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14. ABSTRACT Major source of HgCdSe background electron concentration is Group VII impurities (Br, Cl, F) introduced from Se source material Change in concentration with annealing suggests p-type Hg vacancies and n-type Se vacancies OMSA suggests an inhomogeneous distribution of electrons introduced in growth, reduced with Hg than Se anneal					
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Report Title

Electron transport and Minority Carrier Lifetime in HgCdSe 2013 II-VI Workshop

ABSTRACT

Major source of HgCdSe background electron concentration is Group VII impurities (Br, Cl, F) introduced from Se source material

Change in concentration with annealing suggests p-type Hg vacancies and n-type Se vacancies

QMSA suggests an inhomogeneous distribution of electrons introduced in growth, reduced with Hg-then-Se anneal making mobility more discrete

Lower electron concentration allows us to see PCD transients, which suggest trap present in as-grown material that is increased with Hg-annealing but removed with Se-annealing, could be Se vacancies

Lowering background electron concentration and increasing lifetime will require higher purity Se and optimized anneal process



U.S. Army Research, Development & Engineering Command

Electron transport and Minority Carrier Lifetime in HgCdSe



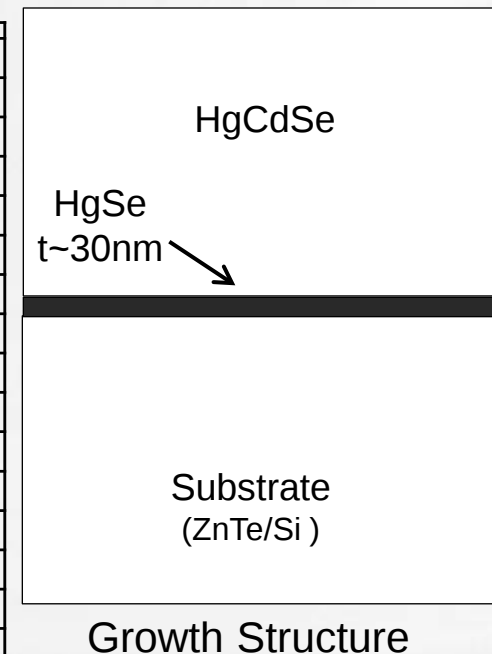
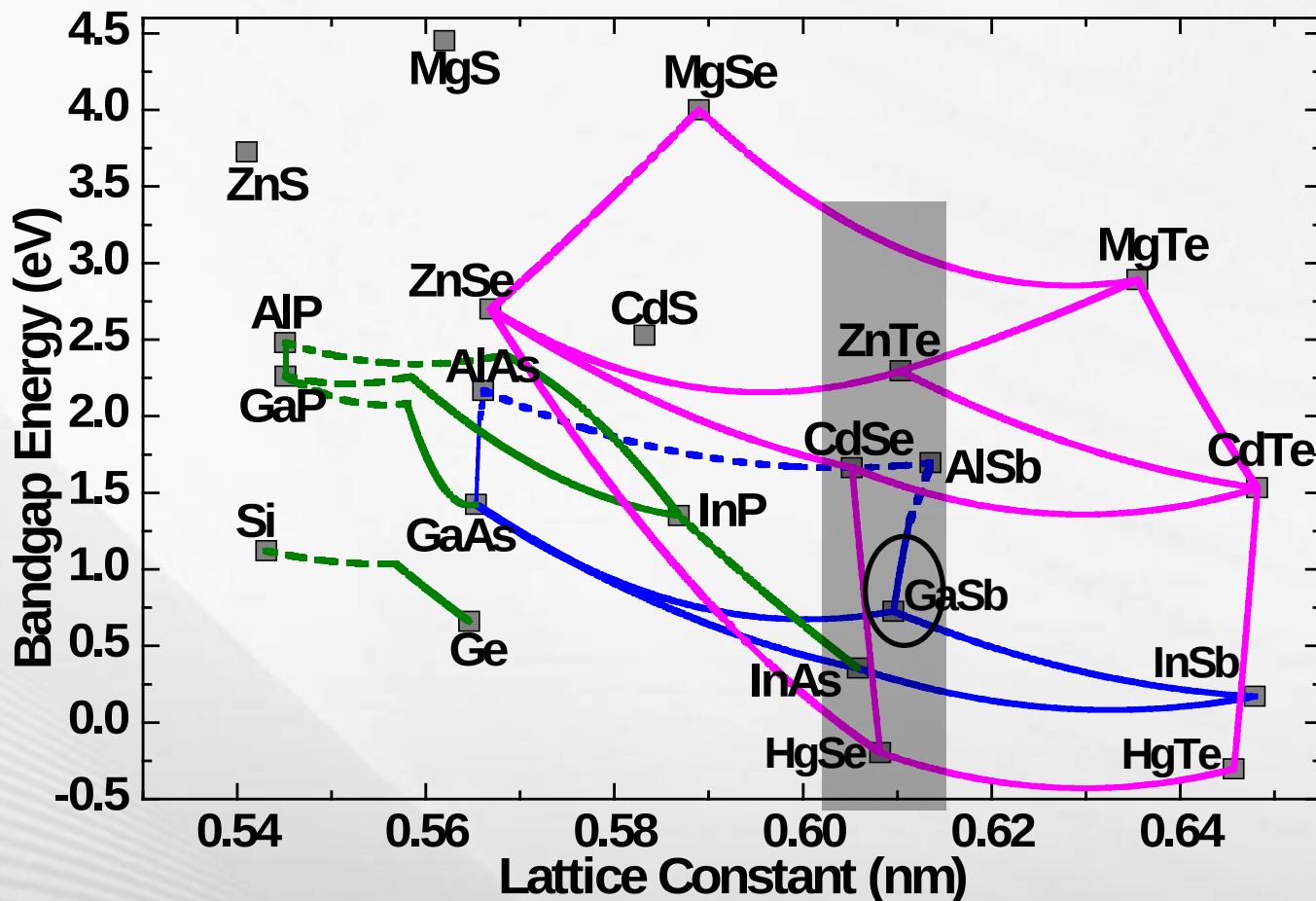
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

K. Doyle¹, C. H. Swartz,² J. Pattison,¹ Y.P. Chen,¹ and T. H. Myers²

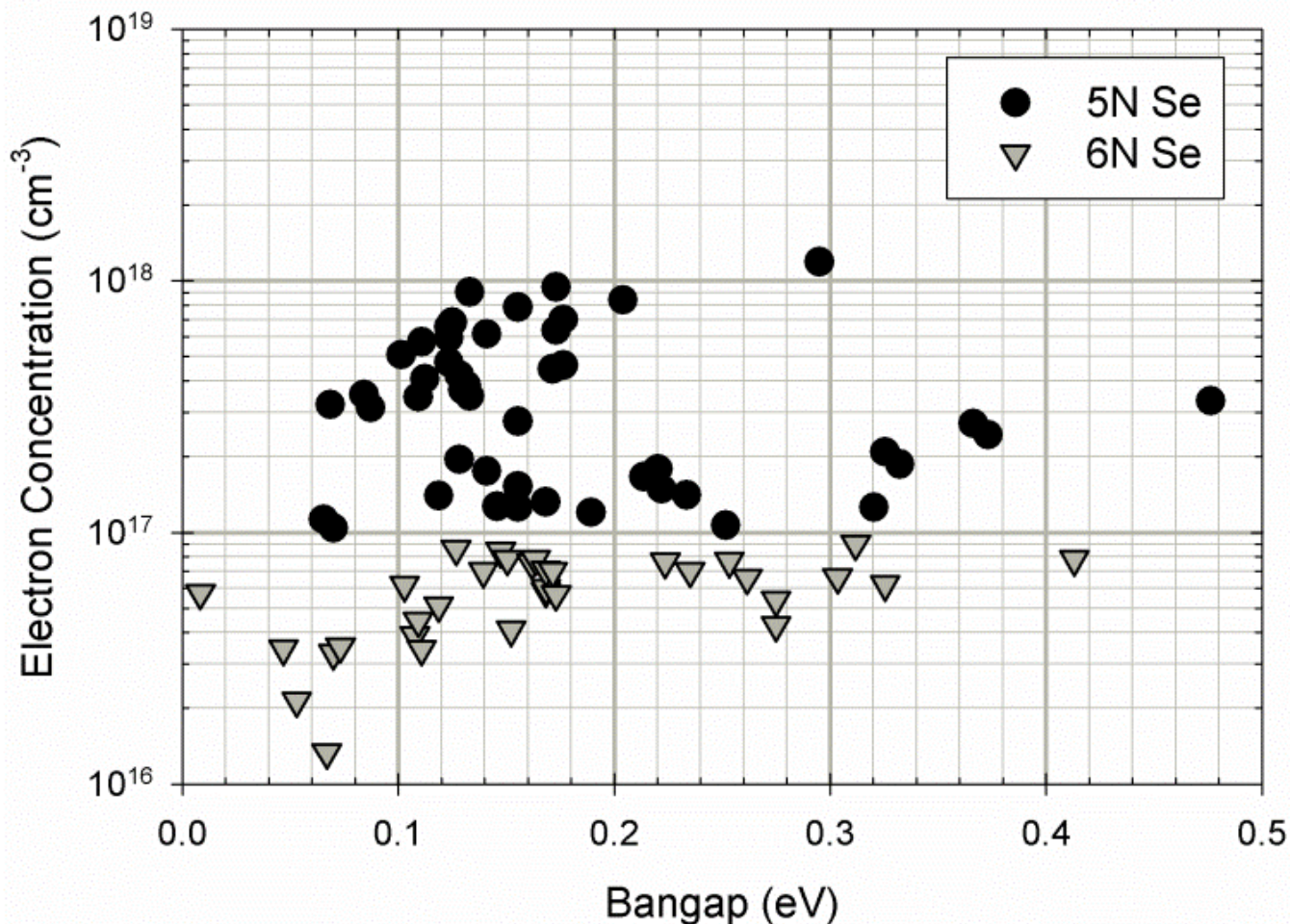
1. Army Research Laboratory, Sensors and Electron Devices
Directorate, Adelphi, MD, USA
2. Texas State University, MSEC department. San Marcos, TX, USA

