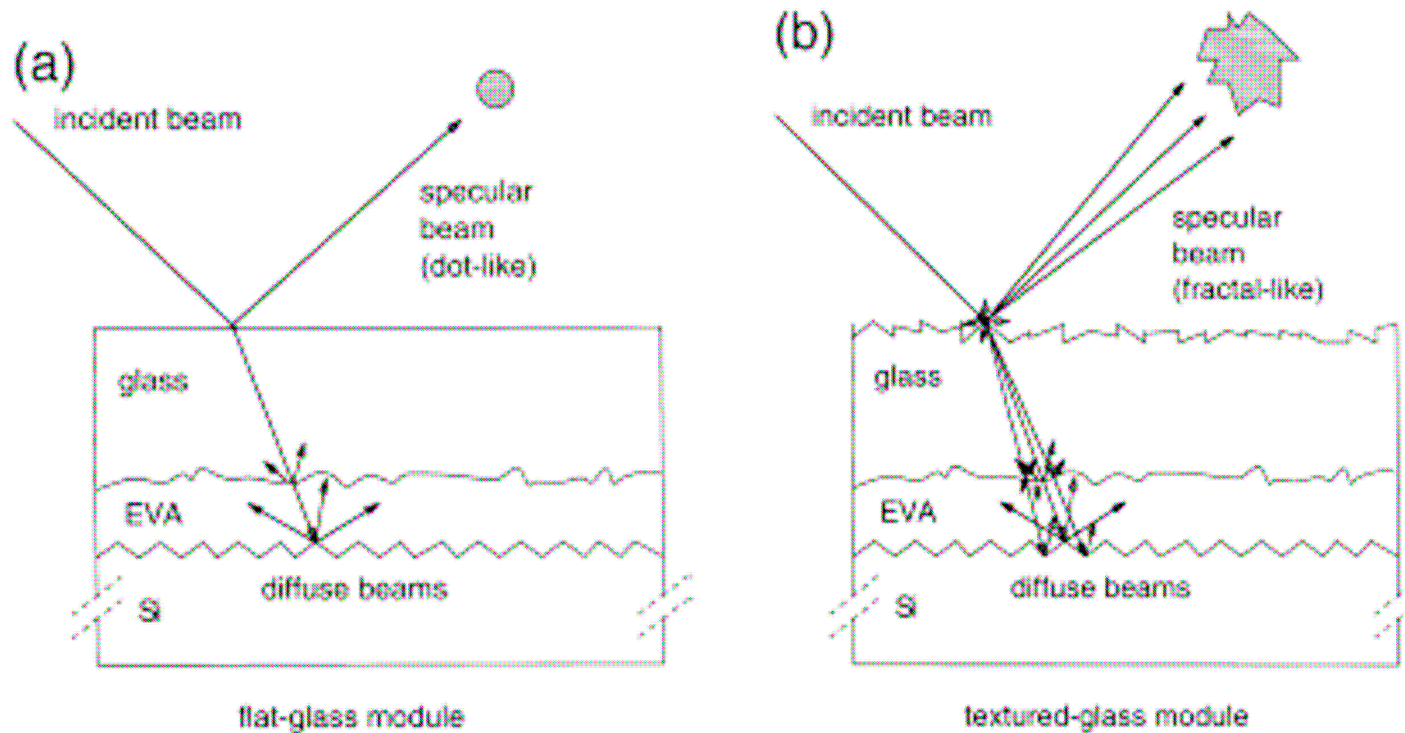
$$R_{tot} = 3.9 + 1.1 \cdot R_{diff} (\%)$$

(Moduli flat glass)

$$R_{tot} = 3.3 + 1.0 \cdot R_{diff} (\%)$$

(Moduli textured glass)

MISURE DI RIFLETTANZA CON FASCIO LASER ($\lambda = 633 \text{ nm}$, $\theta = 10^\circ$)

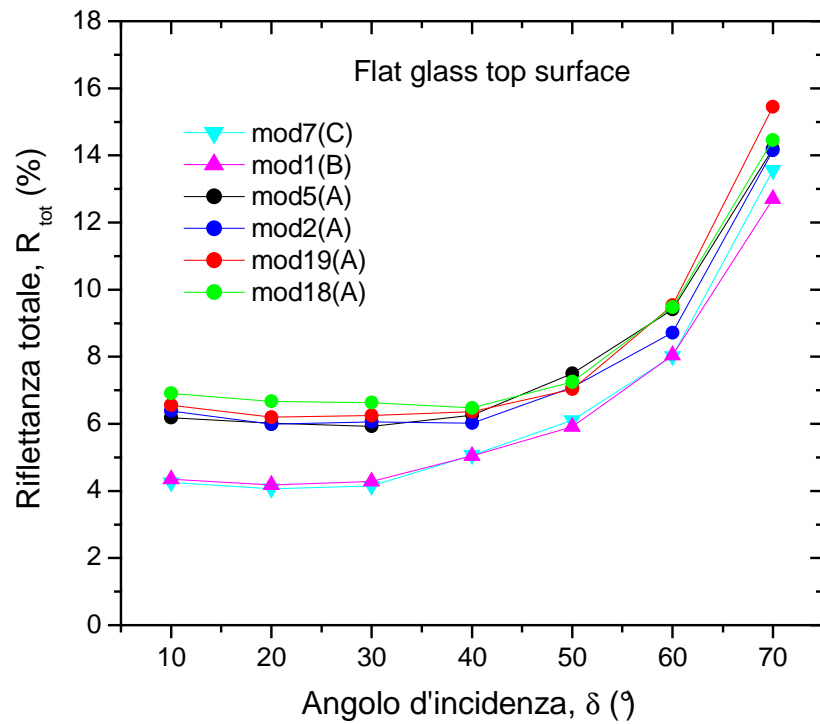


$$R_{tot} = 3.9 + 1.1 \cdot R_{diff} (\%)$$

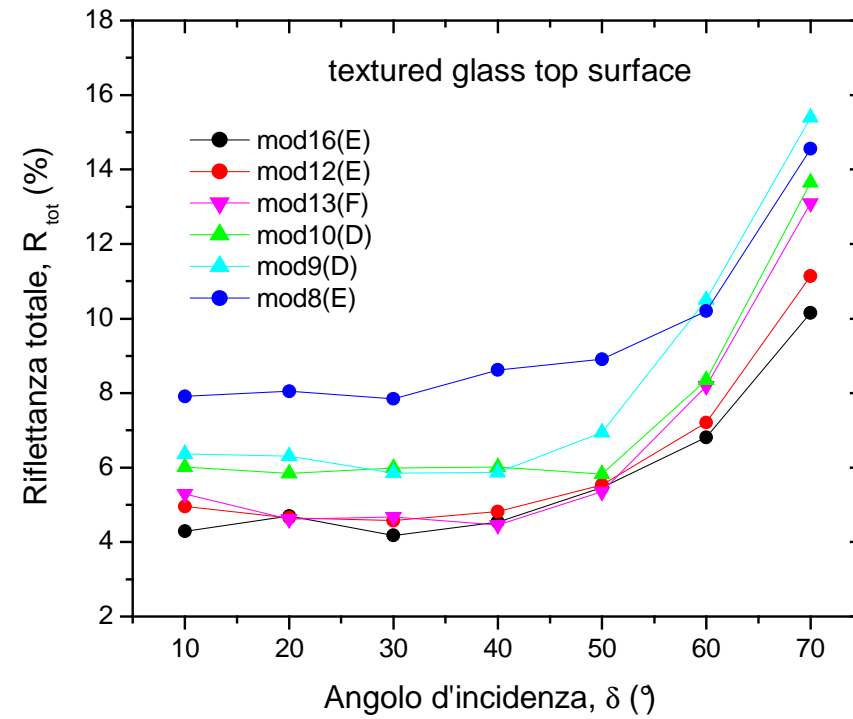
$$R_{tot} = 3.3 + 1.0 \cdot R_{diff} (\%)$$

