Evolution of Detrapping Currents for α-Si FETs Exposed to Radiation

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Detrapping Rates of α-Si after Radiation Damage

Medical α-Si flat-panel X-Ray detectors are increasingly being used for industrial applications with energies up to 450kVp running 24/7

To increase the performance of the detectors we want information on how to optimize FET designs

We have measured detrapping current rates from different regions of the FET and at different dose levels up to 13Mrad

Optimization of the FET design for imaging panels for enhance performance is now possible

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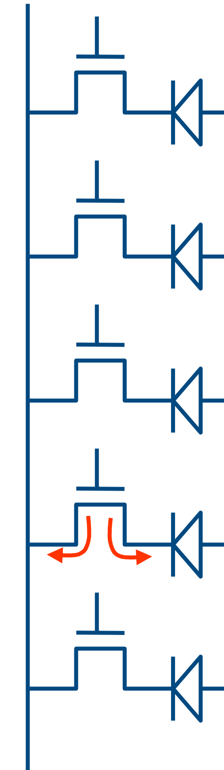
X-ray Flat Panel Detector

Indirect or “modular” detection system
- Scintillator (CsI)
- FET/Diode combo for each pixel
- α-Si based

Many thousands of pixels can be sharing a dataline

Detrapping current comes from the FET with half going to the diode and half going to the dataline

Charge coming off of one FET can be small, but total effect can be large



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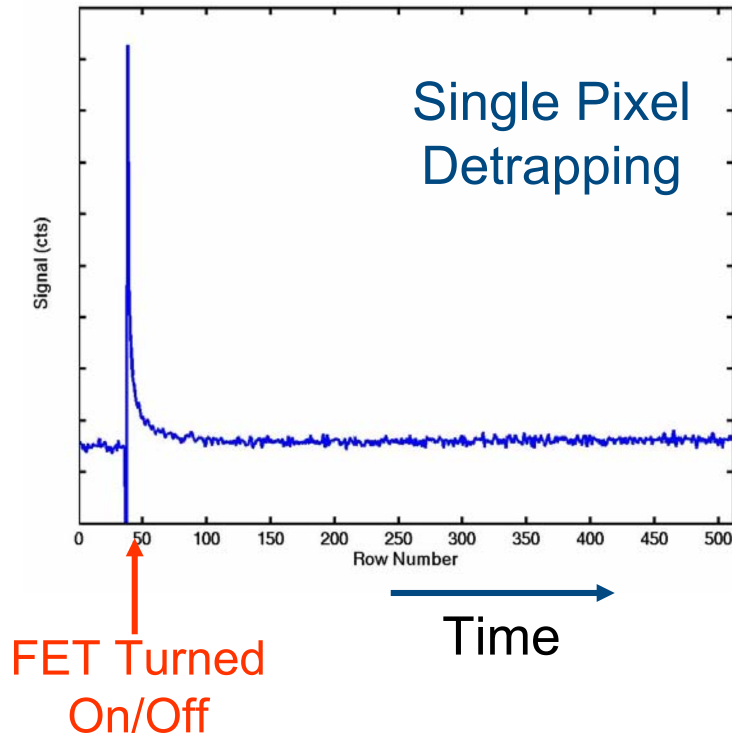
Effects of Charge Retention/Detrapping



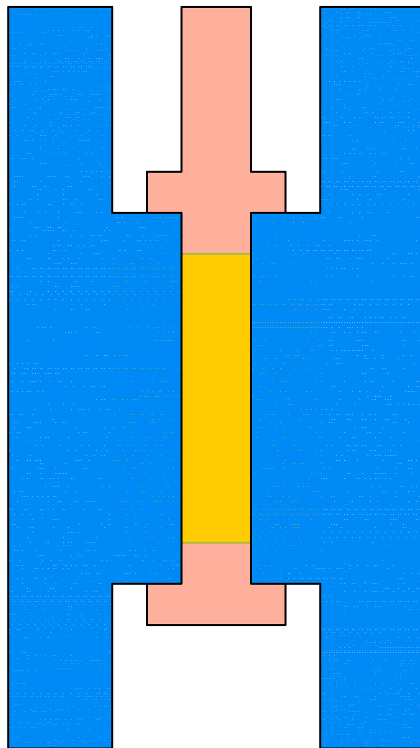
Offsets on imaging detectors partly due to charge retention/detrapping from α-Si FETs

When FETs are turned off, the detrapping current follows $I \propto t^{-n}$ $n \sim 1$