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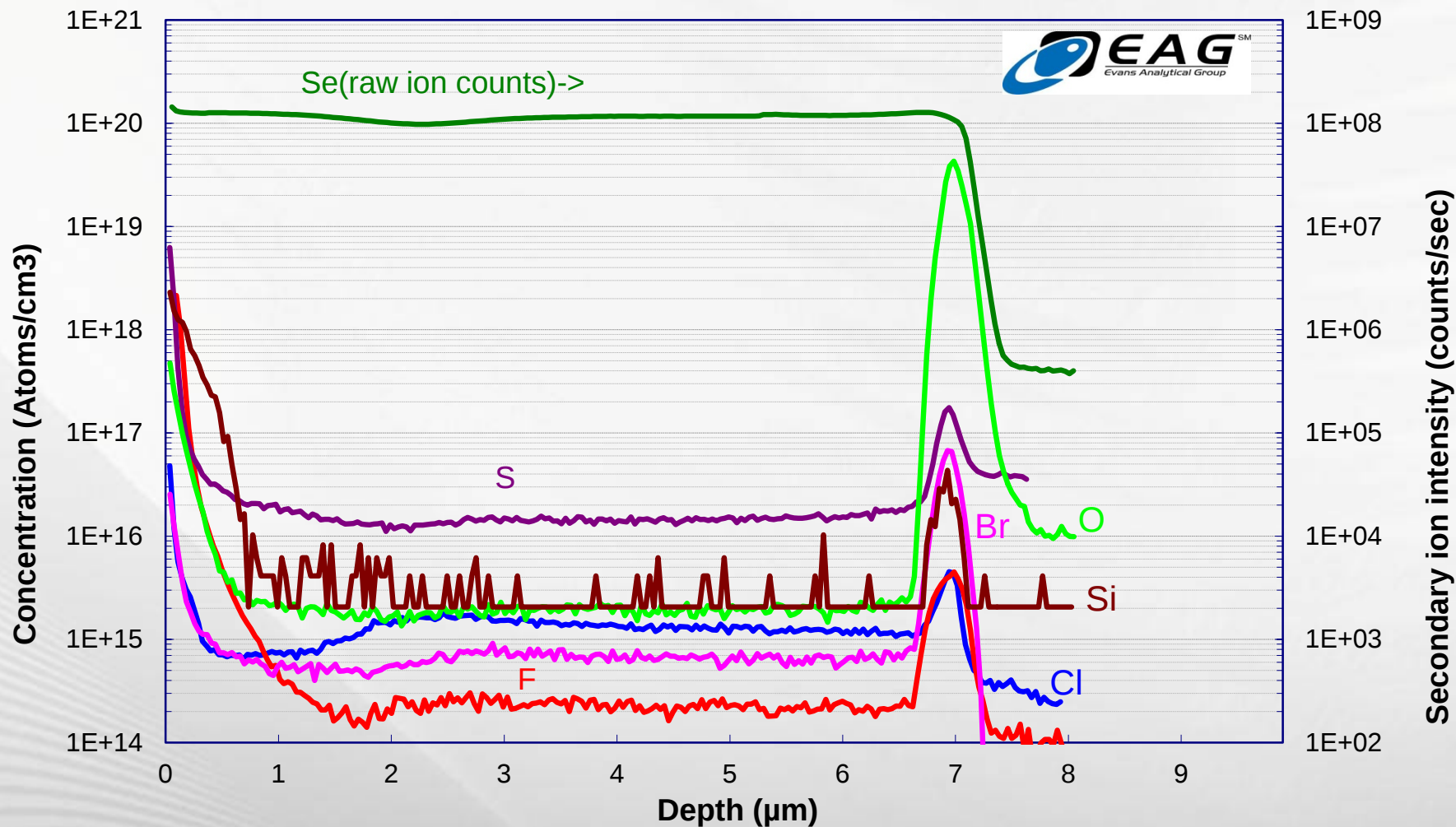




- HgCdSe is being investigated as an alternative IR material since it is closely lattice-matched to GaSb substrates.



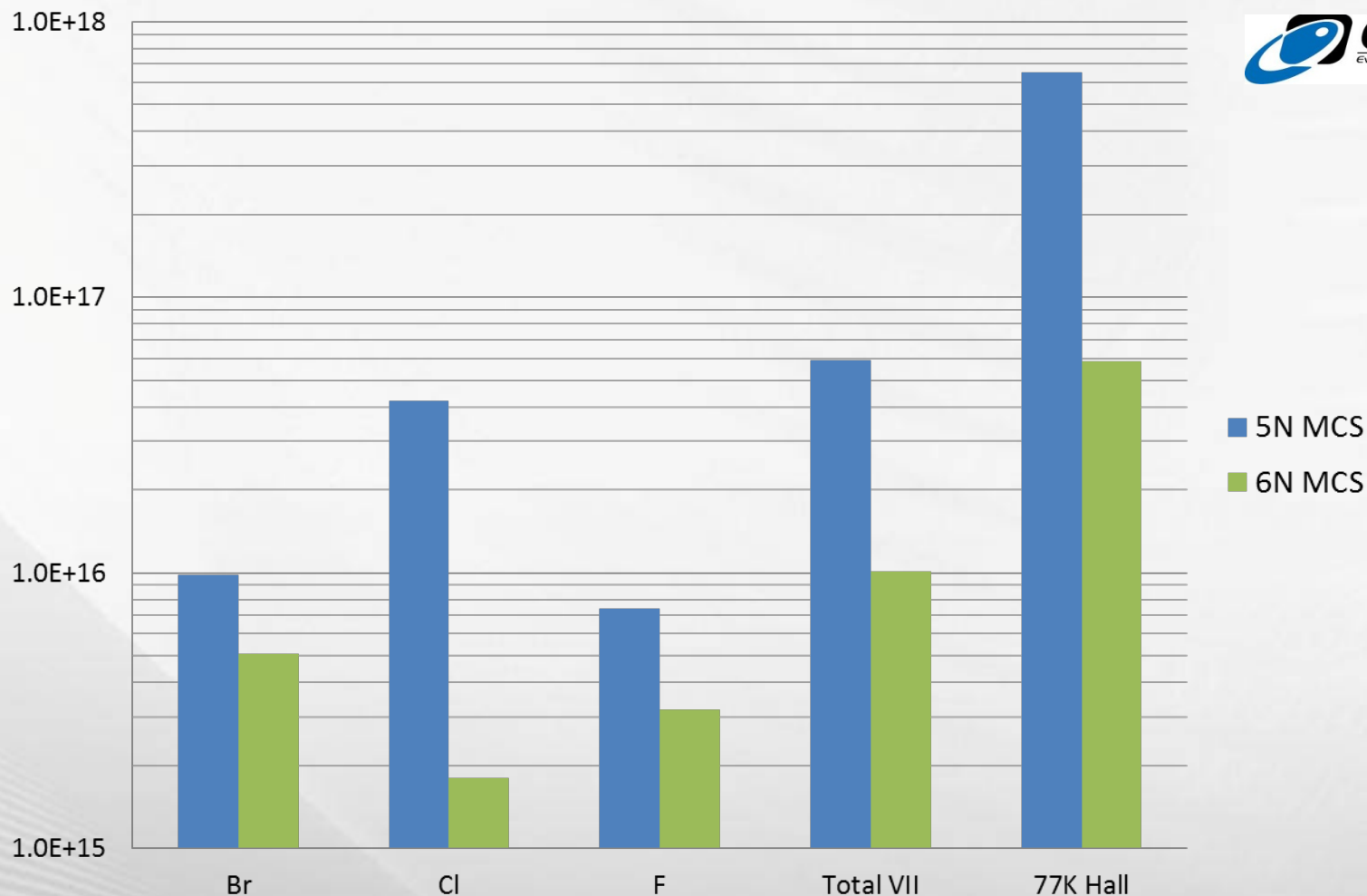
As-grown HgCdSe electron concentration reduced an order of magnitude by switching to higher purity Se source material