$$R_{tot} \approx R(\text{air} / \text{glass}) + R_{diff} (\%)$$

MISURE DI RIFLETTANZA ANGOLARE CON FASCIO LASER ($\lambda = 633 \text{ nm}$)

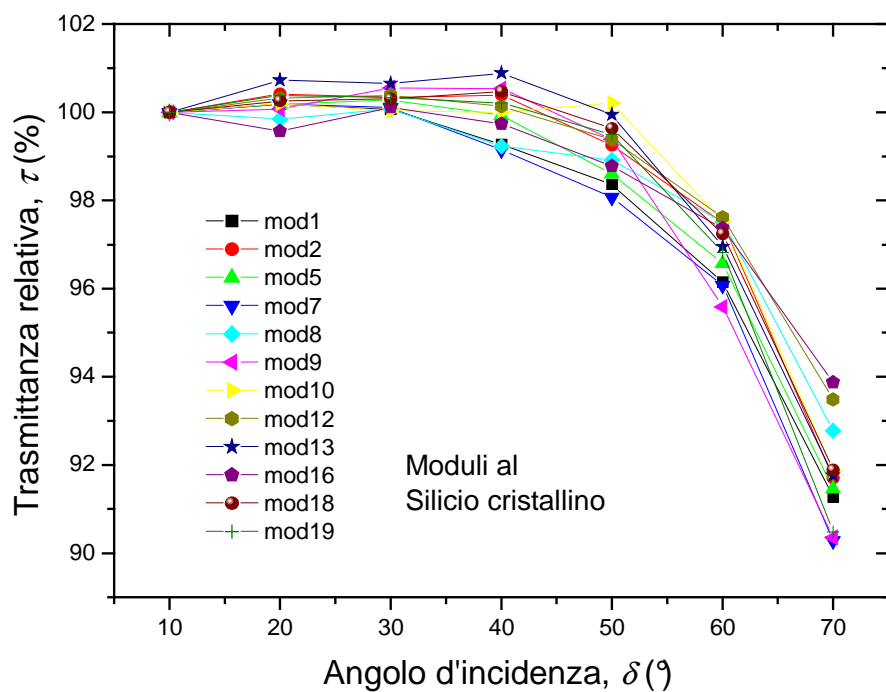


Riflettanza totale (flat glass)

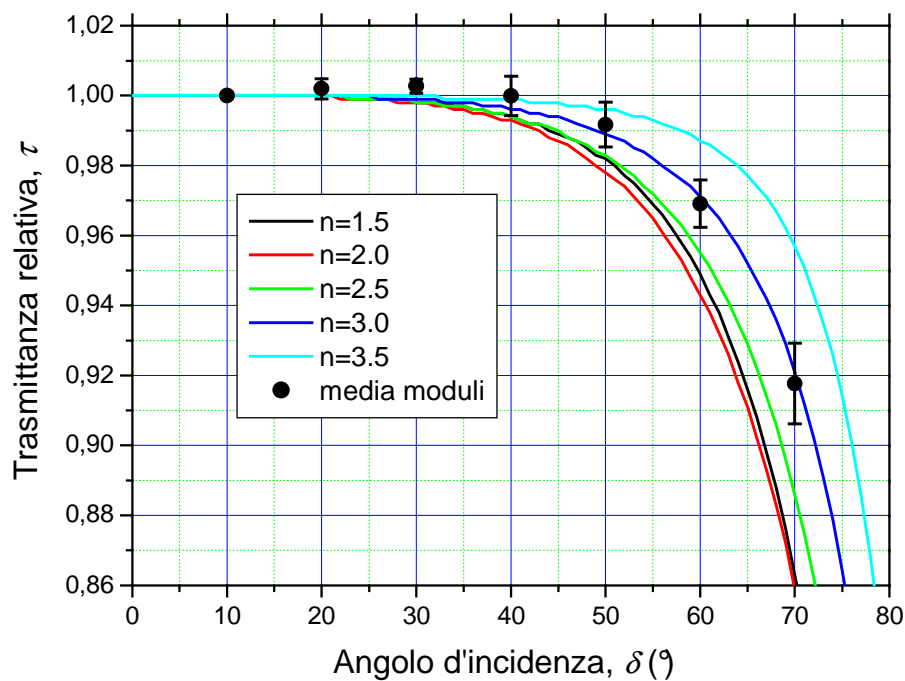


Riflettanza totale (textured glass)

