Room temperature AR coating for MIR-LWIR

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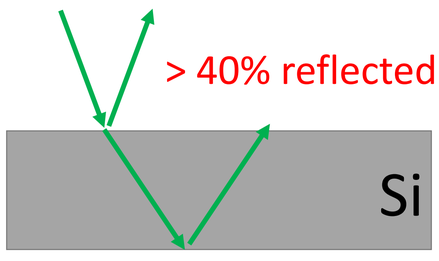
This work focuses on a CMOS-compatible low-temperature deposition process for ZnS films on Silicon and its use for the realization of an antireflection coating (ARC) operating in the medium infrared (MIR) – longwave infrared (LWIR) range. A thin interlayer of Al_2O_3 is employed to achieve good adhesion of a ZnS film deposited on Si by e-beam evaporation at room temperature. Numerical simulations are carried out to optimize the performance of single- and double-side ARC structures. Experimental results on an 8" Silicon wafer demonstrate a peak transmittance of 66% for single-side ARC and 89% for a double-side ARC at a wavelength of 10 µm.

Overview

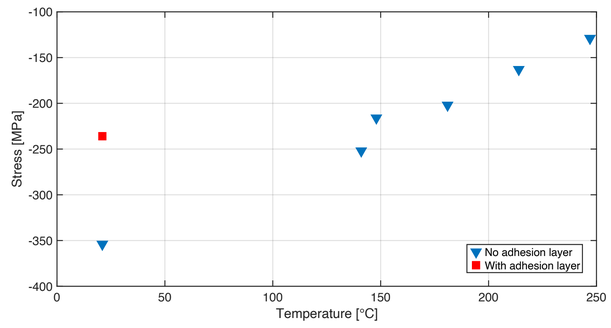
- The aim of the work is to enhance the transmission in the wavelength range 6 – 14 μm, passing through a Silicon cap, by adding an antireflection coating.
- The original transmittance through the Silicon cap is around 50%, due to the high refractive index contrast (n_{Si}= 3.48[1] vs n_{air}=1).

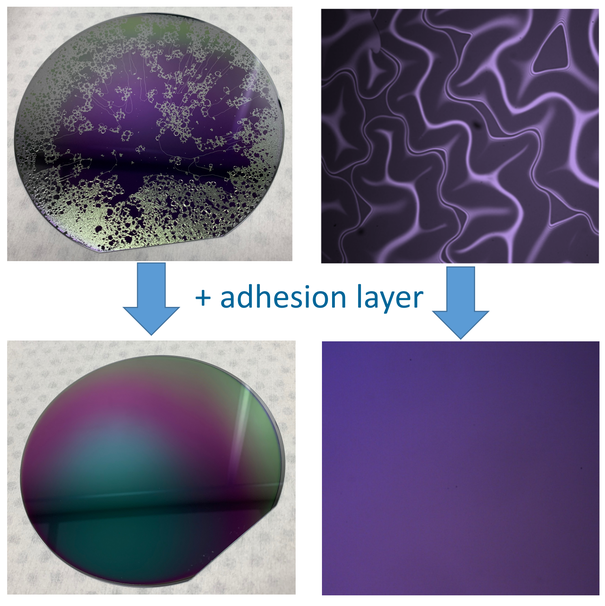


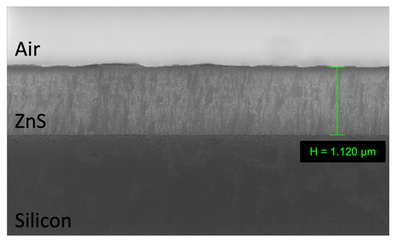
- ZnS exhibits a broad range of transparency, from visible to far IR and a refractive index of 2.2 at 10 µm. These features making it appear as a good candidate for the realization of an ARC on silicon operating at infrared wavelength.