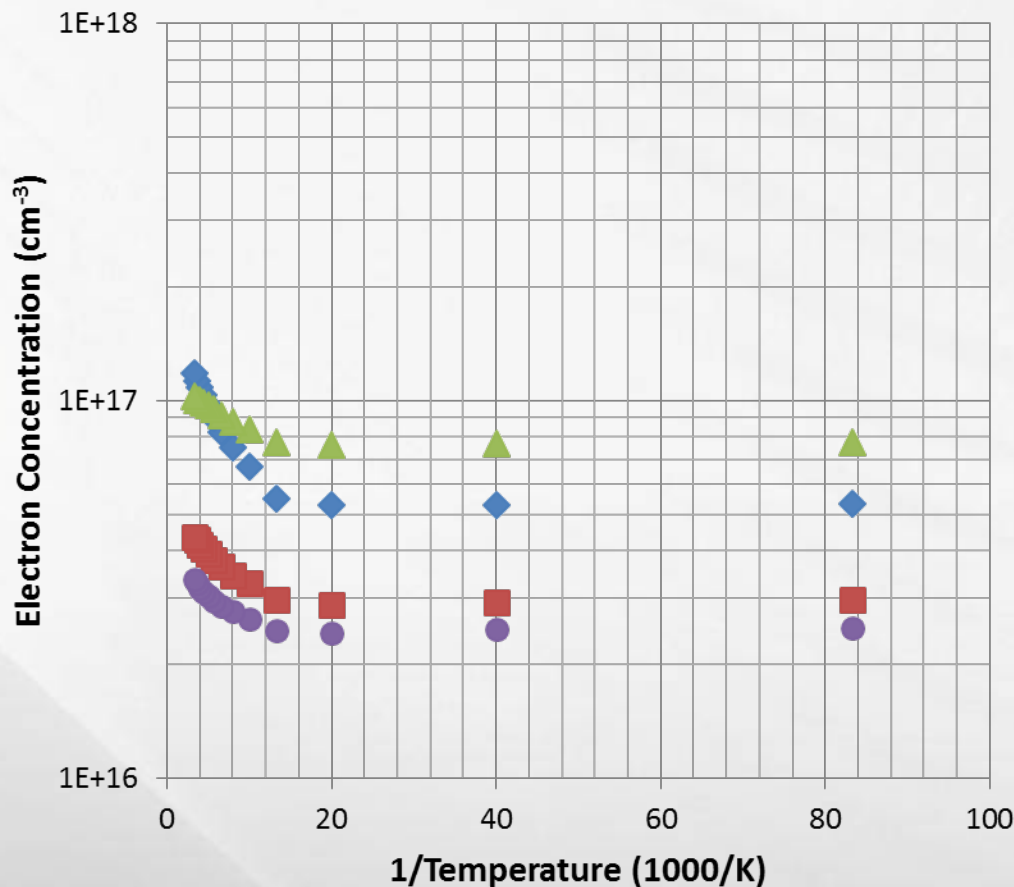
Group VII impurities detected, particularly near the ZnTe interface. Could be acting as donors



Group VII SIMS Concentrations



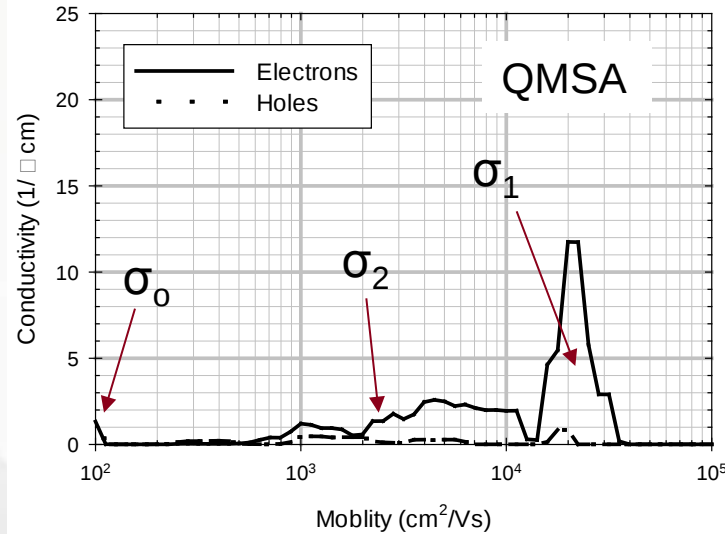
Reduction in electron concentration corresponds with reduction in Group VII elements detected by SIMS.



6N Se,
 $\lambda_c = 5\mu\text{m}$

- ◆ As-Grown
- ▲ Hg-Annealed
- Se-Annealed
- Hg-then-Se Annealed

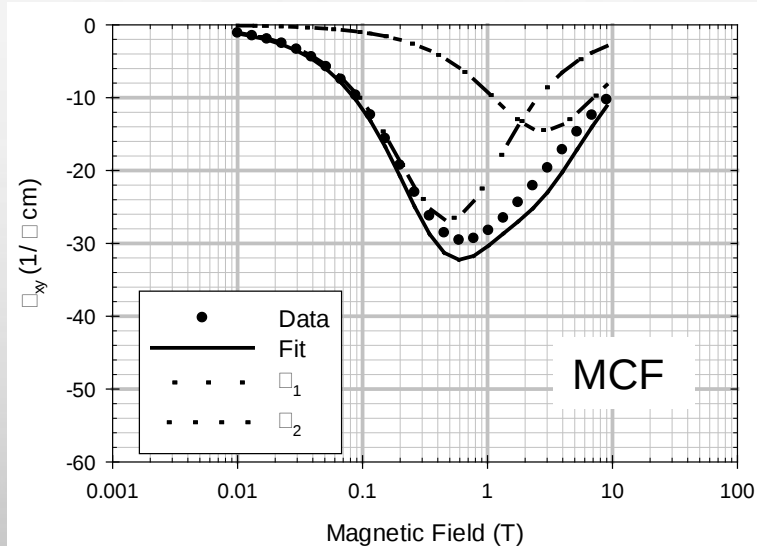
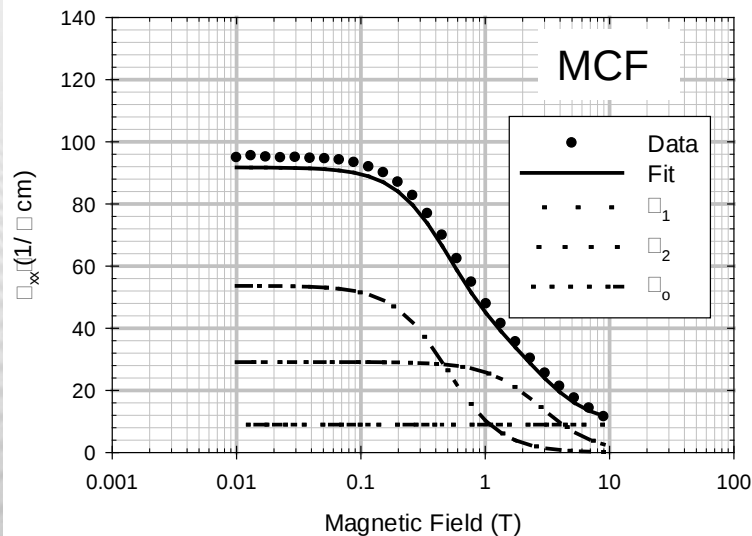
- Electron concentration raised after Hg-annealing, lowered after Se annealing, suggests additional p-type Hg vacancies and n-type Se vacancies.
- Appear to have mixed conduction effects at higher temperatures

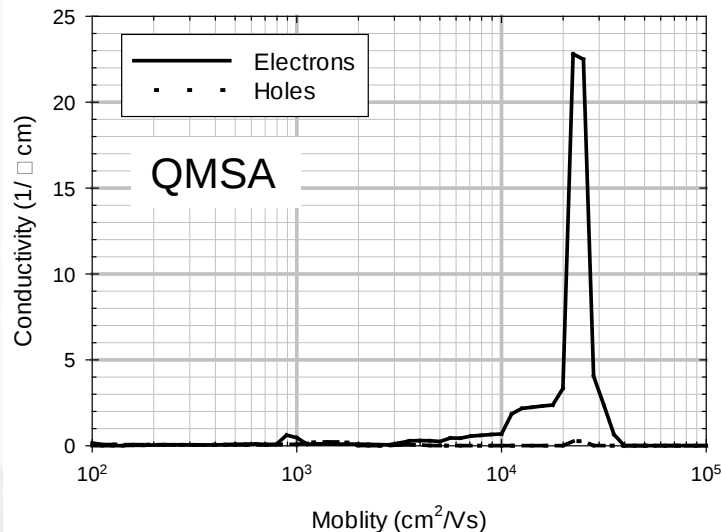


$$\sigma_{xx}(B) = \frac{en_1\mu_1}{1 + (\mu_1 B)^2} + \frac{en_2\mu_2}{1 + (\mu_2 B)^2} + \sigma_o$$

$$\sigma_{xy}(B) = -\frac{en_1\mu_1^2 B}{1 + (\mu_1 B)^2} - \frac{en_2\mu_2^2 B}{1 + (\mu_2 B)^2}$$

