The influence of tellurium precipitates on mobility in CdTe

Andrew W. Davies, A. Lohstroh, M.E. Ozsan, P.J. Sellin, A. Simon

Centre for Nuclear and Radiation Physics
Department of Physics
University of Surrey

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Introduction

Charge transport properties of CdTe were investigated, for potential applications in nuclear medicine gamma cameras.

CdTe wafers were supplied by Eurorad, grown by the Travelling Heater Method.

Good spectroscopic performance relies on excellent electron drift lengths – hole transport is poor in CdTe.

Electron mobility-lifetime product ($\mu\tau$) is the primary measure of the quality of electron transport.

In this work we have used high resolution mapping techniques to study:

- the spatial uniformity of electron $\mu\tau$
- possible correlations between charge trapping and Te precipitates

Ion beam imaging is a powerful technique that produces quantitative maps of charge transport with a 1 μm spatial resolution

Detection Parameters

Large atomic number → large photoelectric absorption cross section

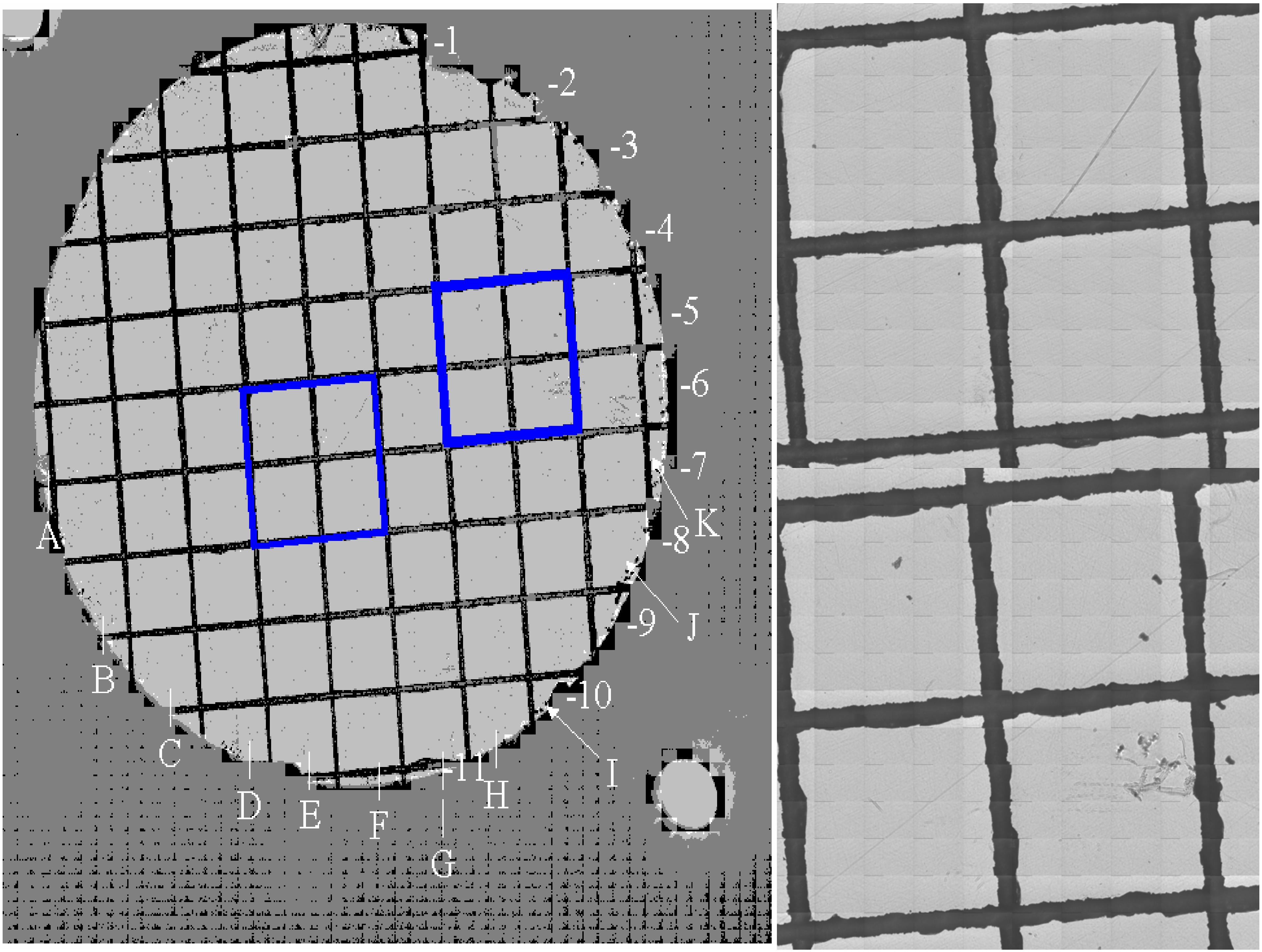
Band Gap of 1.5eV

Electron and hole lifetimes greater than drift time across the device

⇒ Good electron and hole mobility

Low concentration of trapping centres and structural defects

Semiconductor	**Z**	E_g eV @300K	μ_e $Cm^2v^{-1}s^{-1}$	μ_h $Cm^2v^{-1}s^{-1}$
Si	14	1.12	1500	600
Ge	32	0.67	3900	1800
CdTe	48-52	1.50	1000	80
HgI_2	80-53	2.1	100	4