Detrapping current is due to defects
→ Defects leads to tails in the DOS
→ Defects increase with radiation damage

Total detrapping current depends on:
- Timing (frame time, read time)
- Material
- FET design (channel size…)

FET Design and Silicon "Types"



Only α-Si above the gate matters

Two "types" of α-Si:
- Contact Silicon
- Channel Silicon

Channel α-Si has an additional etch applied

→ Different thickness
→ Different surface states

Full detrapping current:

$$I = K_{Chan} \cdot A_{Chan} \cdot t^{-n_{Chan}} + K_{Con} \cdot A_{Con} \cdot t^{-n_{Con}}$$

Difficult to separate channel and contact contributions

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Test Devices

Desire was to get information on devices with true pixel dimensions and accurate processing conditions

A test panel was created with ~100 different pixel variations repeated numerous times across the panel

Pixel variations include:

- FET size variation
- Diode shapes
- Diode size
- Data/Scan Line effects

Use a small subset to examine detrapping current out of FETs

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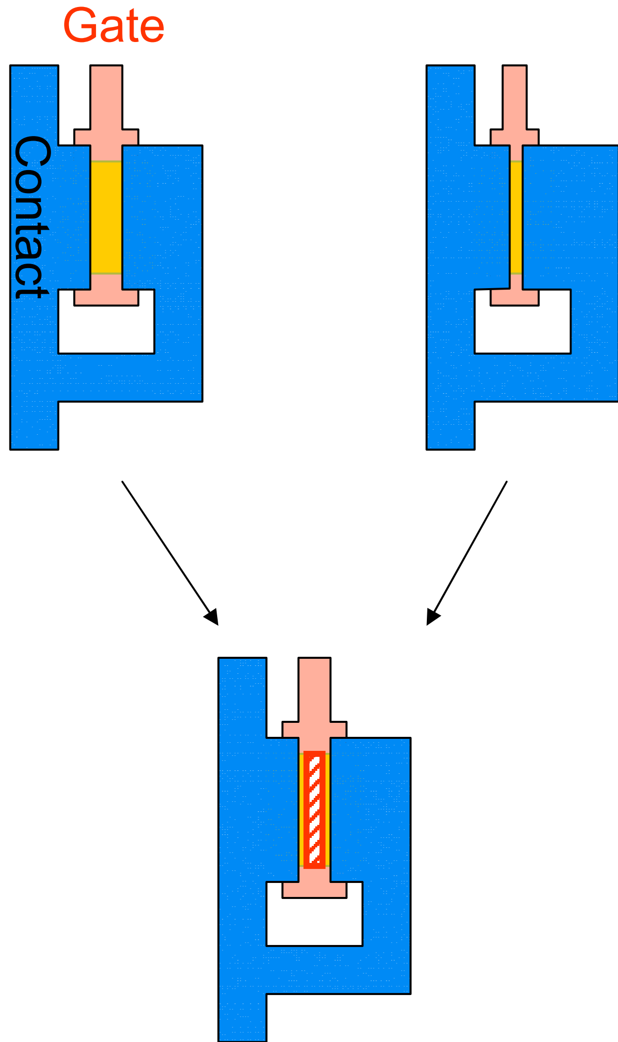
Determine Channel Silicon



Two Different FET Designs

- S/D tied together
- Same contact area
- Different channel lengths

Measure detrapping rates for both devices and subtract

Eliminates contact area, stray field effects, etc.

Results sensitive to detrapping from channel region only

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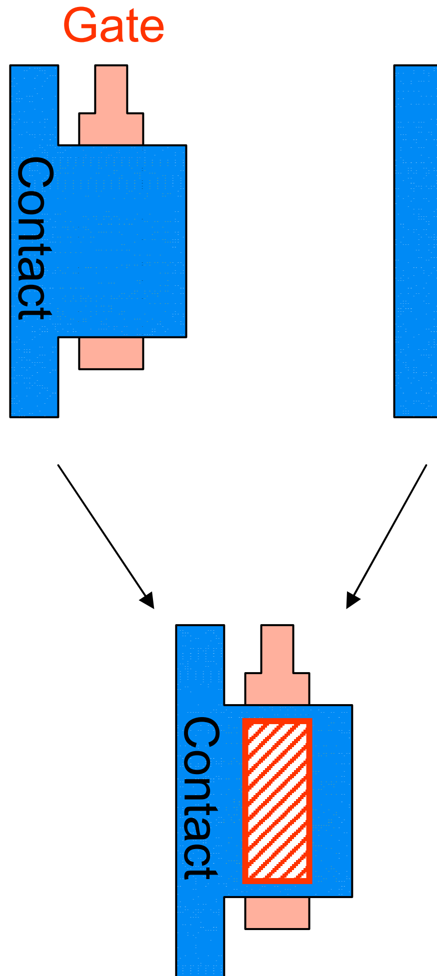
Determine Contact Silicon



Two Different FET Designs
- No Channel FET
- Dataline only FET

Measure detrapping rates for both and subtract

Eliminates capacitive effects, systematic variations etc.