$(\mu B) \ll 1$



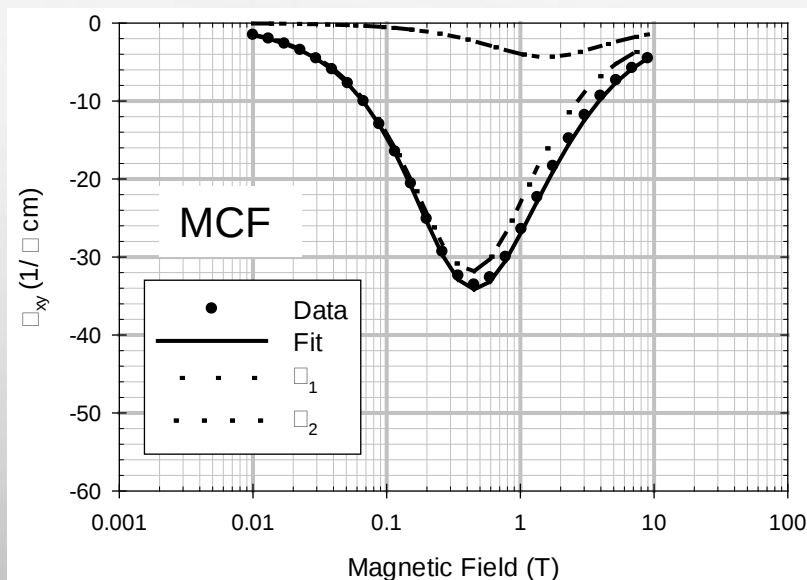
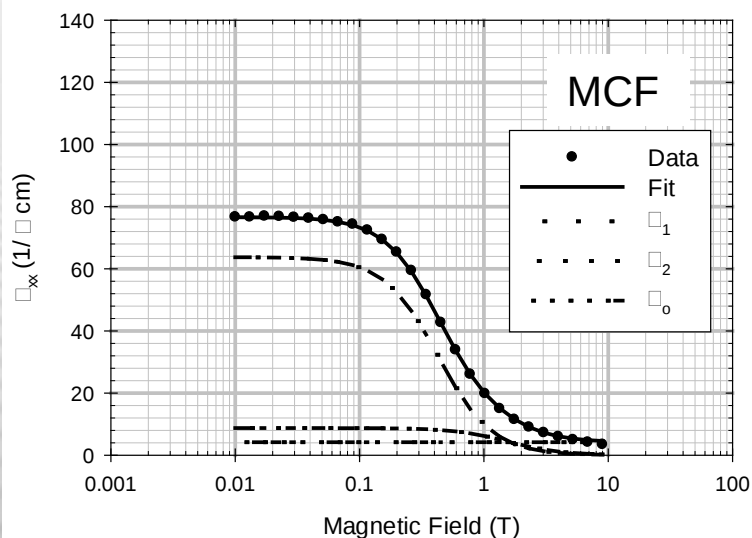


Stage	Element	Temp.	Duration
1	Hg	250 °C	24 hrs
2	Se	250°C	24 hrs

$$\sigma_{xx}(B) = \frac{en_1\mu_1}{1+(\mu_1B)^2} + \frac{en_2\mu_2}{1+(\mu_2B)^2} + \sigma_o$$

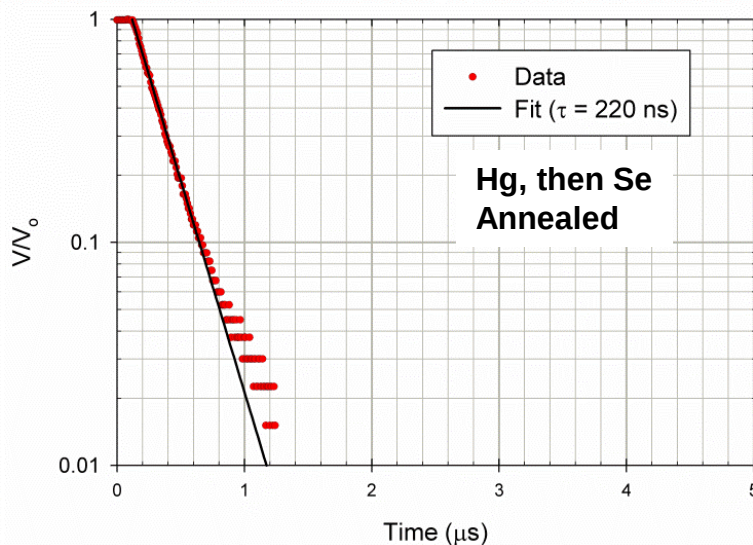
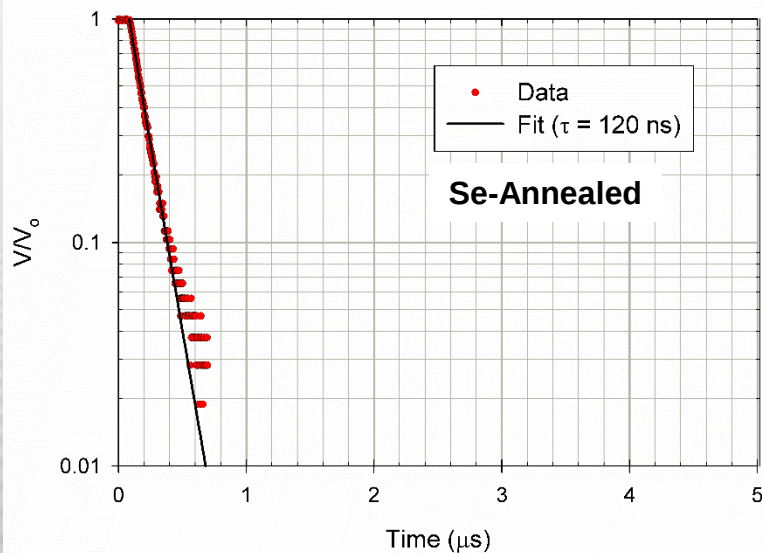
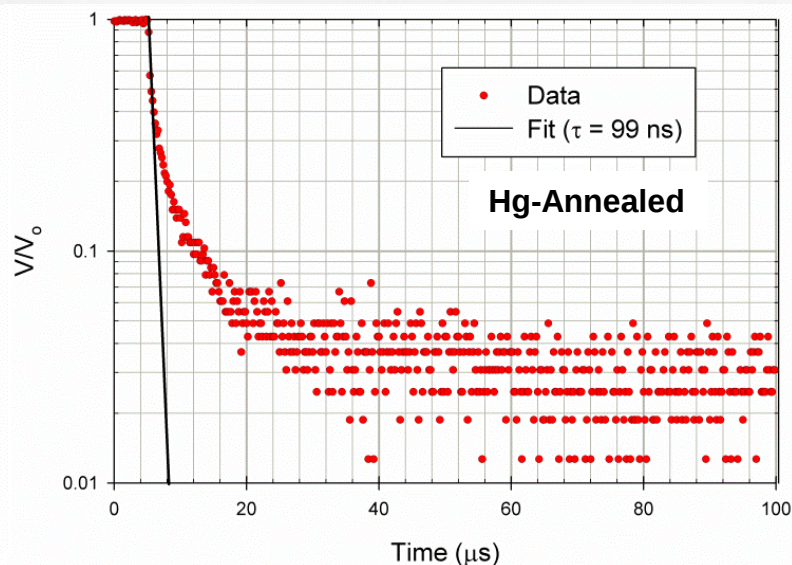
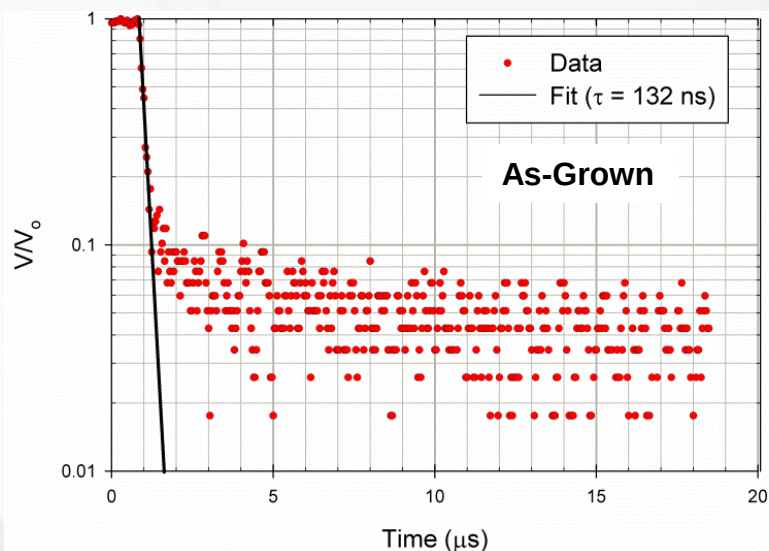
$$\sigma_{xy}(B) = -\frac{en_1\mu_1^2B}{1+(\mu_1B)^2} - \frac{en_2\mu_2^2B}{1+(\mu_2B)^2}$$