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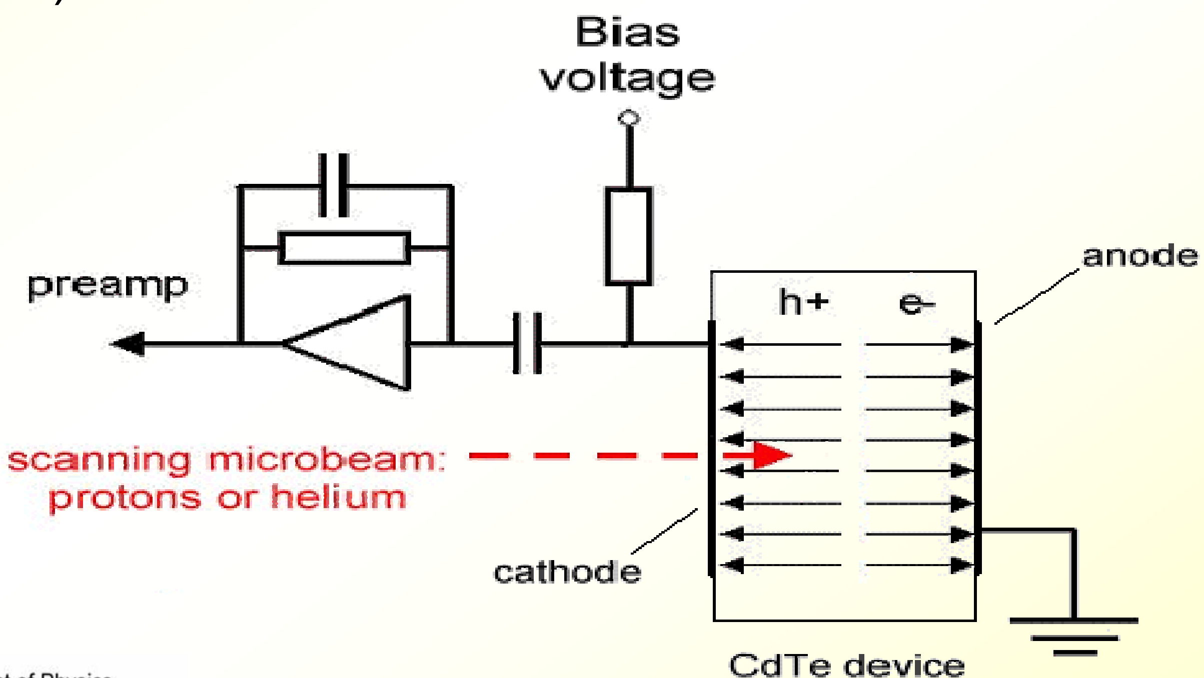
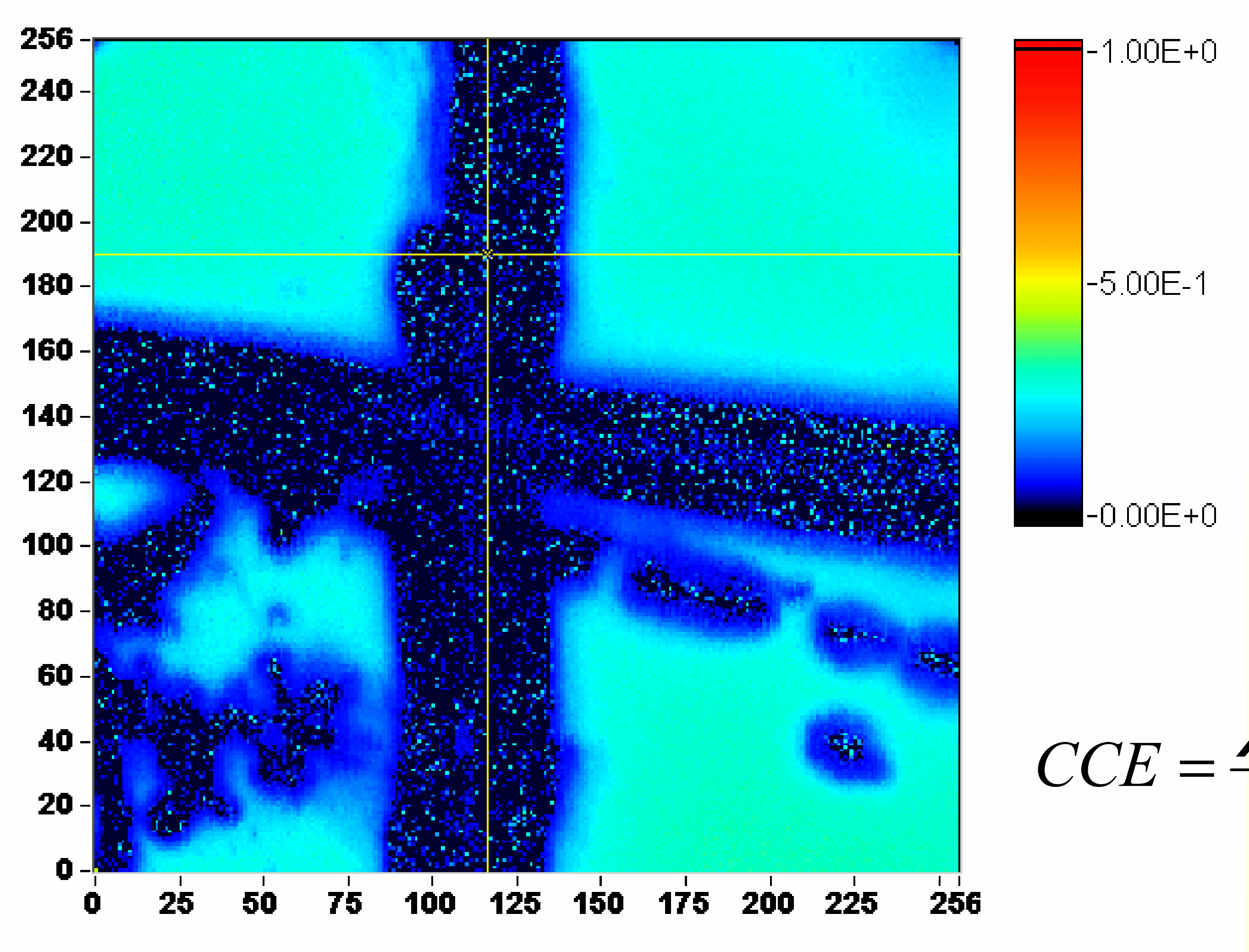
Ion Beam Induced Charge (IBIC) imaging

- Ion Beam consisted of protons focused to a spot of < 4µm and was raster scanned over the sample
- Induced charge signal was recorded →Charge collection efficiency (CCE) images were constructed (over 6 bias voltages)
- Cathode irradiated – sensitive to electron transport only
- IBIC was carried out on a CdTe sample processed with pixellated (3x3) metal electrodes