Results sensitive to detrapping from contact region only

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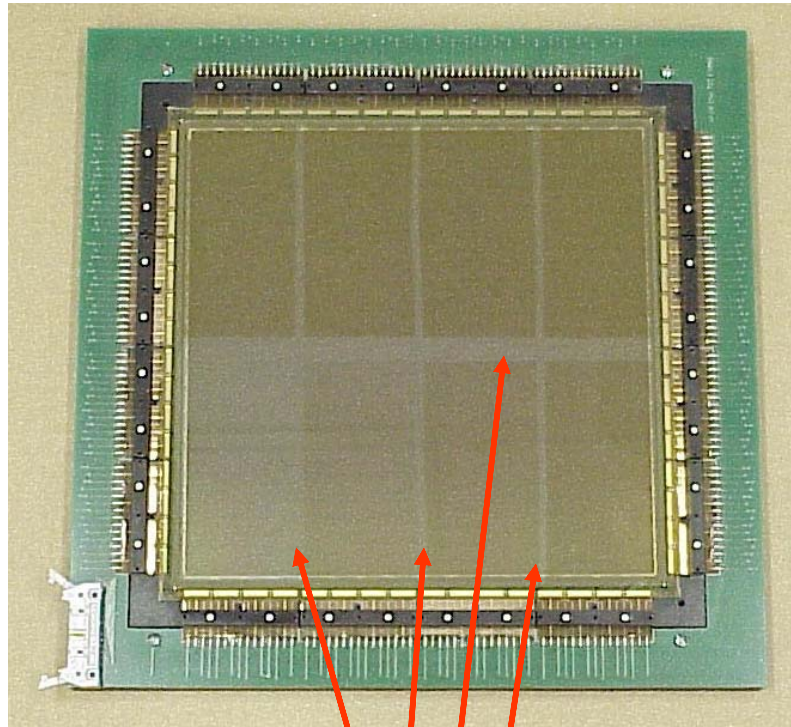
Radiation Damage



Shadows where protected

FETs were under simulated read conditions while irradiated (powered up and active)

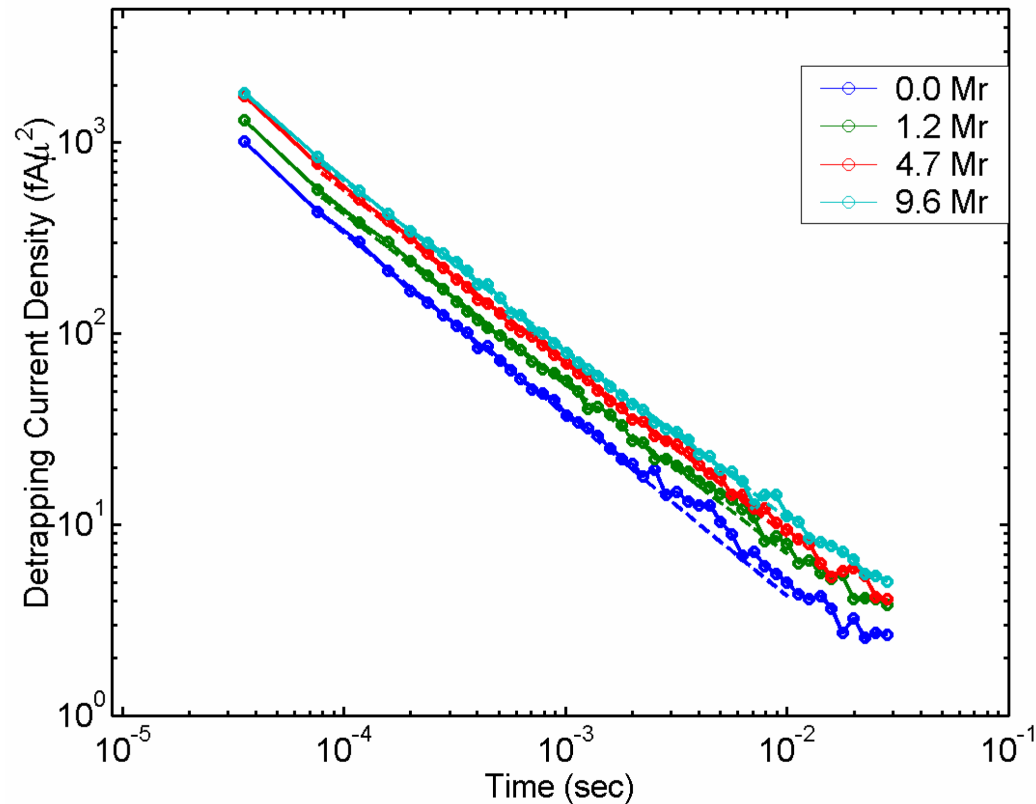
Panel was divided into 8 regions and covered with Pb