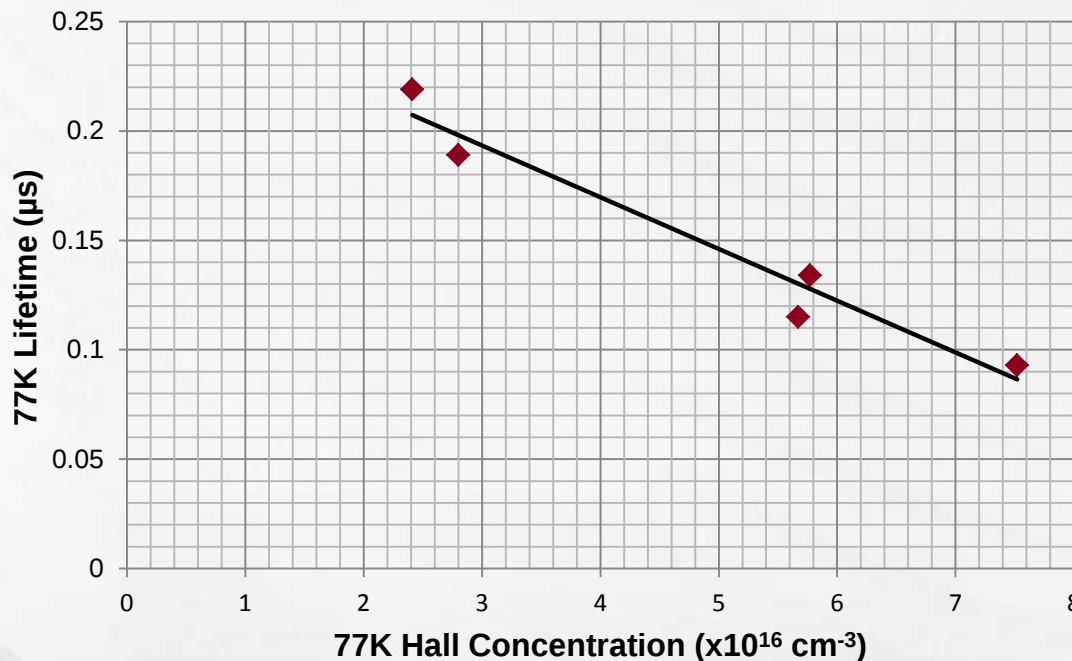
$(\mu B) \ll 1$





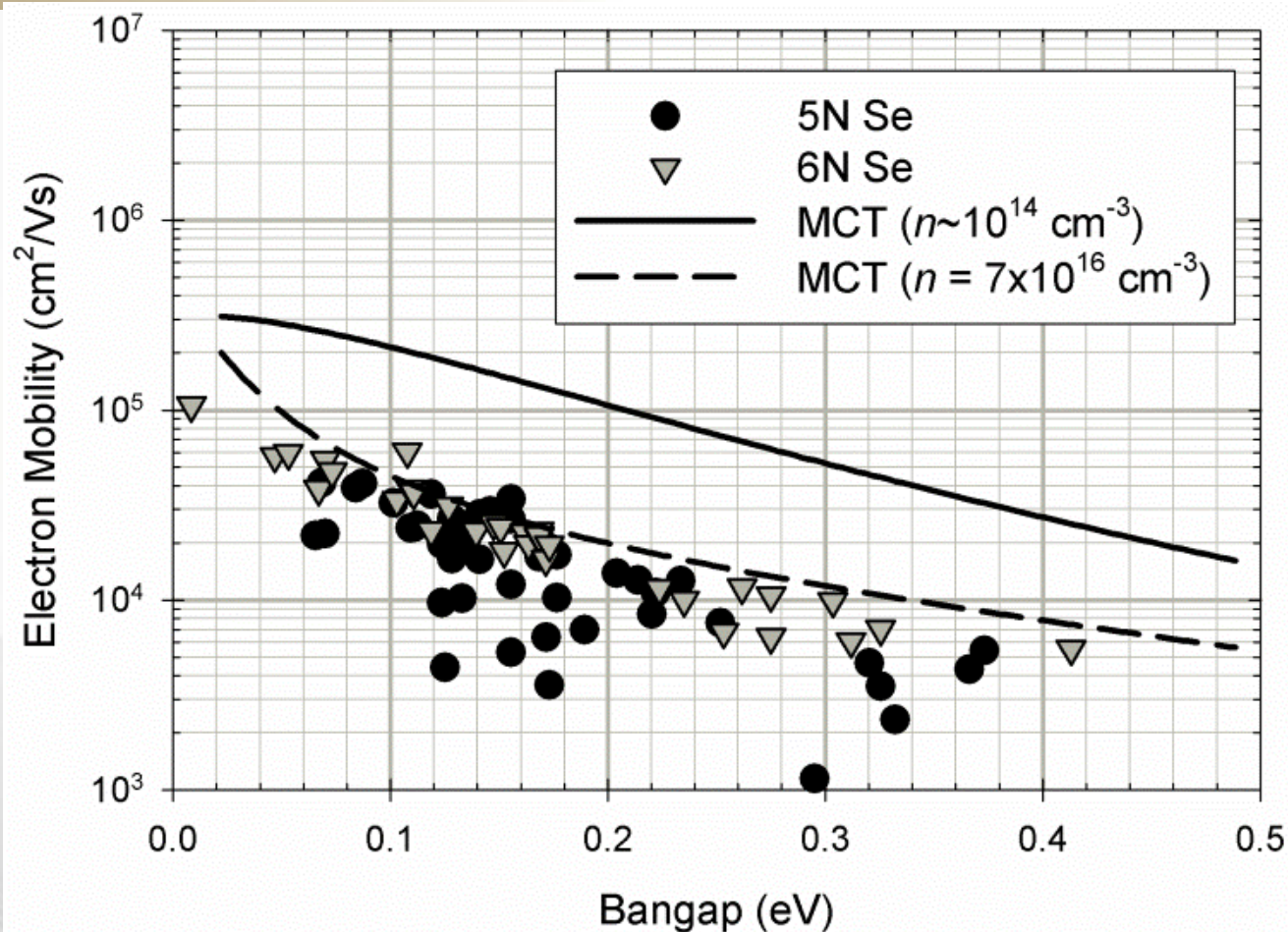
Parameter	As-Grown	Hg-Annealed	Se-Annealed	Hg, then Se Annealed	Unit
n_1	1.48	3.95	1.70	1.71	$\times 10^{16} \text{ cm}^{-3}$
μ_1	21,304	13,973	22,205	23,298	cm^2/Vs
n_2	4.40	4.21	1.23	0.85	$\times 10^{16} \text{ cm}^{-3}$
μ_2	4,285	4,279	6,233	6,429	cm^2/Vs
σ_1	50.51	88.42	60.47	63.82	$1/\Omega\text{cm}$
σ_2	30.20	28.86	12.28	8.75	$1/\Omega\text{cm}$
σ_0	13.66	7.17	5.87	4.20	$1/\Omega\text{cm}$
σ_1	53.52	71.05	76.91	83.13	%
σ_2	32.00	23.19	15.62	11.40	%
σ_0	14.47	5.76	7.47	5.47	%