CCE imaging using IBIC



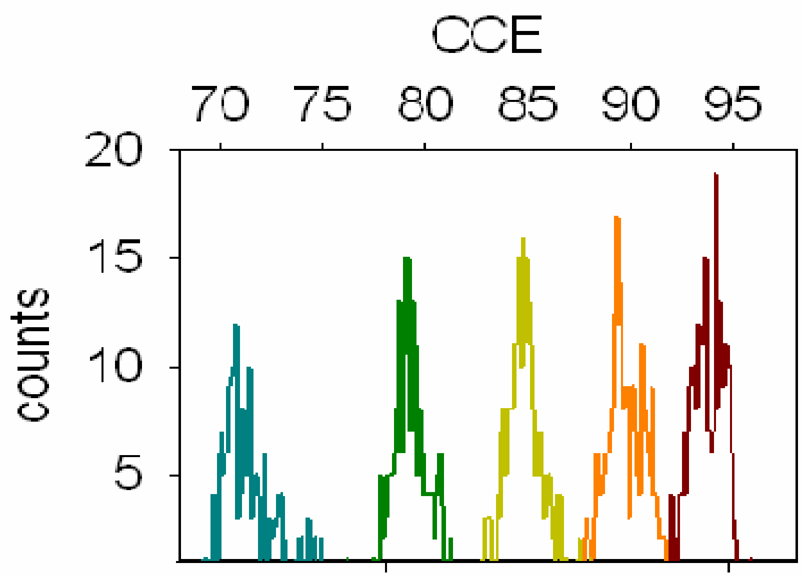
$$CCE = \frac{\lambda_e}{d} = \frac{\mu_e \tau_e E}{d}$$

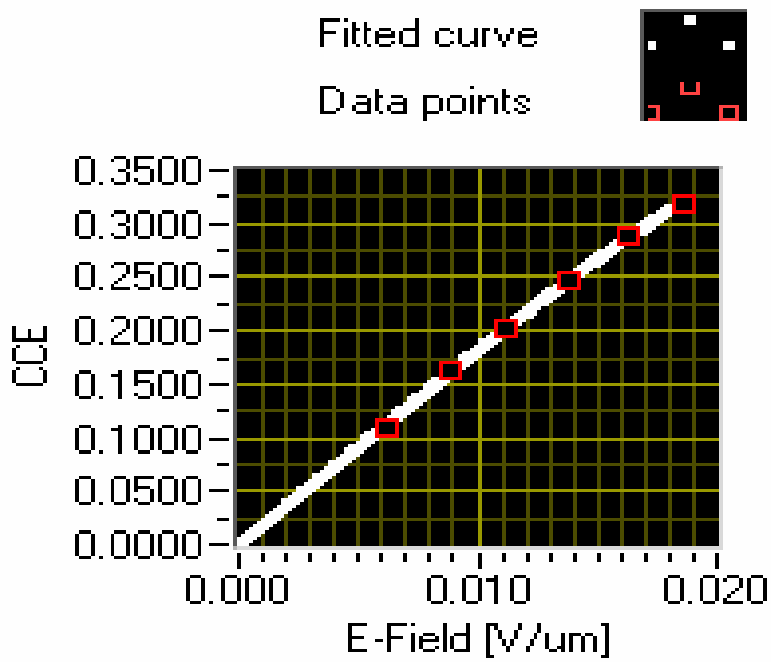
Drift length and μτ products

The variation of CCE with bias voltage is described by the Hecht equation

$$CCE = \frac{\mu_e \tau_e E}{d}\left[1 - \exp\left(-\left(1 - \frac{x}{d}\right)\right)\left(\frac{\mu_e \tau_e E}{d}\right)^{-1}\right]$$

$\mu_e\tau_e$ products obtained by: 1)Recording the CCE vs. Voltage data for each pixel and 2)Fitting the Hecht equation via the Levenberg-Marquardt algorithm