TRASMITTANZA ANGOLARE RELATIVA



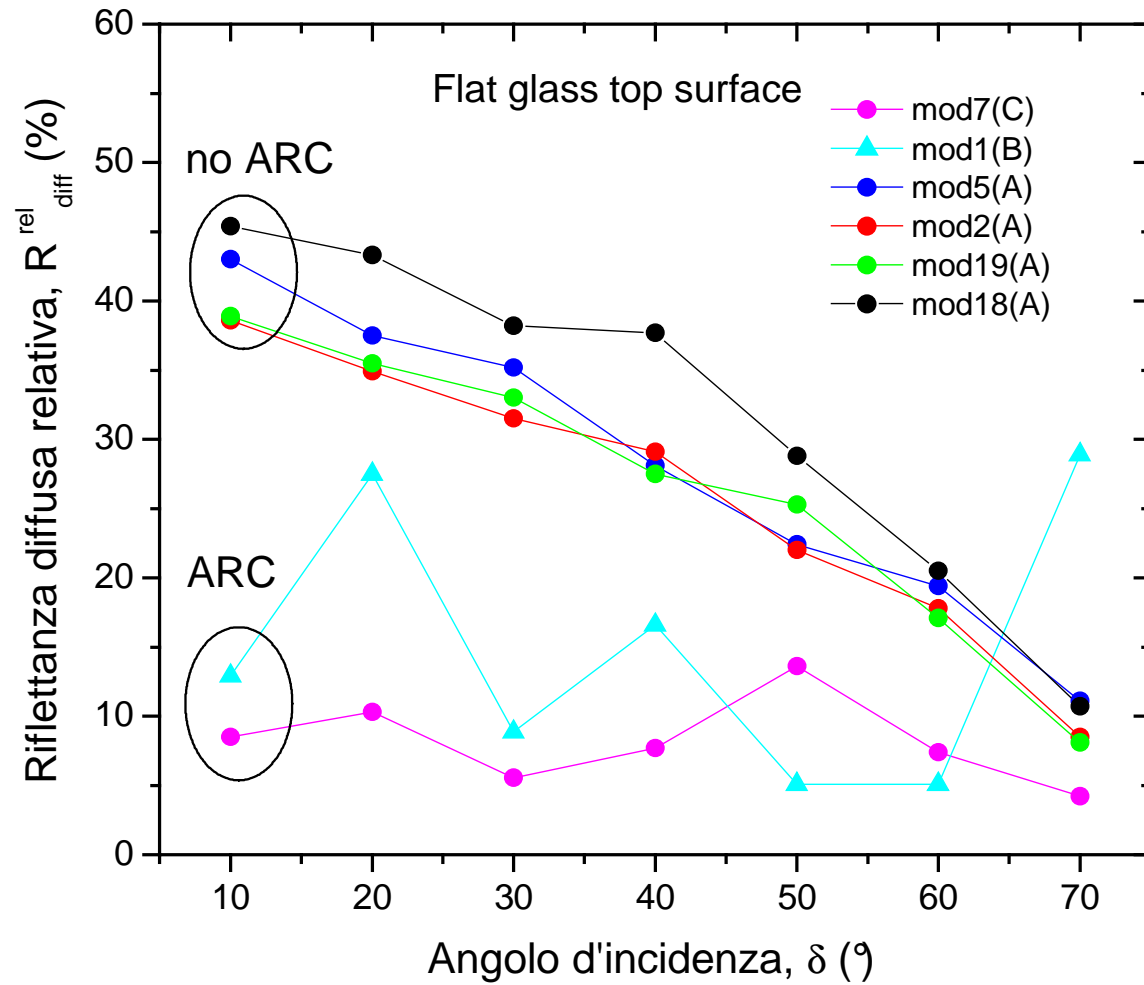
Trasmissione relativa
(tutti i moduli)