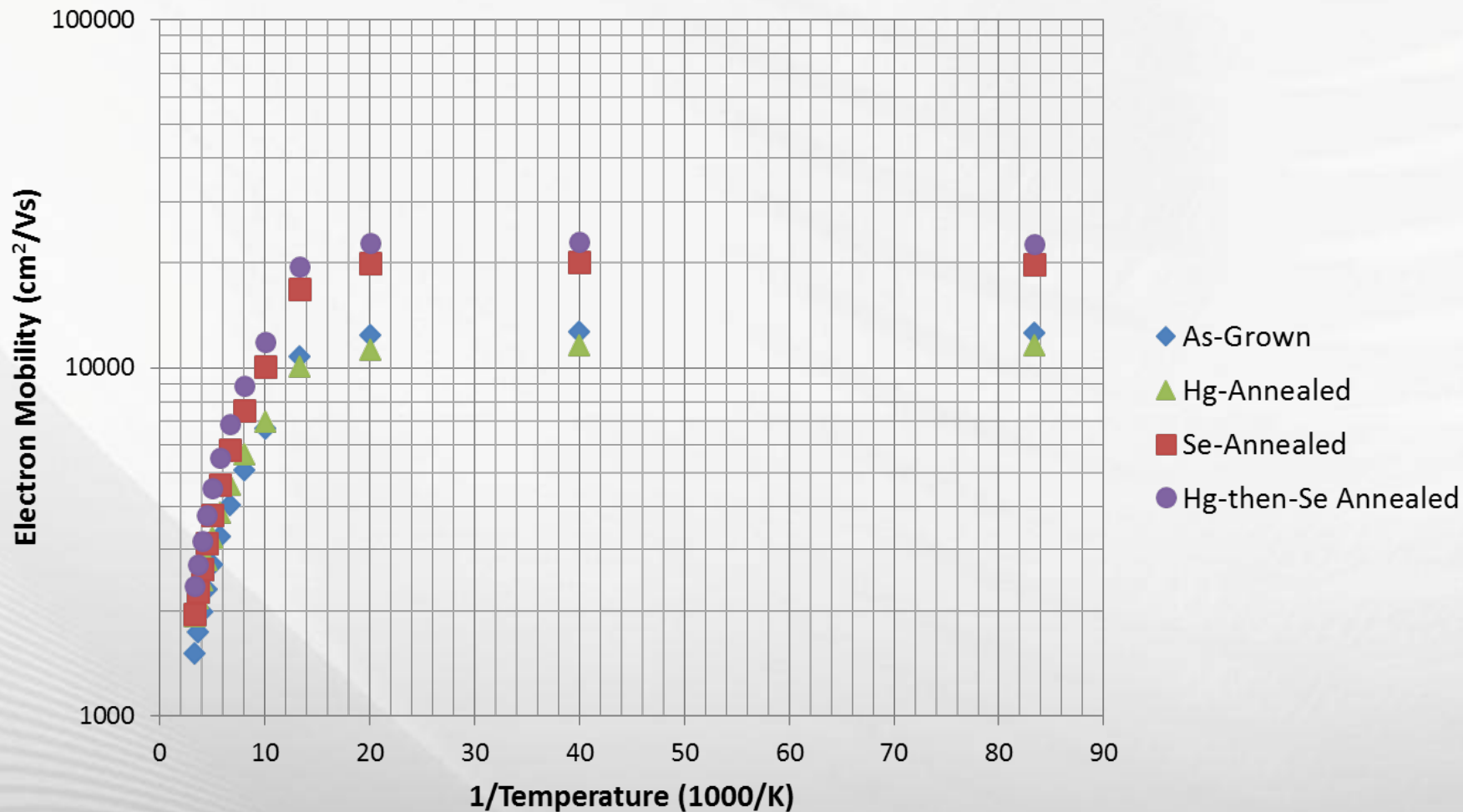


- Transients were fitted. For samples with more than one slope, the first slope was taken as the photo-conductance lifetime.
- As electron concentration decreased with annealing, lifetime increased.
- Longest 77K lifetime was observed for sample annealed under Hg then Se (220 ns)

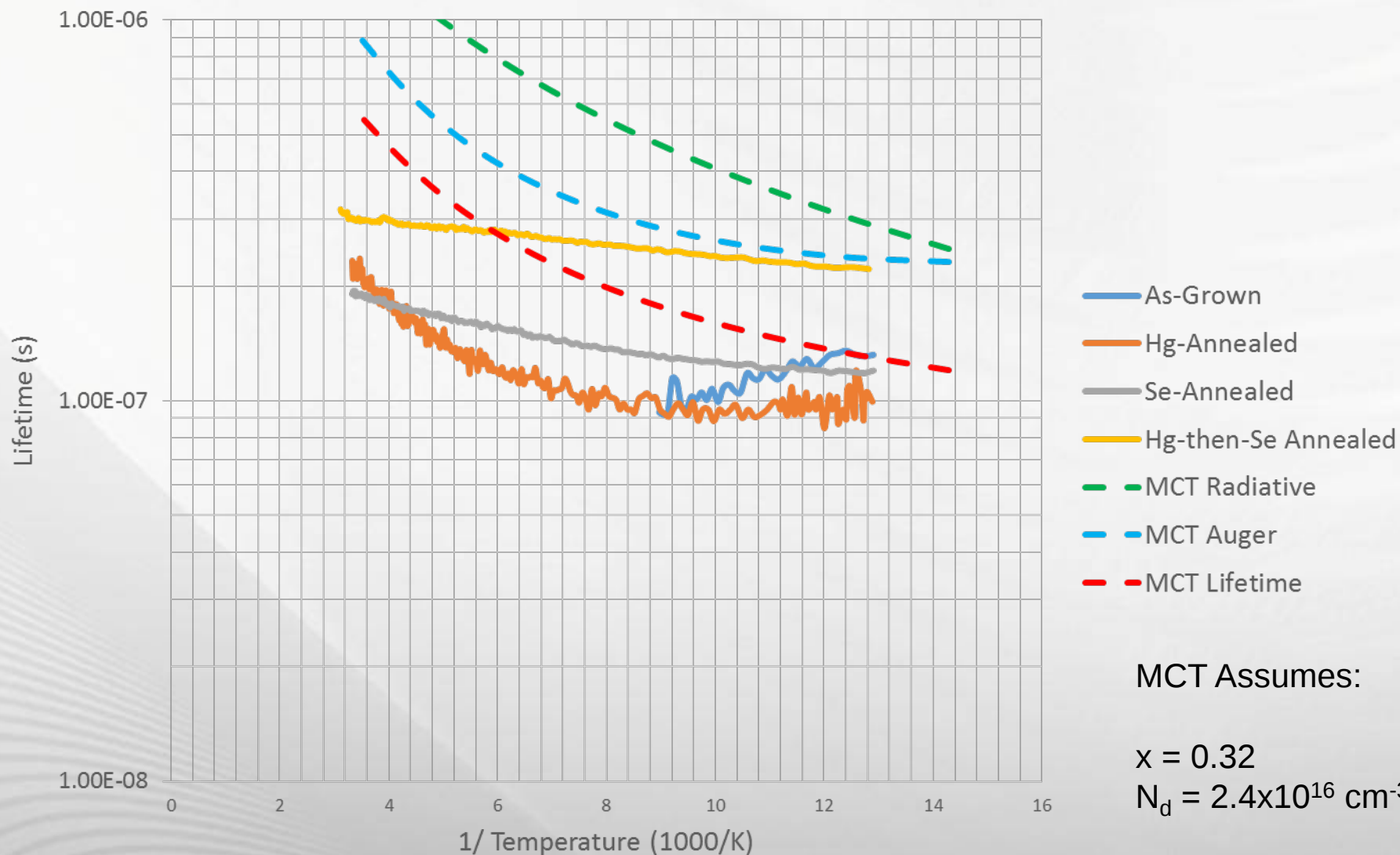
- Major source of HgCdSe background electron concentration is Group VII impurities (Br, Cl, F) introduced from Se source material
- Change in concentration with annealing suggests p-type Hg vacancies and n-type Se vacancies
- QMSA suggests an inhomogeneous distribution of electrons introduced in growth, reduced with Hg-then-Se anneal making mobility more discrete
- Lower electron concentration allows us to see PCD transients, which suggest trap present in as-grown material that is increased with Hg-annealing but removed with Se-annealing, could be Se vacancies
- Lowering background electron concentration and increasing lifetime will require higher purity Se and optimized anneal process



As-grown HgCdSe electron mobility comparable to HgCdTe of similar electron concentration.