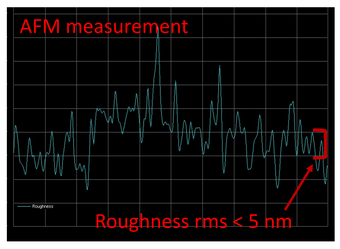
Film deposition and characterization

- The ZnS was evaporated with the Evatec BAK 640 rate is 4 nm/s. Targeting a low temperature process, the effect of the deposition temperature on the film quality in term of optical properties, adhesion, film stress, etc. was investigated.
- Above 200°C (compressive stress module over -250 MPa) the adhesion is excellent while with deposition at room temperature the ZnS film exhibits a very poor adhesion. we employed **a thin layer of Al_2O_3**, whose thickness (20 nm) is the minimum thickness guaranteeing good adhesion of the ZnS film to the Si substrate and at the same time gives acceptable loss in the LWIR range.



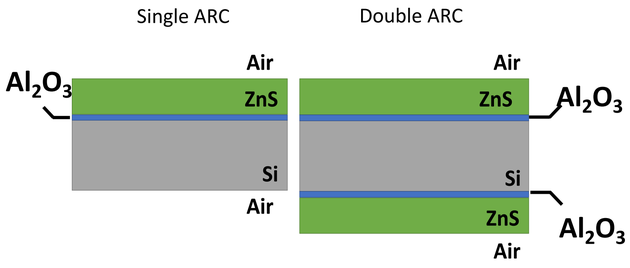


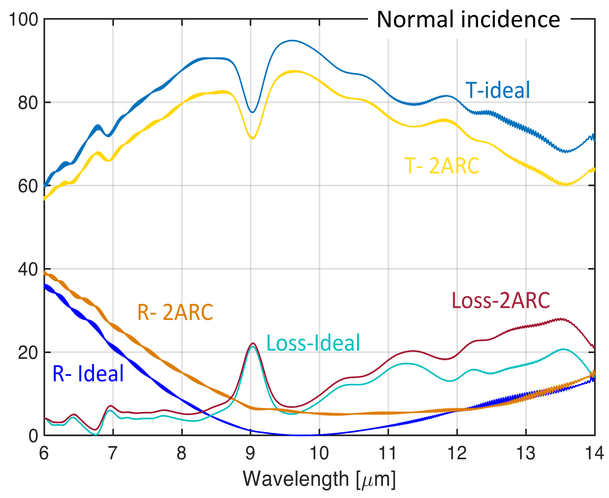


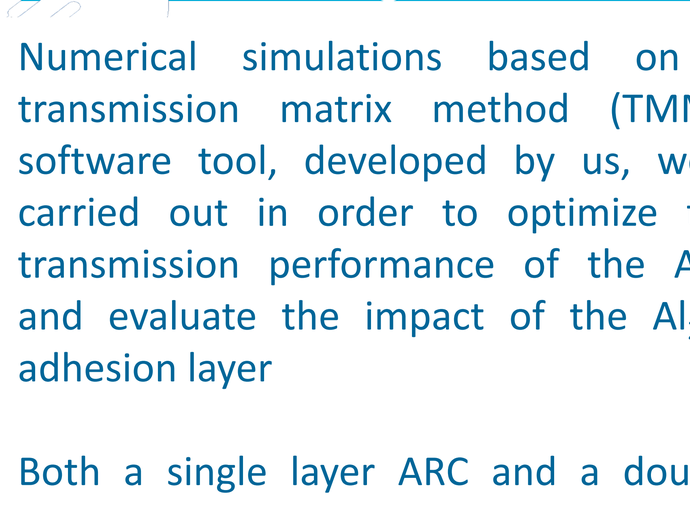


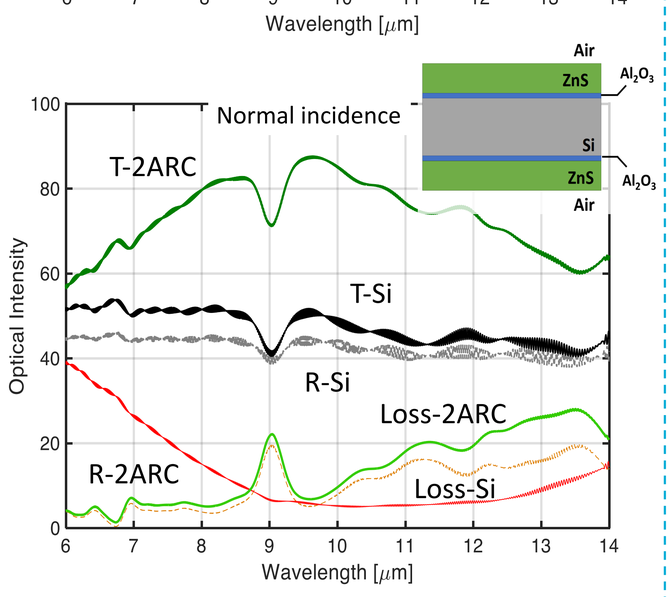
ARC Design

- Numerical simulations based on a transmission matrix method (TMM)[2] software tool, developed by us, were carried out in order to optimize the transmission performance of the ARC and evaluate the impact of the Al_2O_3 adhesion layer