Trasmissione teorica
vs.
trasmissione sperimentale

$$\bar{n}_{eq} \approx 3.0 \pm 0.5$$

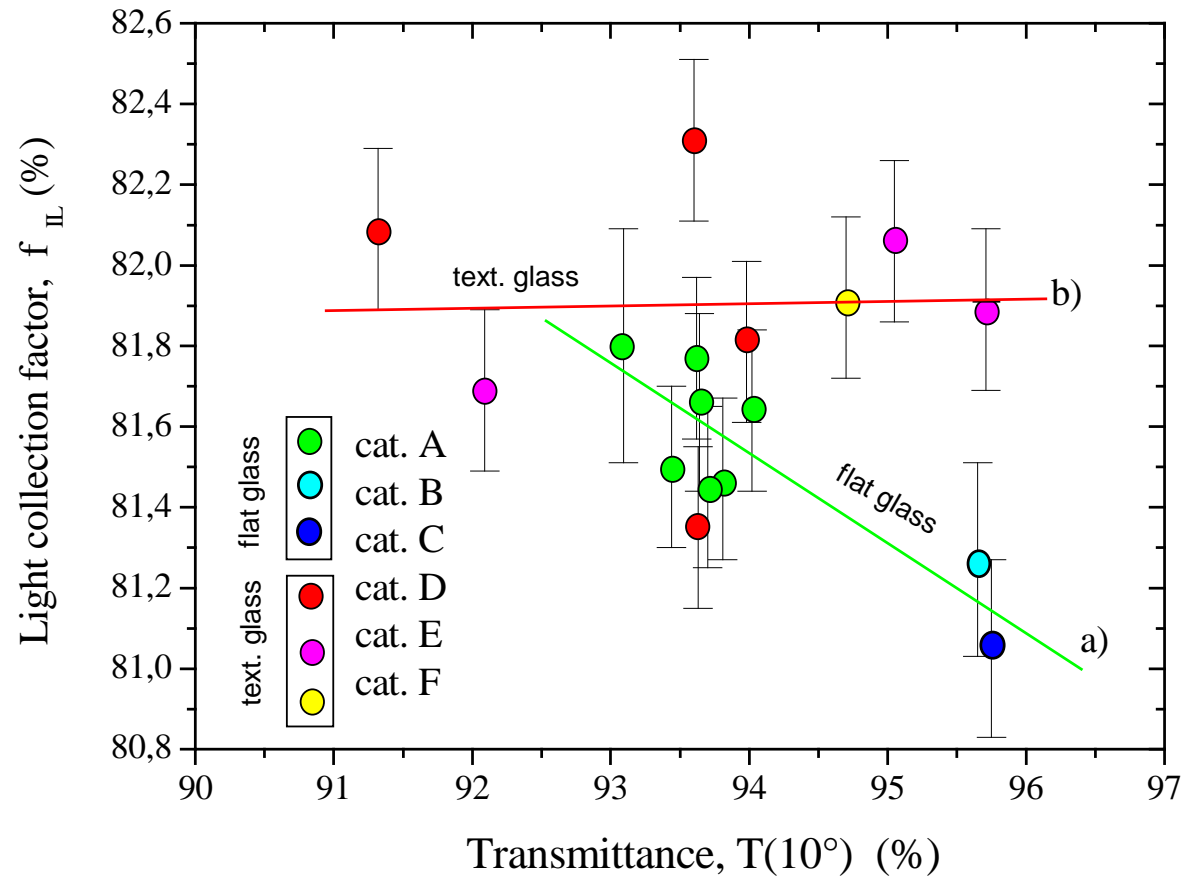
RIFLETTANZA ANGOLARE DIFFUSA



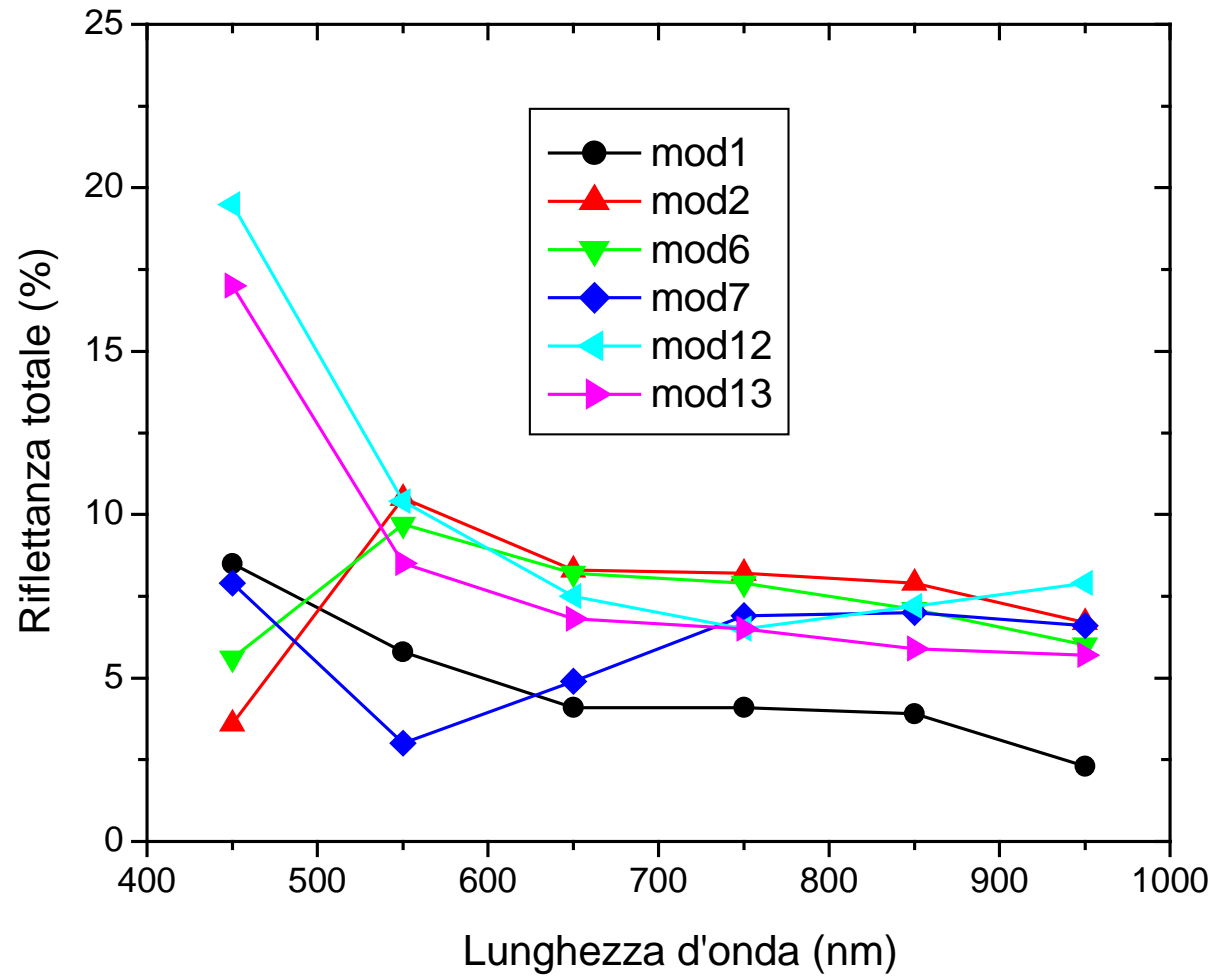
LIGHT COLLECTION EFFICIENCY FACTOR, f_{IL}

$$f_{IL} = \frac{2}{\pi} \cdot \int_0^{\pi/2} \tau(\theta) \cdot d\theta$$

$$f_{IL} = \frac{1}{9} \cdot \left[0.5 + \sum_{\theta_j=10^\circ}^{60^\circ} \tau(\theta_j) + 1.5 \cdot \tau(70^\circ) \right]$$



RIFLETTANZA SPETTRALE

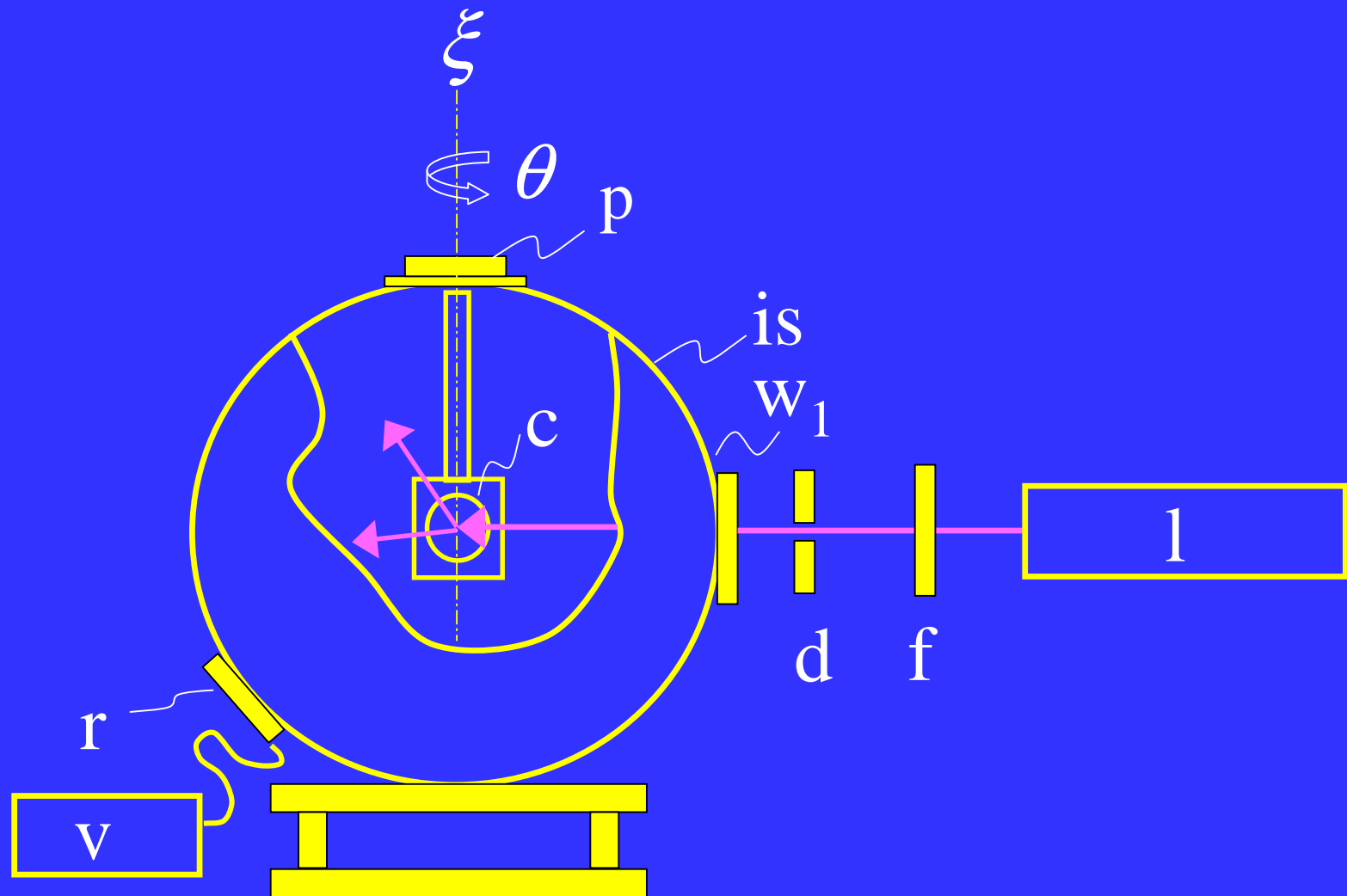


A. Parretta, A. Sarno, P. Tortora, H. Yakubu,
P. Maddalena, J. Zhao, A. Wang

*“Angle-dependent Reflectance and Transmittance Measurements
on Photovoltaic Materials and Solar Cells ”*

Optics Communications 172 (1999) 139-151

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Misure di R (light trapping), A vs. θ , λ su celle solari, TCO/glass.