Dose controlled by exposing panel to 220kVp spectrum and removing Pb in each region

All regions received final dose at the same time (minimizes relative annealing effects)

Final dose to silicon determined by Monte Carlo simulations

Channel Detrapping Rates



Each dose from similar FETs at different regions of the panel

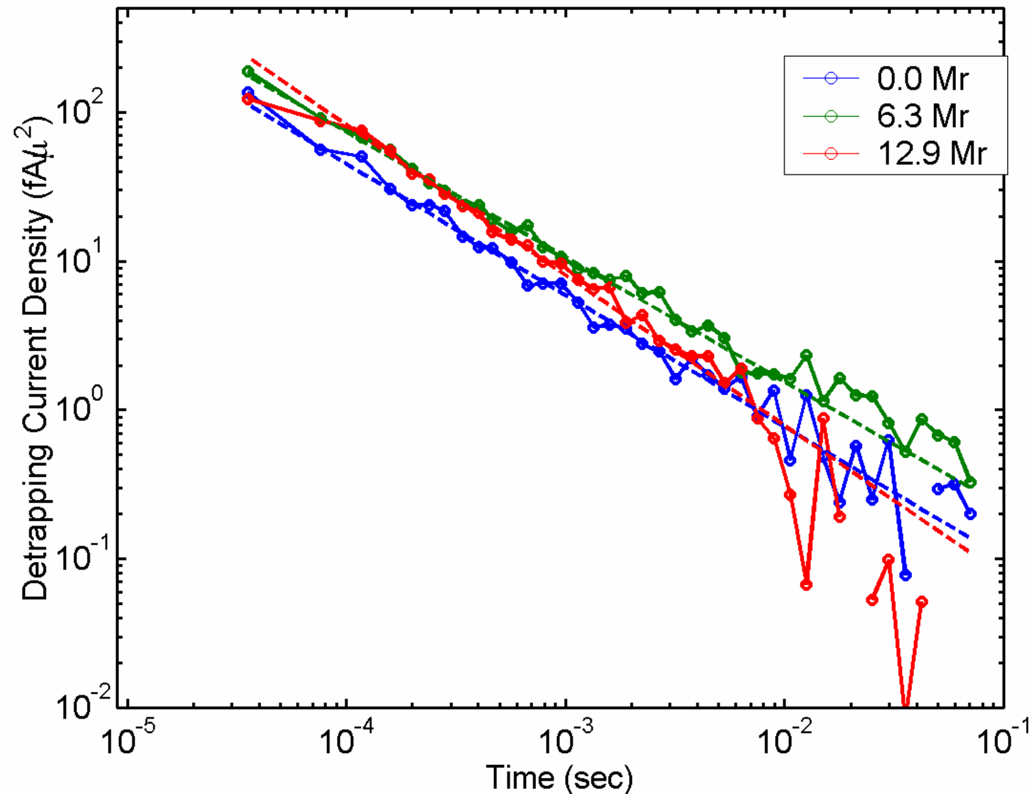
Follows power law behavior from 30 μs to >30 ms (greater than 20sec observed)

Change with dose appears as a uniform shift

$$I = K_{Contact} \cdot area \cdot t^{-n}$$

K (fA/μ²)	n
0.053	**0.95**

Contact Detrapping Rates



Similar collection method as for channel silicon

Follows power law behavior from 30 μs to >30 ms

Larger noise and less uniform behavior as a function of dose compared to channel rates