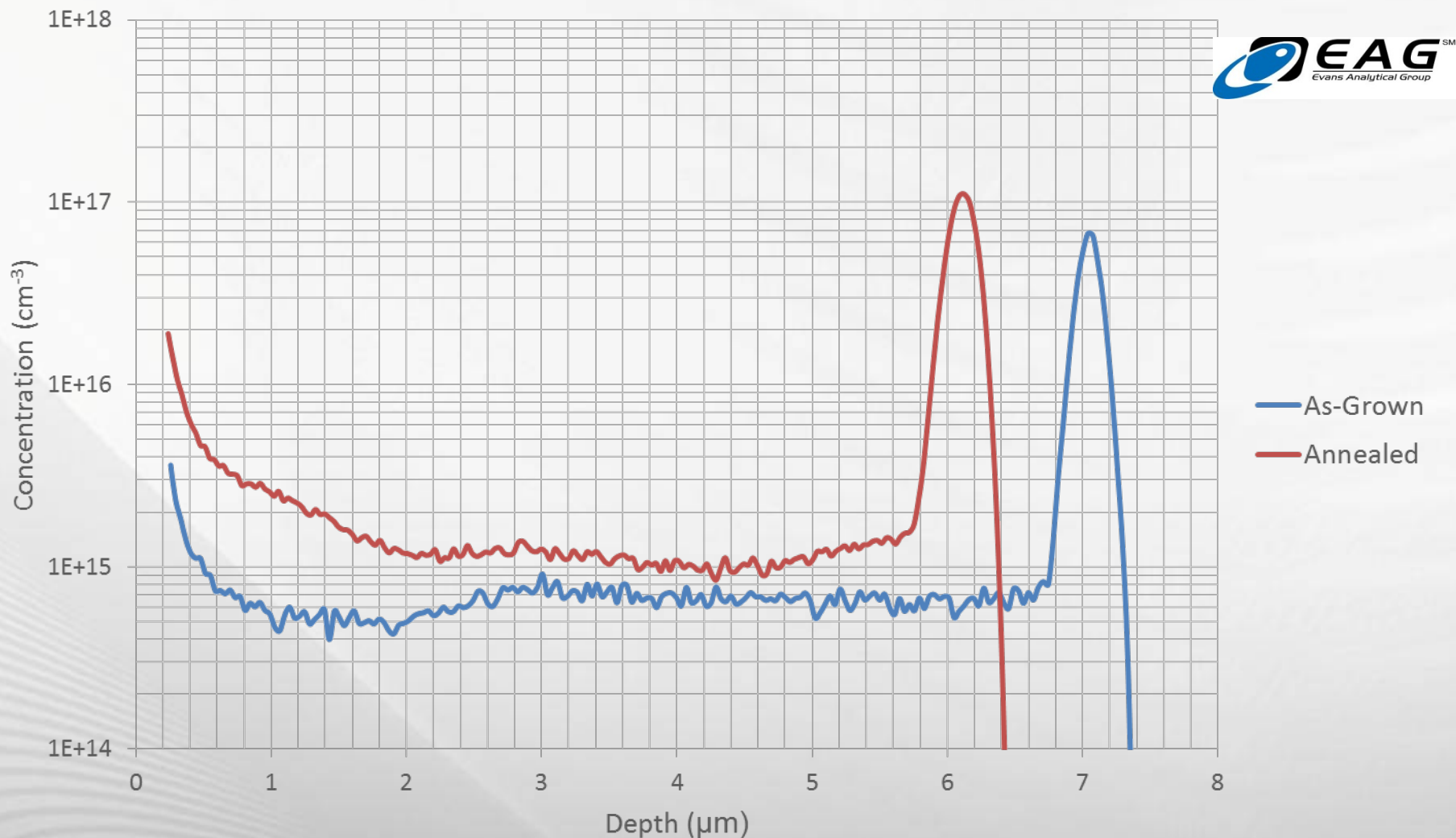
- Electron mobility raised/lowered with concentration after anneal

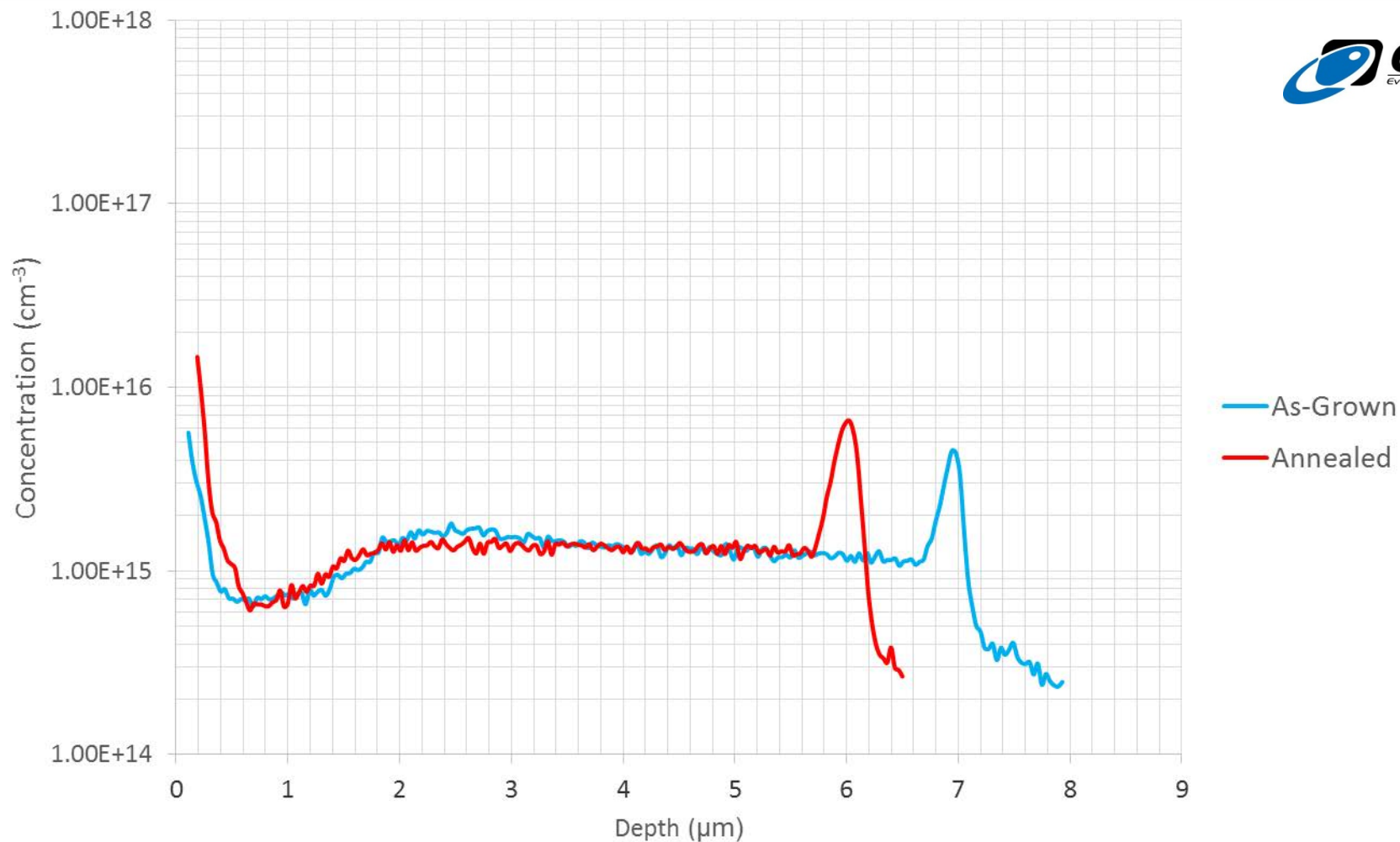


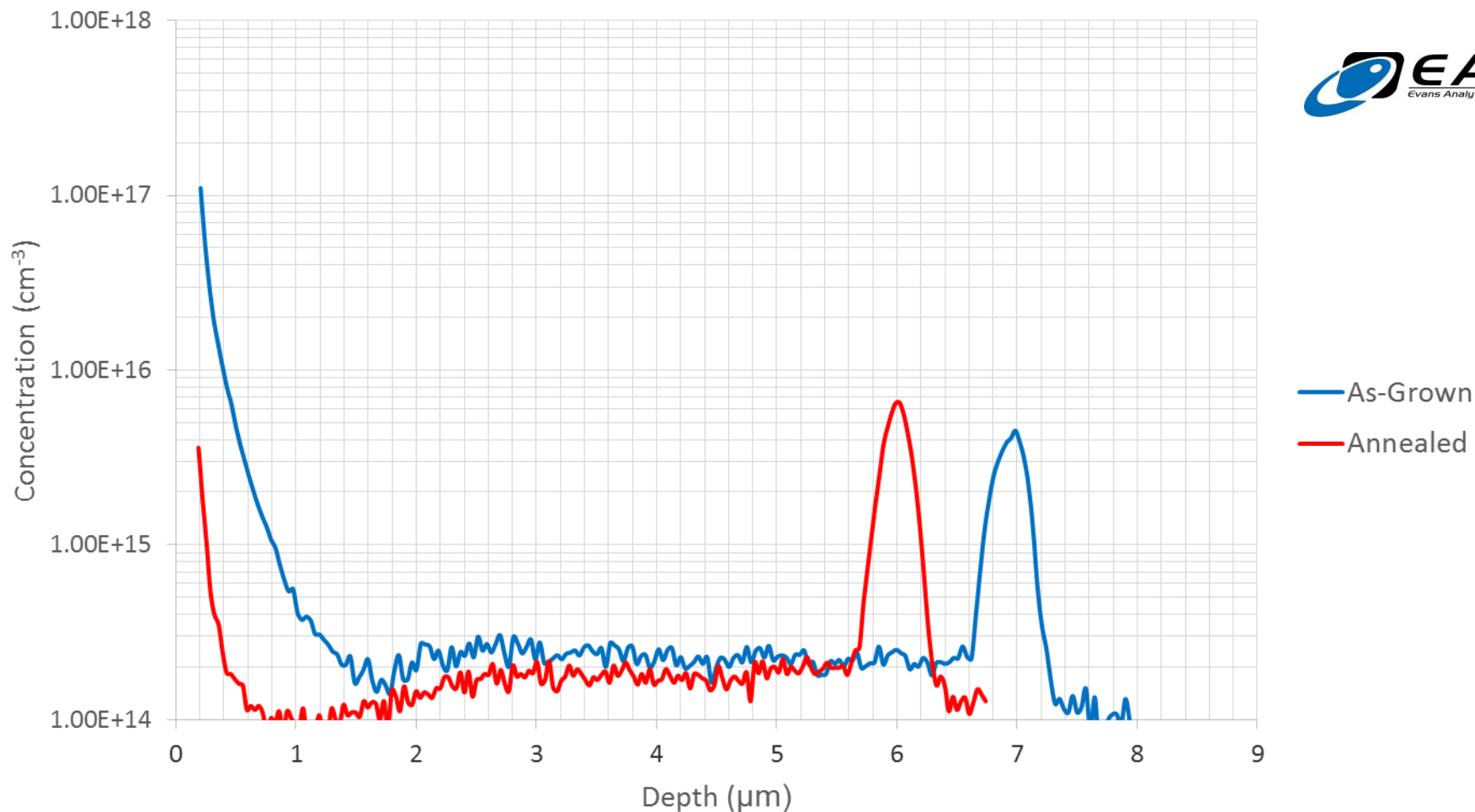
MCT Assumes:

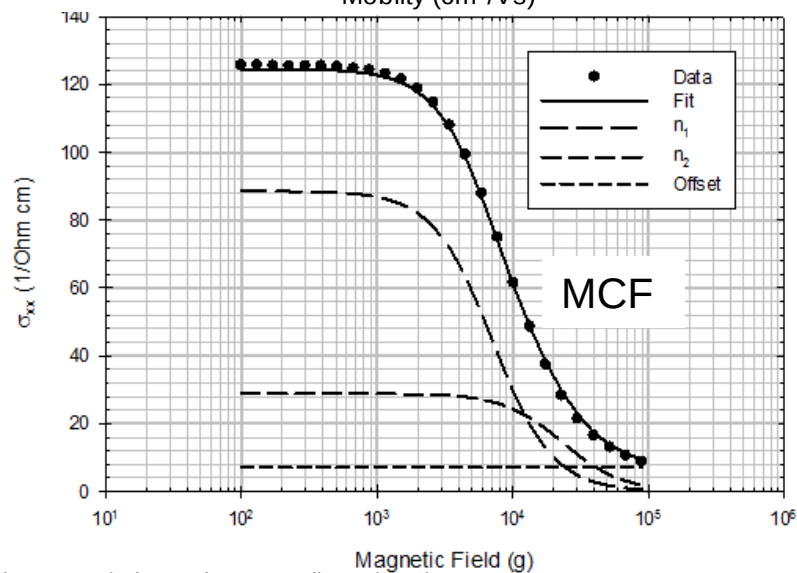
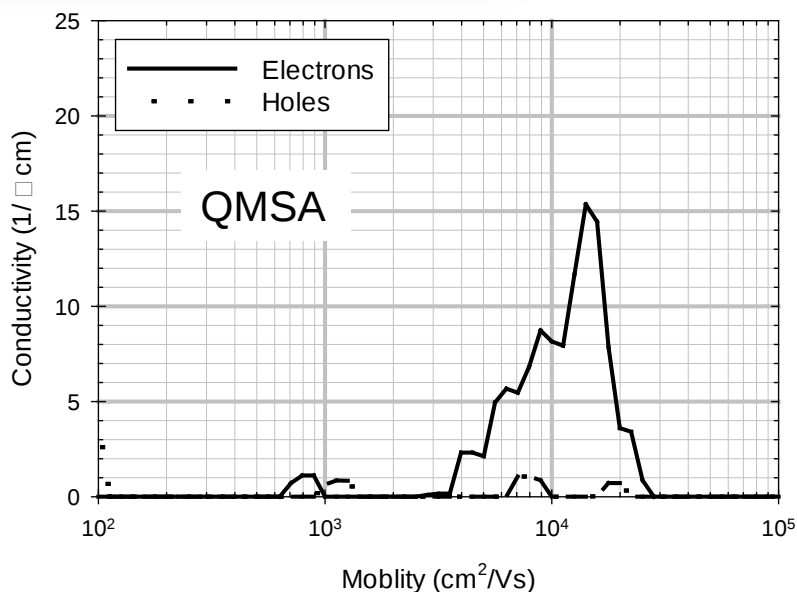
$$x = 0.32$$

$$N_d = 2.4 \times 10^{16} \text{ cm}^{-3}$$







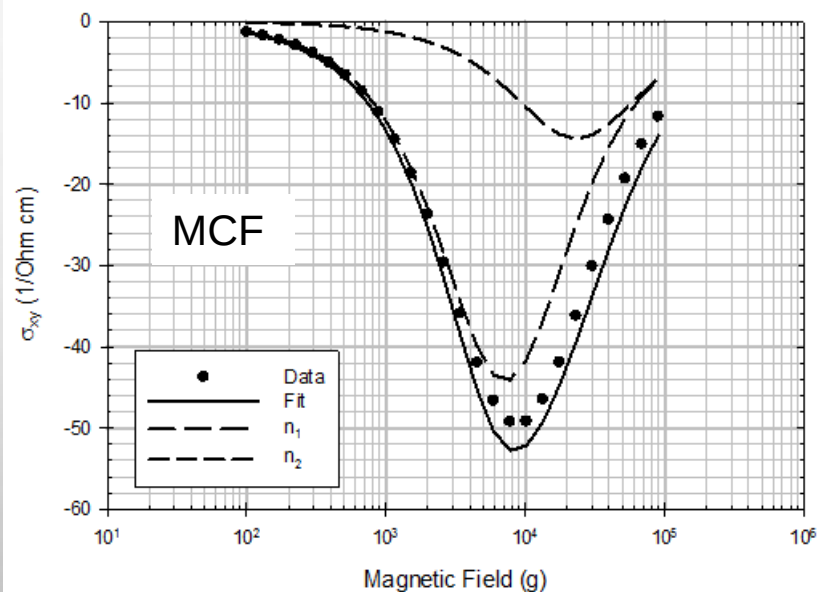


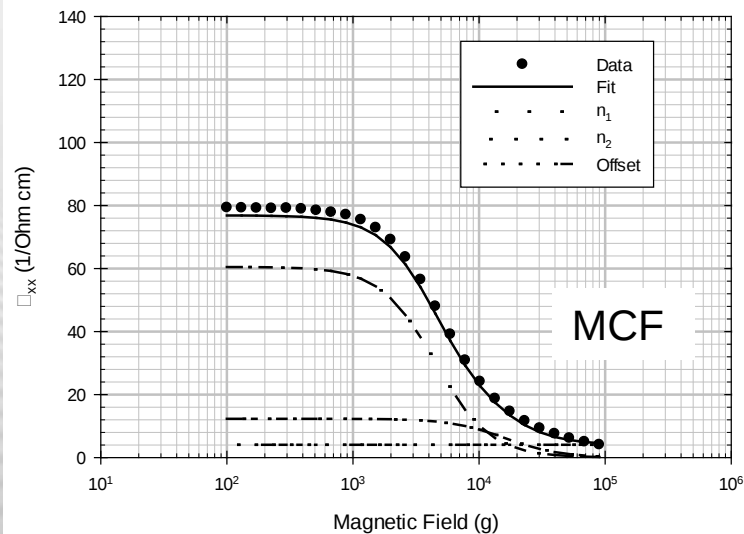
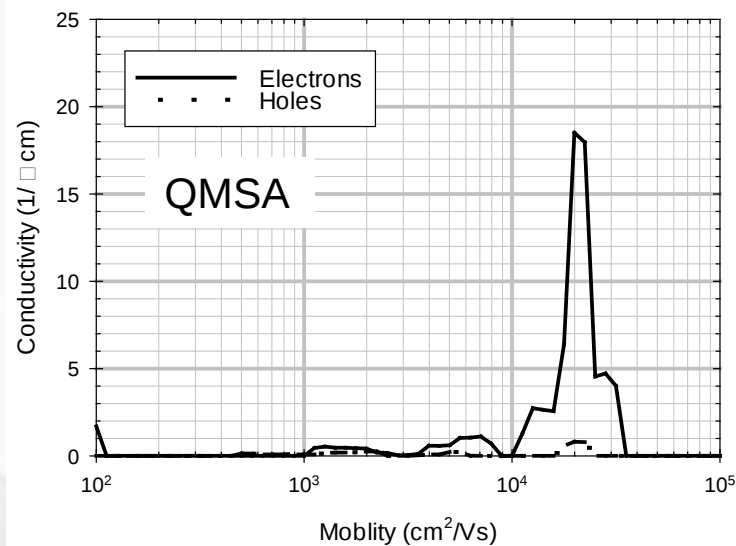
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$(\mu B) \ll 1$





Stage	Element	Temp.	Duration
1	Se	250 °C	24 hrs

$$\sigma_{xx}(B) = \frac{en_1\mu_1}{1+(\mu_1 B)^2} + \frac{en_2\mu_2}{1+(\mu_2 B)^2} + \sigma_o$$

$$\sigma_{xy}(B) = -\frac{en_1\mu_1^2 B}{1+(\mu_1 B)^2} - \frac{en_2\mu_2^2 B}{1+(\mu_2 B)^2}$$

$(\mu B) \ll 1$