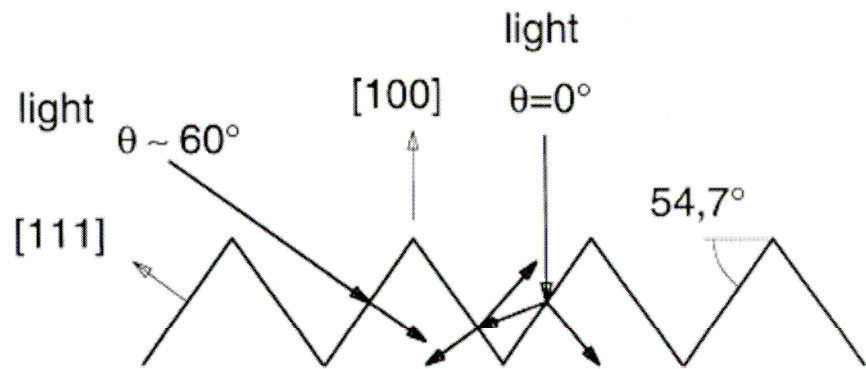
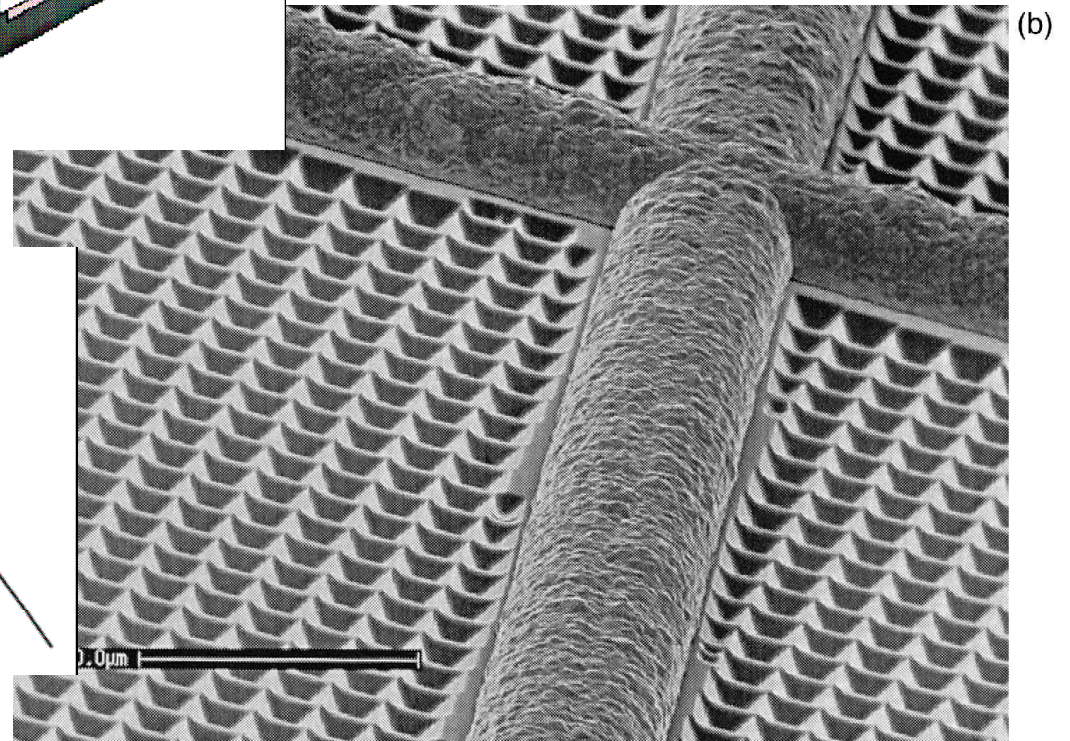
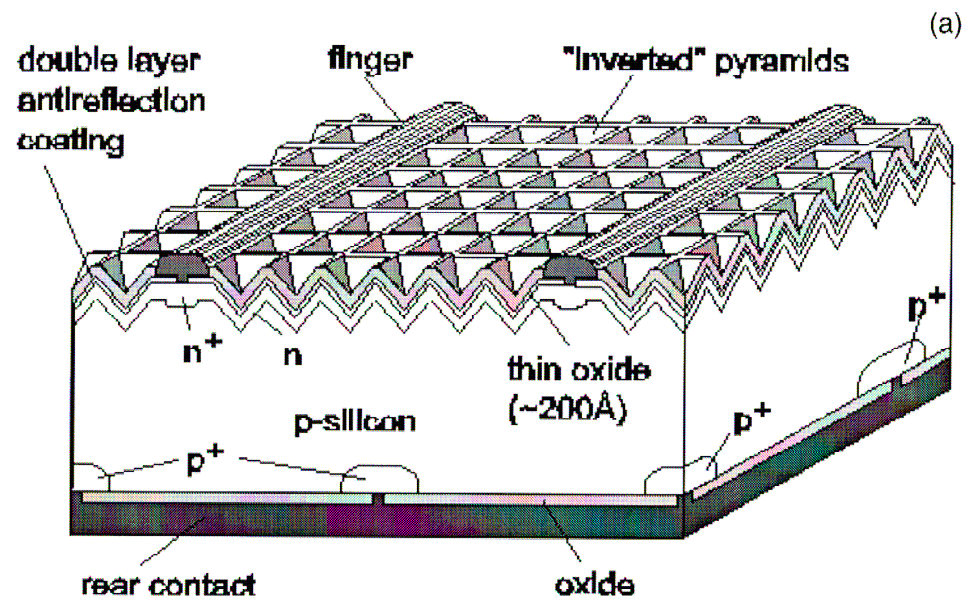
RIFLETTOMETRO ROSE