$I = K_{Contact} \cdot area \cdot t^{-n}$	
K (fA/μ²)	n
0.013	**0.88**

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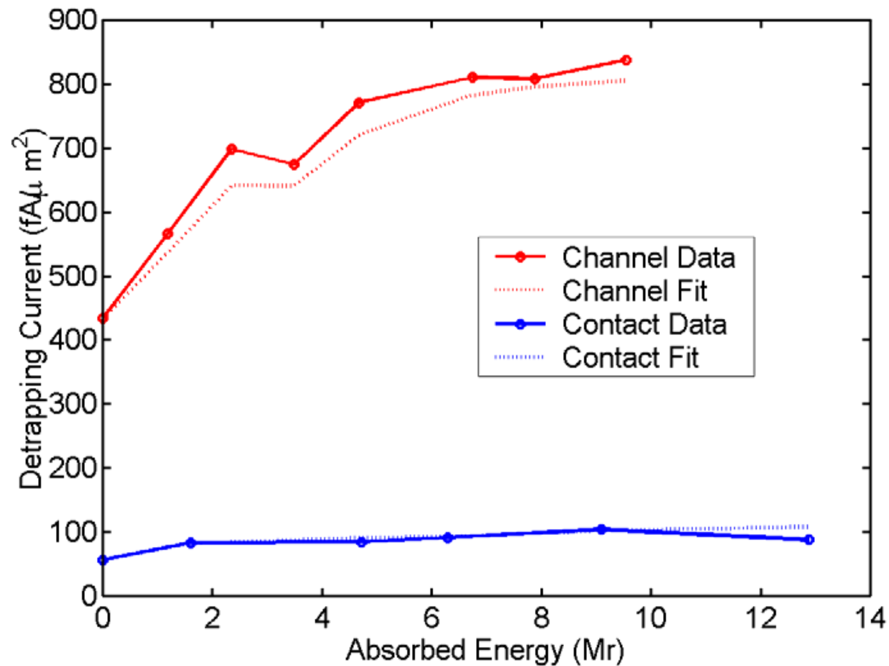
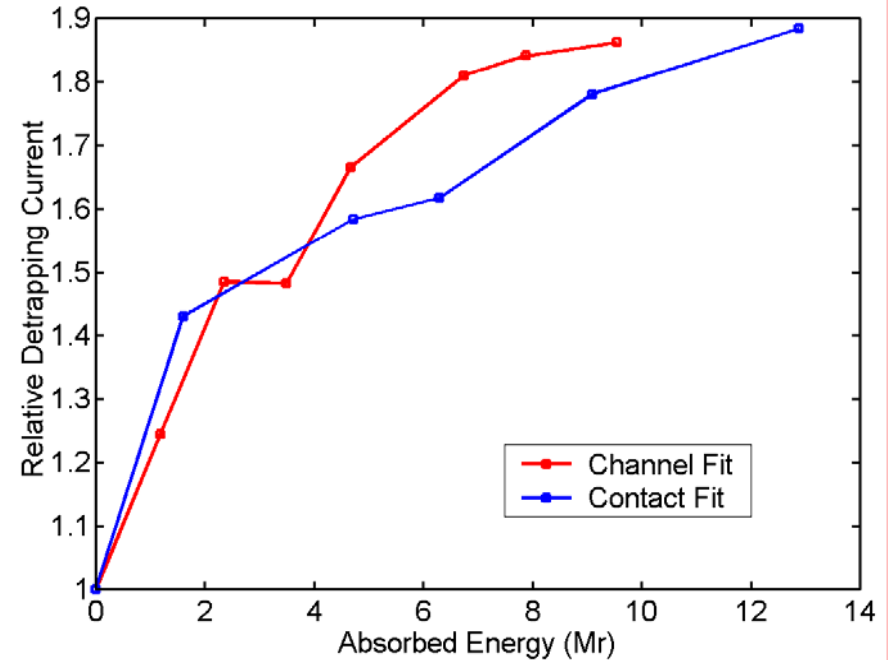
Initial Detrapping Current vs Dose





Detrapping Current at ~70 μs

Channel silicon current is 4-9 x larger than Contact silicon current

When exposed both regions show similar relative changes

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Summary

- Directly measured charge retention current behavior of α-Si from 0 to 13Mr on "realistic" FET devices
- Experimental devices allowed independent measurement of current from channel and contact α-Si
- Confirmed t^{-n} ($n \sim 0.9$) behavior in current from FETs before and after irradiation
- Channel Si contributes 4-9x more charge retention current than contact Si, probably due to defects created during the back channel etch
- Change in detrapping current with dose similar for channel and contact silicon
- Minimizing FET detrapping current means minimizing channel size with more relaxed dimensions for the contact region (able to balance current, RC, yield etc…)

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