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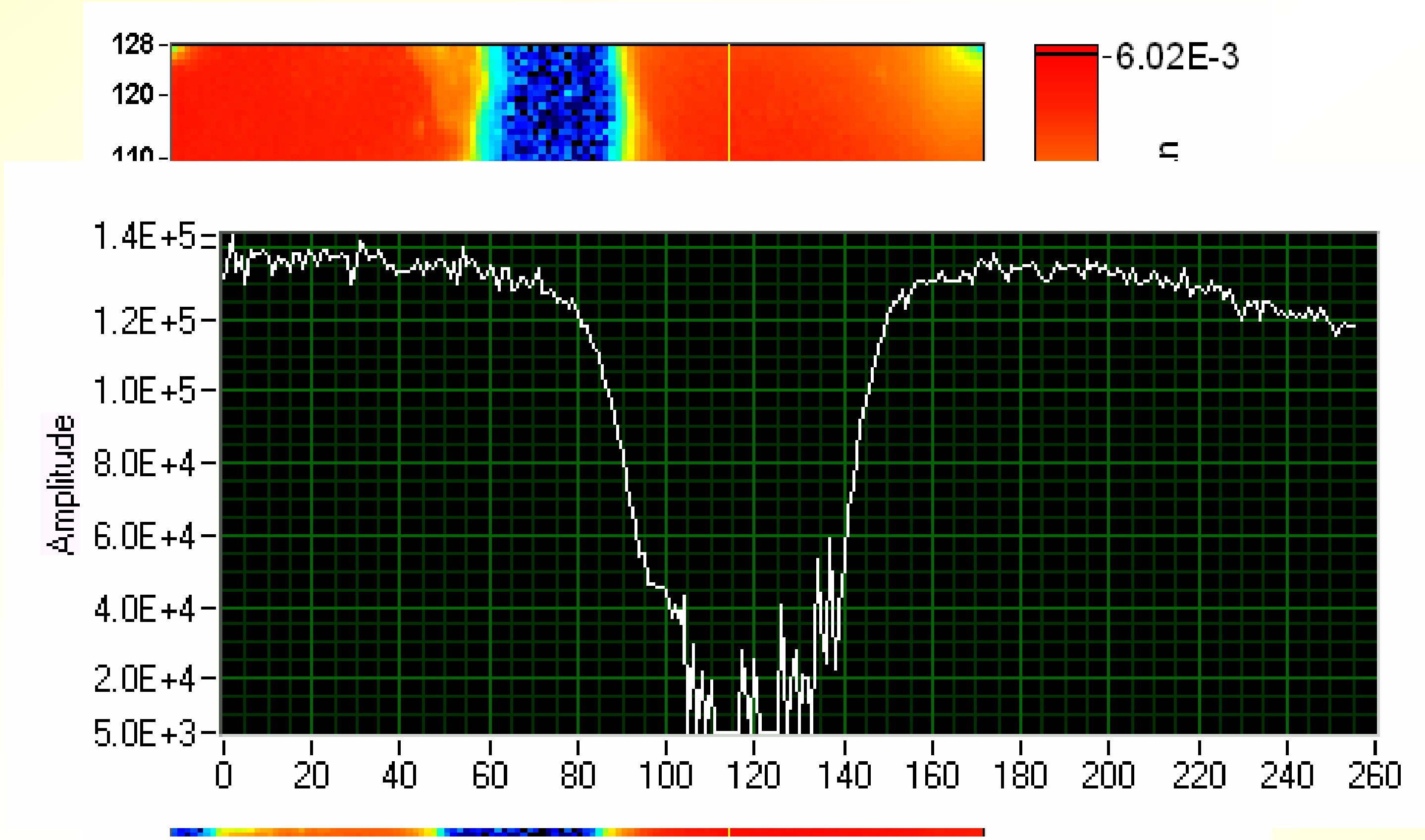
$\mu_e \tau_e$ maps from IBIC data



Compare this to IR microscopy data to assess the effect of precipitates on $\mu_e \tau_e$