Prof. Haruna Yakubu
University of Ghana

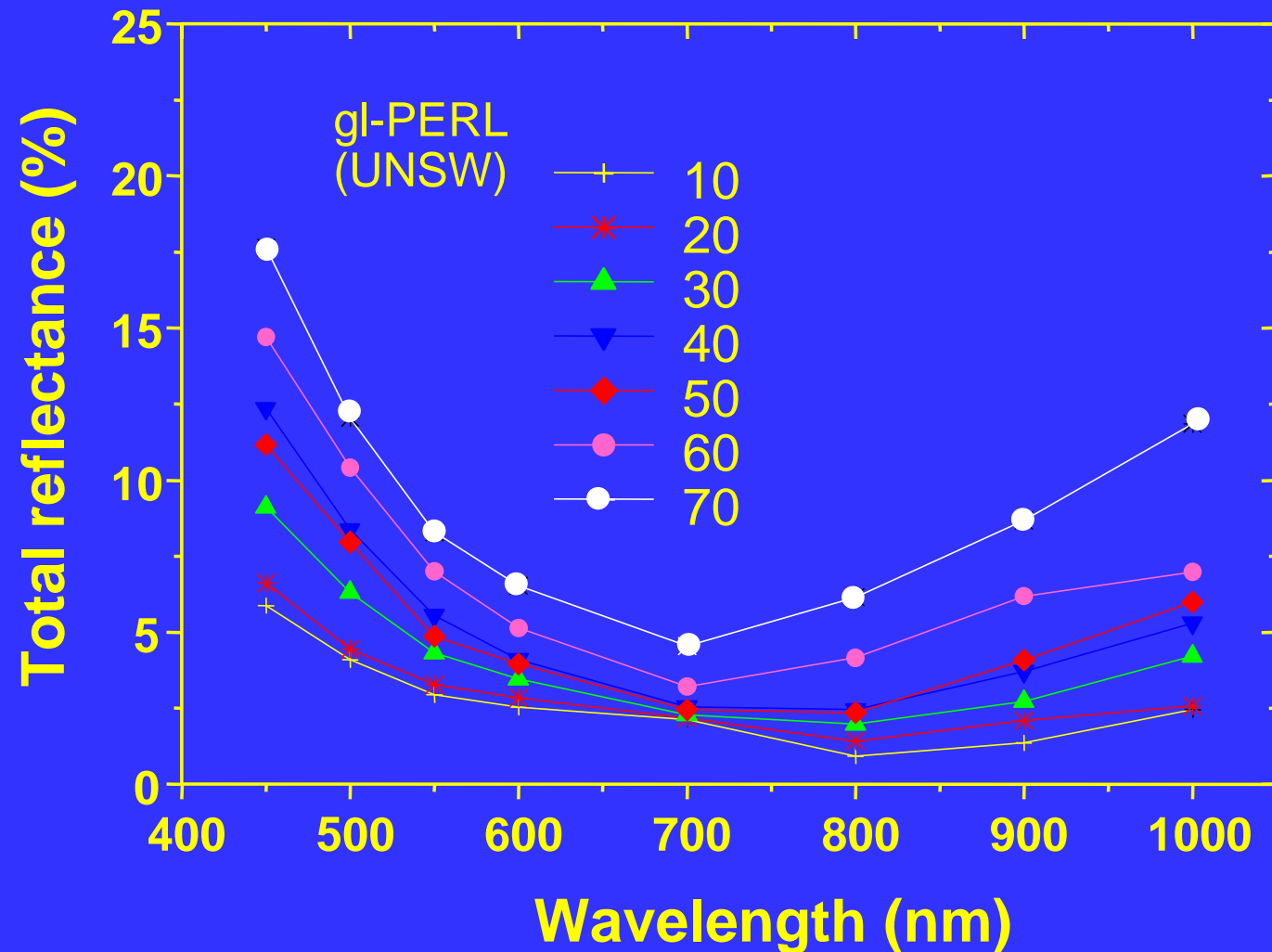


La caratterizzazione di piccoli campioni (celle solari)
è fatta fissando il campione su un portacampioni
e posizionandolo al centro della sfera.

CELLE PERL-UNSW

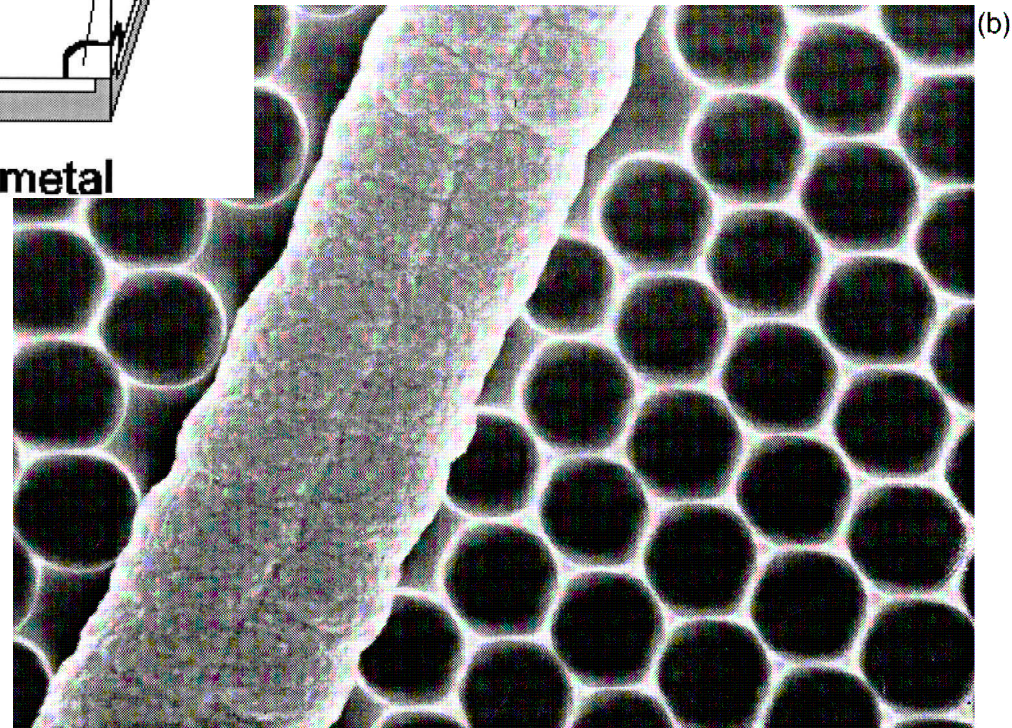
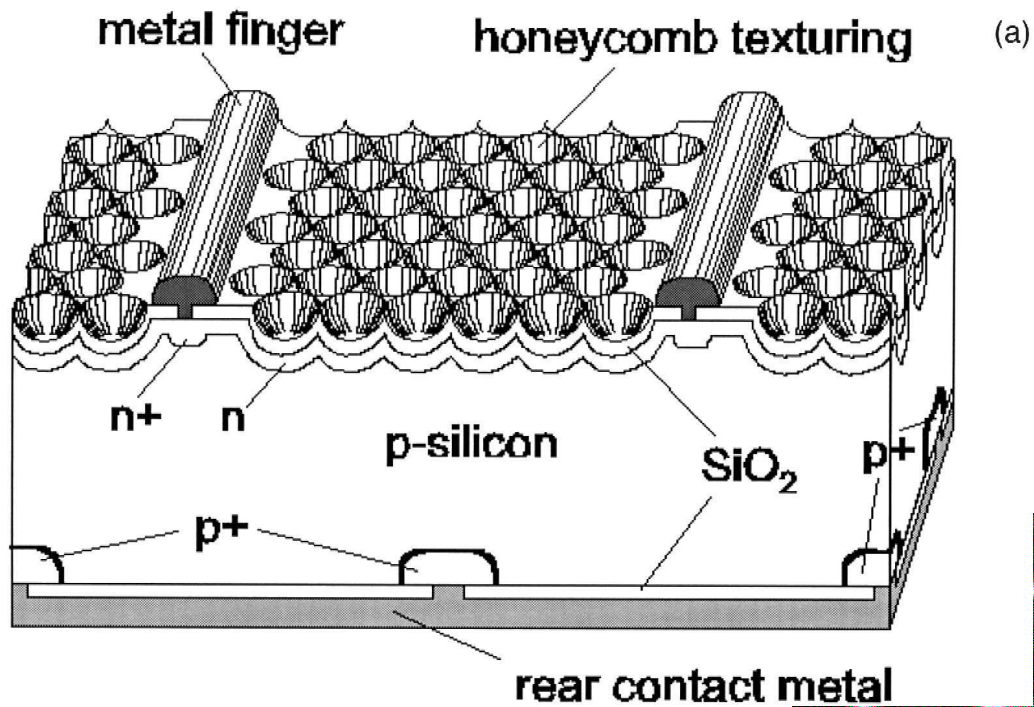