- Both a single layer ARC and a double layer ARC have been studied. The ideal $\frac{\lambda}{4}$ antireflection coating gains only few percent better in transmittance with respect to our double ARC solution, while the transmittance peak of the double ARC is around 90% with respect to the 55% of the bare Silicon.



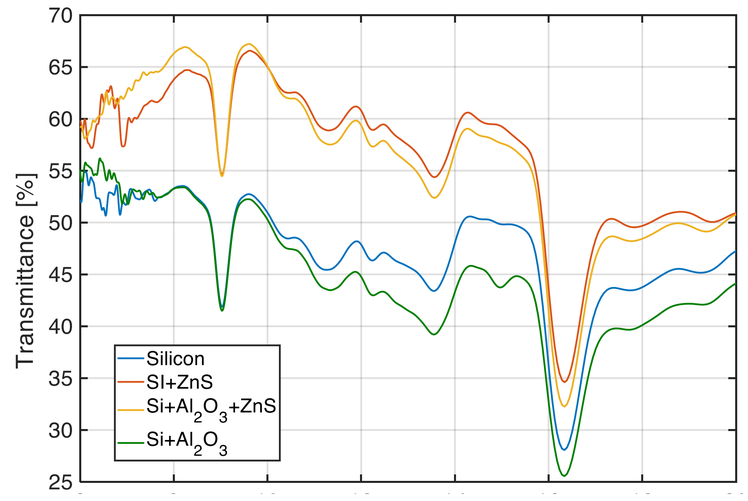


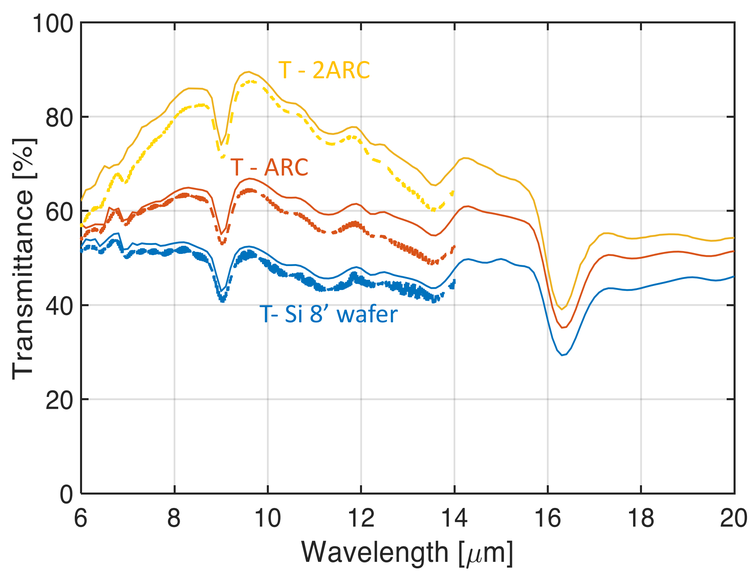




FTIR characterization

- The multilayer was characterized at STm Catania with FTIR measurements, confirming the curves obtained with the simulator. The single ARC stack (orange) has a transmittance enhancement of 27% while the double ARC stack (yellow) has a transmittance enhancement of 72% with respect to Silicon (blue).





References

[1] D. Chandler-Horowitz and P. M. Amirtharaj. High-accuracy, midinfrared (450 $cm^{-1} \leq \omega \leq 4000\ cm^{-1}$) refractive index values of silicon, J. Appl. Phys. 97, 123526, 2005

[2] Charalambos C., "General transfer-matrix method for optical multilayer systems with coherent, partially coherent, and incoherent interference," Appl. Opt. 41, 3978-3987 (2002)

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