Can find ut product via IBIC but cant find the values of μ and τ

Drift mobility using Time of Flight measurements

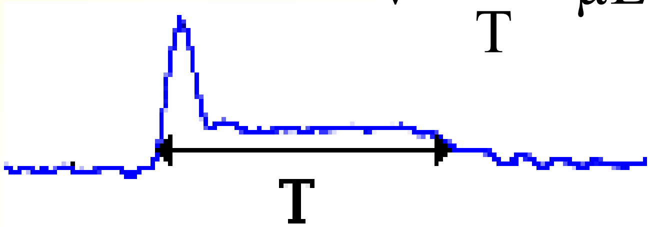
Electron hole pairs are created using a laser pulse – drift of carriers induces a current pulse

Mobility can be measured directly using digital analysis of the transient current pulse:

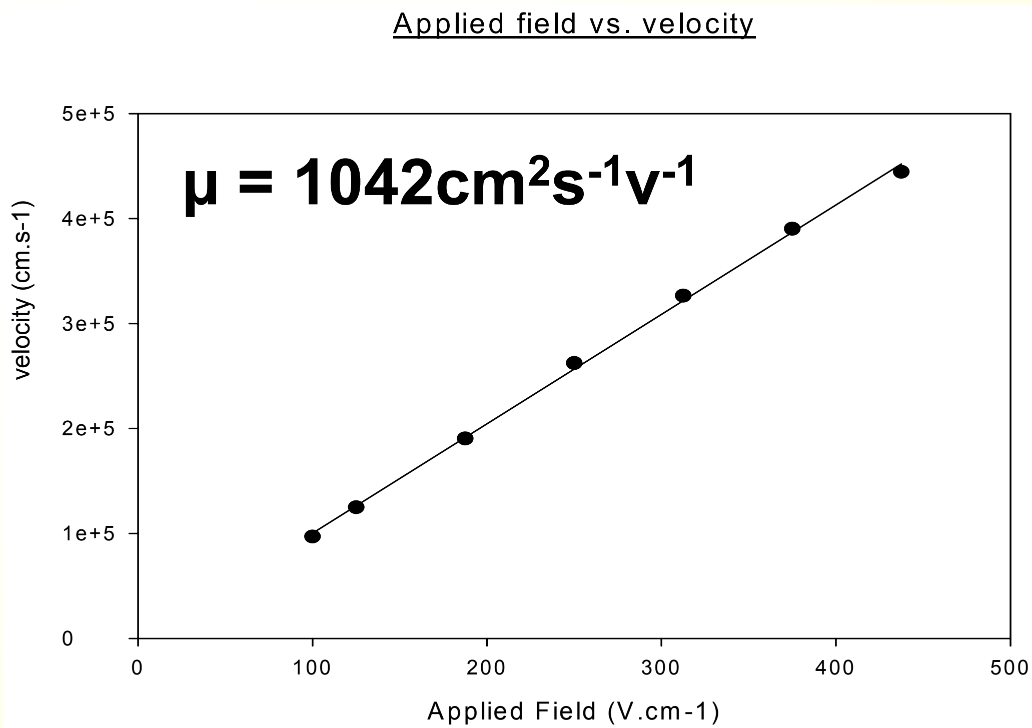
Current pulse amplitude depends on:

$$i(t) \propto v(t)\, q\, N$$

Current pulse width gives electron drift time *T*, and hence mobility: $v = \frac{d}{T} = \mu E$



Results show good match with published data



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Conclusions

Te precipitate distribution concentrated in outer 5mm of each wafer

- IR images is a contactless whole-wafer technique for fast material inspection
- Very low density of Te precipitates in central regions of CdTe wafers

IBIC used to derive high resolution maps of $\mu\tau$

- High electron $\mu\tau$ (6.02×10^3 cm^2 V) with excellent uniformity over length scales >1 micrometer
- Non uniformity of ut observed in certain regions due to presence of precipitates or poor electrode contact (eg. contact delamination)

Laser TOF measurements used to derive electron drift mobility

- Good electron mobility ~ 1040 cm^2 Vs^{-1} – in agreement with published values of ~1000 [semiconductor and semimetals vol3]

Further work to investigate influence of small-scale precipitates:

- Additional ion beam measurements in progress to investigate charge trapping around individual Te precipitates