RIFLETTOMETRO ROSE

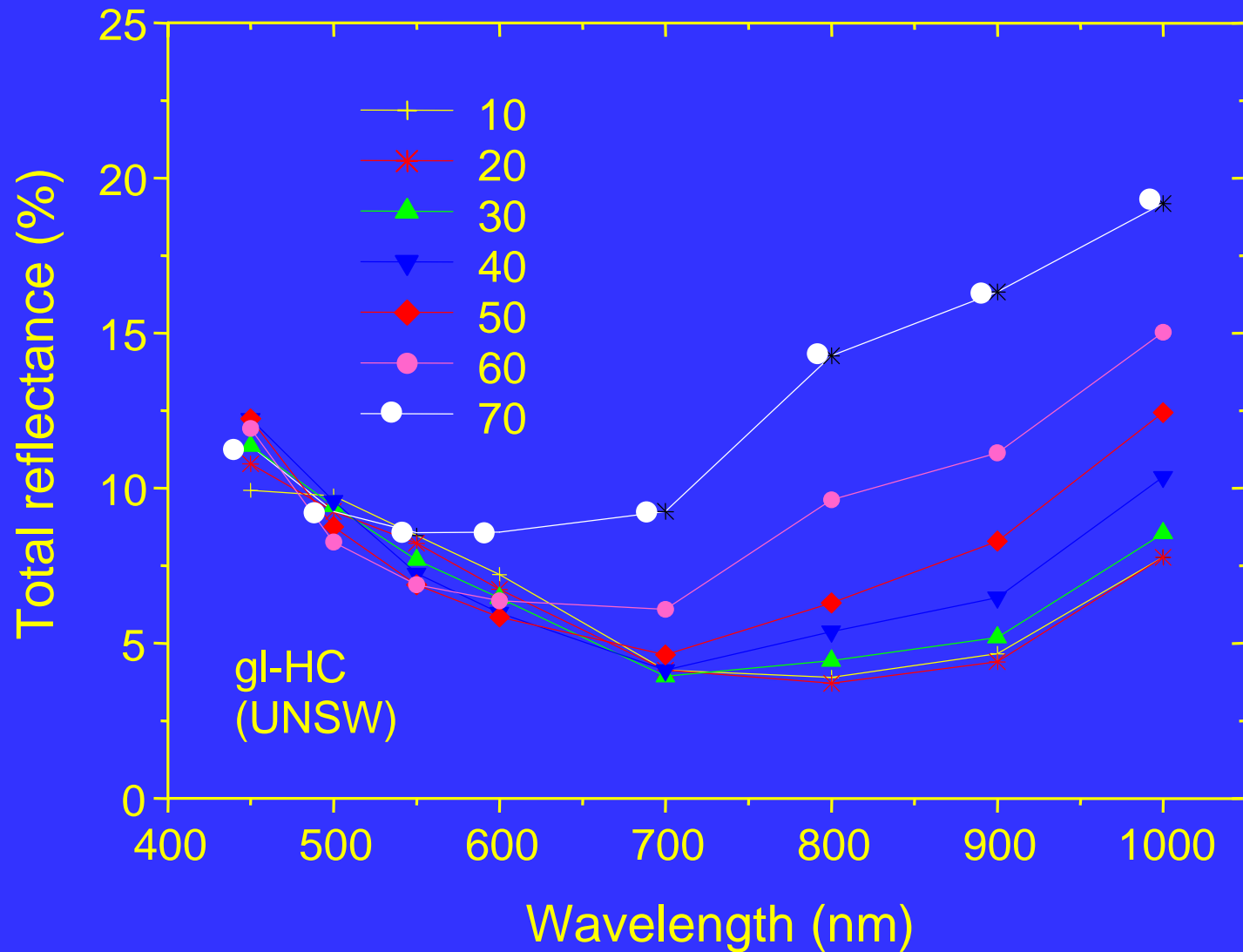


Misure di $R^{\text{dh}}(\theta, \lambda)$ su celle solari al silicio monocristallino (PERL-UNSW) testurizzate con piramidi inverse e realizzate prive di griglia (gl).
Misure adatte ad essere trasferite a celle solari testurizzate per concentrazione.

