Tree rings in ITL sensors

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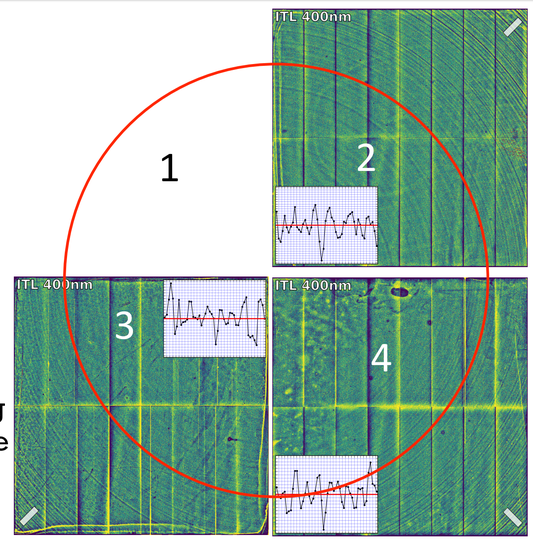
Background

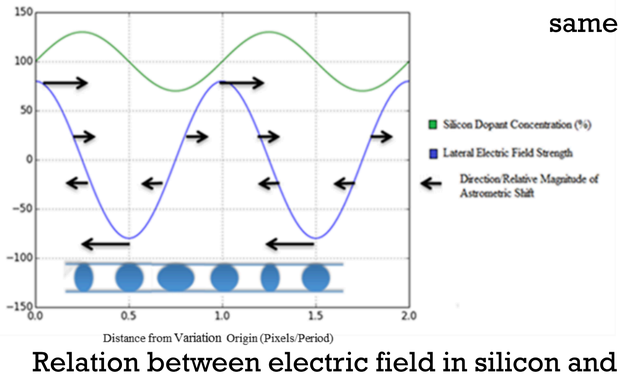
- DESC (Dark Energy Science Collaboration) will analyze LSST data to measure most precisely cosmological parameters. SAWG (Sensor Anomalies Working Group within DESC) is studying CCD sensor effects to understand limitations coming from the instrument. This work considers tree rings and infra-red fringes, which are important sensor effects.
- Fringes in IR originate from the varying thickness of the silicon wafer. They are visible in flats. In shorter wavelength region, before fringes start to dominate, one can also see tree-rings caused by variation in the wafer resistivity [1,2,3].
- Manufacturing process of growing single crystal silicon boule leads to circularly symmetric variation of dopant concentration (hence resistivity), which brings about tree-ring-like patterns. Changing resistivity causes variation in electric field hence the star shapes could be distorted depending on their location on the sensor.

Methods

- Flat images of 320nm ~ 1080nm wavelengths with 10nm steps taken at BNL were assembled with bias subtraction.
- Used David Kirkby's AstroCCD [4] to emphasize the effect shown in the image by subtracting median signal, smoothing and clipping.



Example image of grouping sensors originating from the same wafer

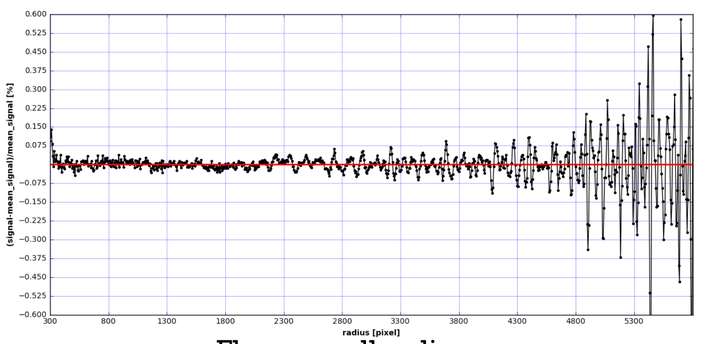


Relation between electric field in silicon and shape of nominally round sources [1]

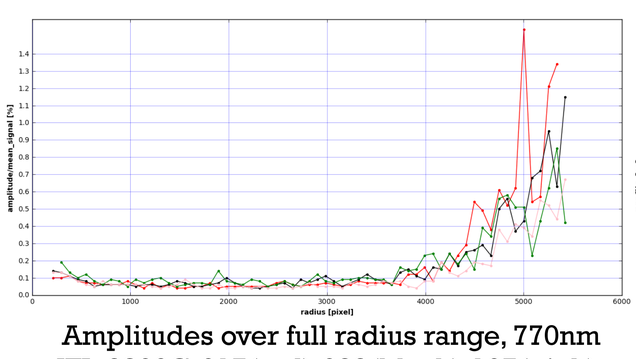
- Found center of the ring by calculating from chosen points on a ring.
- Compared amplitudes vs ring radius for all ITL sensors tested at BNL in fall 2016.
- Group sensors from same wafer then compared the tree-ring pattern.

Results

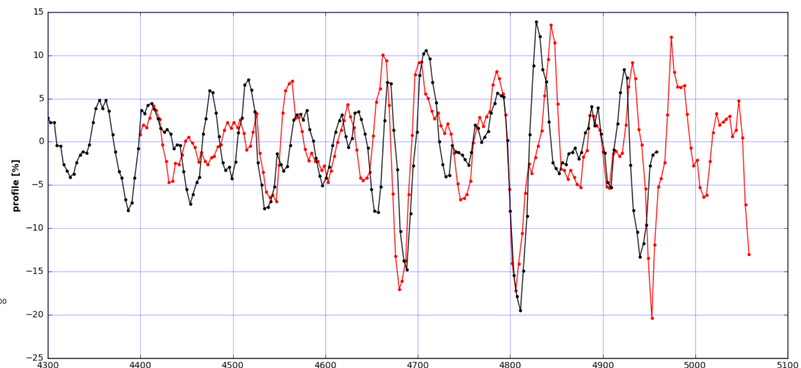
- Tree ring effects appear more clearly from ~4300 pix from the center and amplitude is larger in outer part of the wafer.