CELLE HONEYCOMB-UNSW

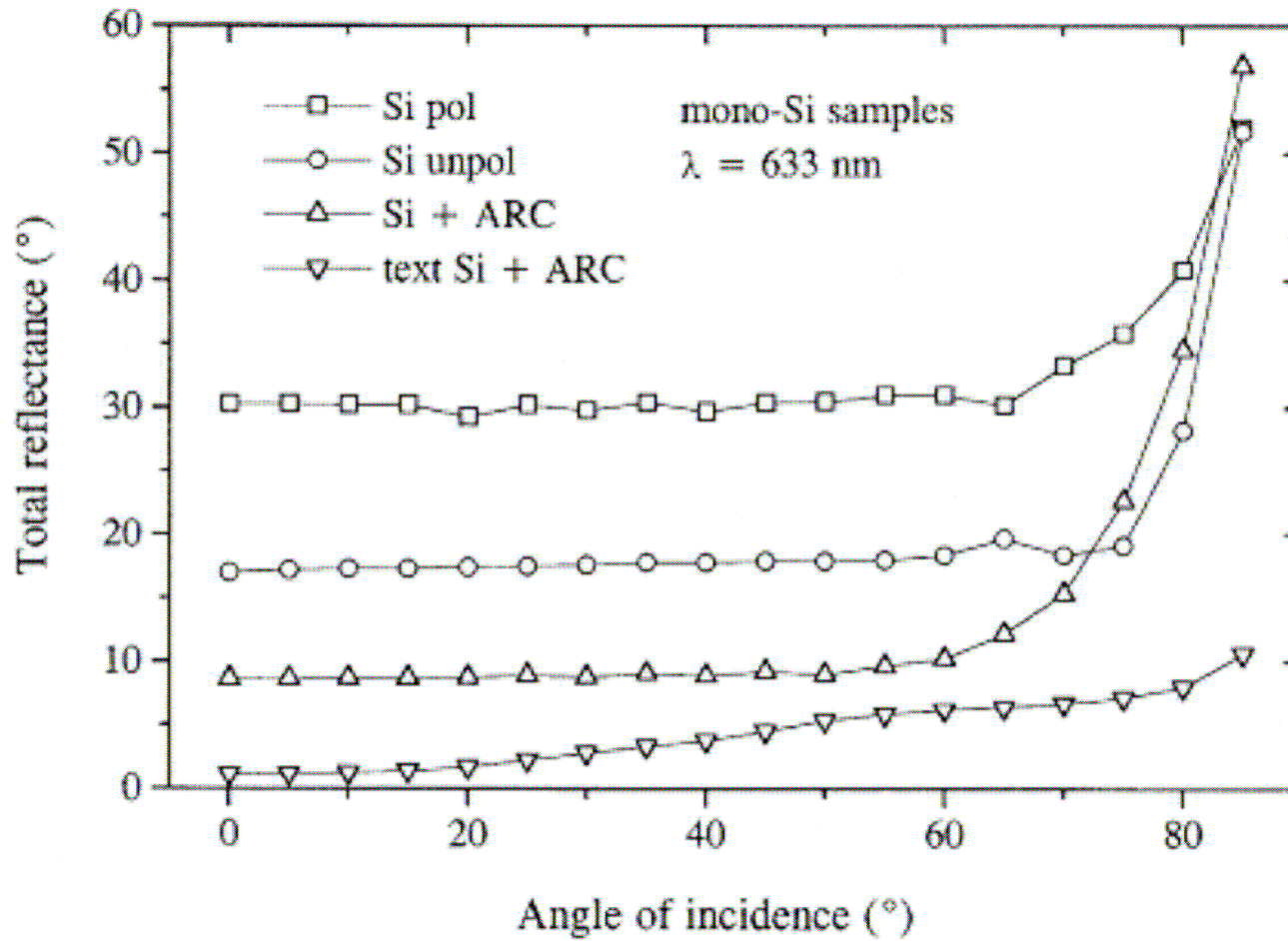


RIFLETTOMETRO ROSE

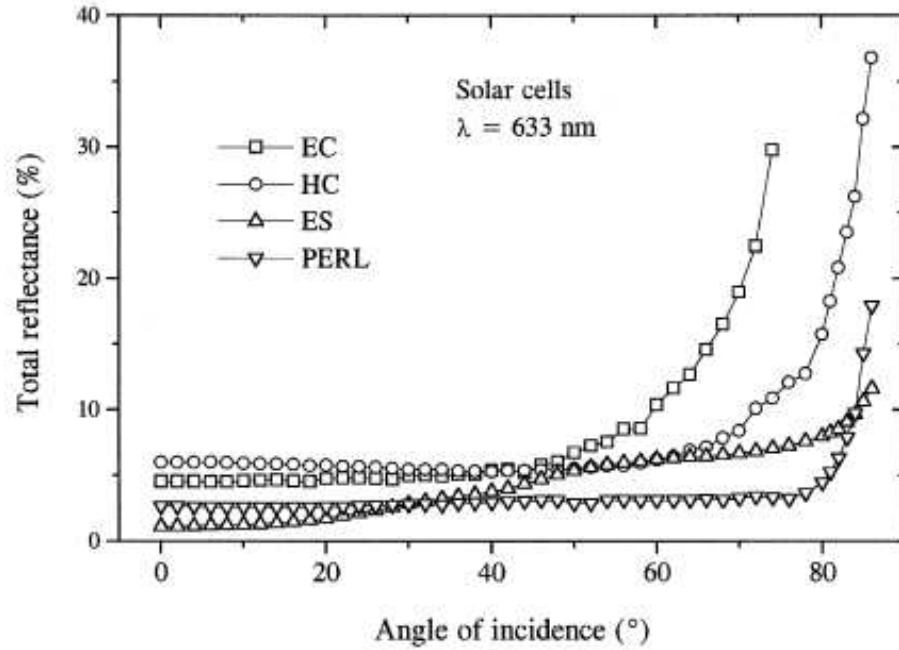


Misure di $R^{dh}(\theta, \lambda)$ su celle solari al silicio multicristallino (HC-UNSW) testurizzate con buche semicircolari e realizzate prive di griglia (gl).

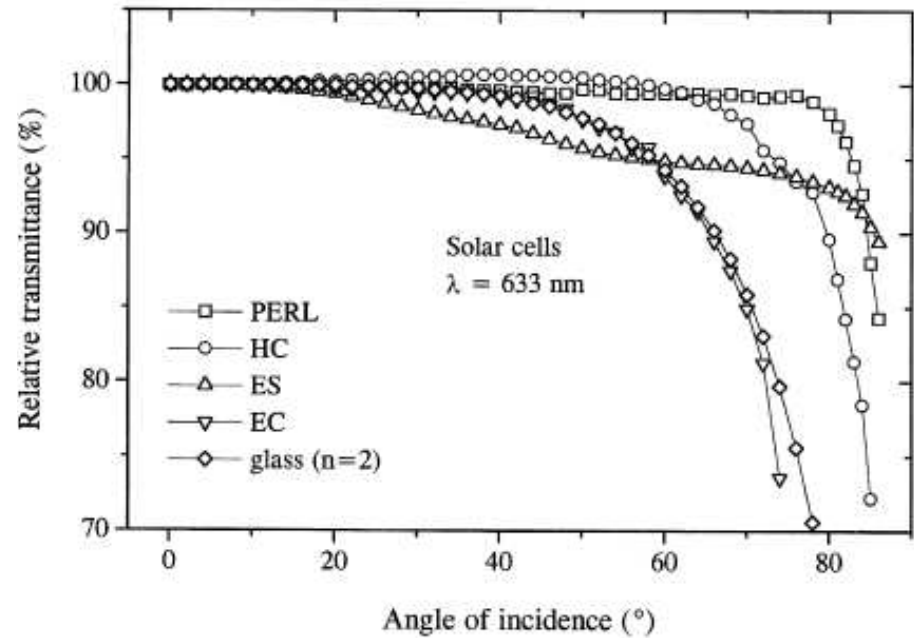
RIFLETTANZA DI CAMPIONI DI SILICIO



RIFLETTANZA DI CAMPIONI DI SILICIO



Riflettanza totale



Trasmittanza relativa