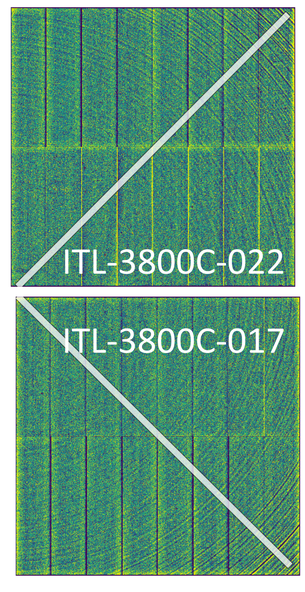
Flux over all radius range, ITL-3800C-017, 770nm

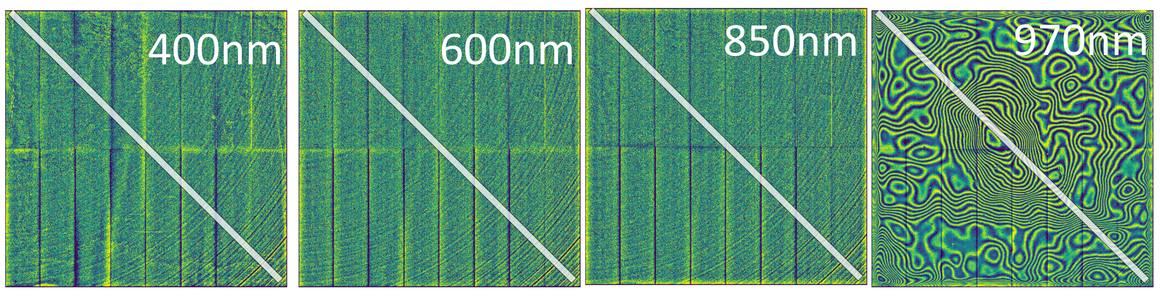


Amplitudes over full radius range, 770nm ITL-3800C-017(red),022(black),107(pink), and 145(green)

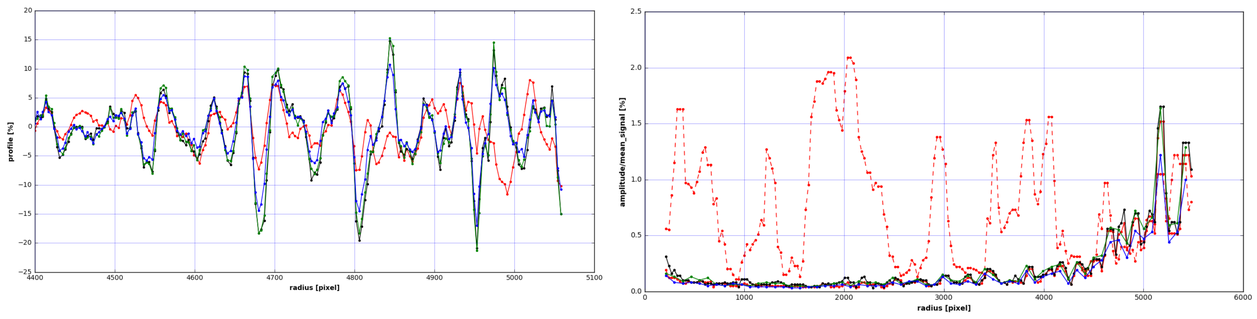


Flux over (r=4400~5100) range, ITL-3800C-017(red)&022(black), 770nm





- ITL-3800C-017 and 022 are from same wafer so I compared amplitudes over the full radius range and flux over r=4400~5100 range to demonstrate their similarity.
- Pattern didn't match precisely but improving the ring center finding algorithm should result in more accurate comparison.



Comparing amplitudes among several wavelengths, ITL-3800C-017
400(black),600(green), 850(blue), and 970nm(red, red dashed for profile on diagonal line)

- When comparing images for different wavelength, the profile pattern or amplitudes didn't change until ~880nm where fringe effect starts to dominate.
- Around 850nm before fringe dominates, the tree ring amplitude gets smaller because longer wavelengths penetrate deeper into the silicon.
- At 970nm the fringing amplitude is ~2%.

Conclusion

- Tree ring amplitude gets larger as it gets closer to outer part of the wafer, from 0.1 to 1.0%, suggesting that the resistivity variation is larger for larger radii.
- Amplitude of tree rings shows weak dependence on the wavelength.

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References:(1) B.Beamer, A study of astrometric distortions due to "tree rings" in CCD sensors using LSST Photon Simulator, 2015 JINST 10 C05027.
(2) Y.Okura, Spurious shear induced by the tree rings of the LSST CCDs, 2015 JINST 10 C08010.
(3) A.A.Plazas, On-sky measurements of the transverse electric fields' effects in the Dark Energy Camera CCDs, Publ. Astron. Soc. Pac. 126 750.
(4) D.Kirkby, Astro CCD https://github.com/dkirkby/AstroCCD.