Germanium Solar Cells: The Problems to the Solution

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Introduction

Solar panels that are typically made of semiconductors are only up to 33% effective. One reason is because solar panels do not absorb all the light. In order to combat this, *hyperdoping* was developed to incorporate ultra high concentrations of other elements. This results in more light absorption but, there is less time for energy conversion due to new structural damages. This leads to using soft furnace annealing and PLM (Fig 1) which helps to remove some damages and restore a crystalline structure. With Tellurium hyperdoped Germanium (Ge:Te) there are dopant tails that come from the tellurium which negatively impacts lifetime. These damages are fixed by *pre-amorphization* which should keep dopant tails from forming. This experiment is to test the quality of Ge:Te and the impacts of pre-amorphization and annealing.

Methods

We utilize Terahertz Spectroscopy on various samples of Germanium.

- All samples are excited with a 400nm light at 0.6mW
- Various factors such as conductivity, mobility and lifetime can be measured

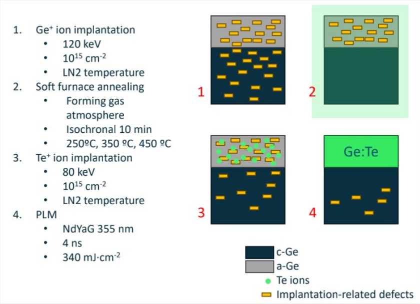


Fig 1. Depiction and explanation of possible processes on Ge
- Ge+ ion implantation = pre-amorphization
- Ion Implantation = II
- PLM = Pulse Laser Melting

Results and Discussion

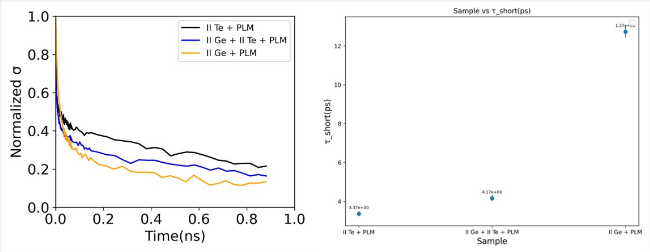


Fig 2 & 3 representing conductivity (left) and lifetime (right) measurements for samples that were hyperdoped (black), hyperdoped and pre-amorphized (blue), and pre-amorphized (orange)

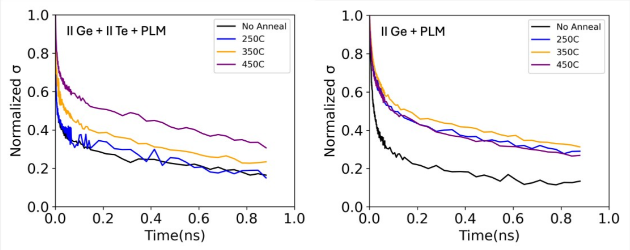
What does pre-amorphization actually do?

- Normalized conductivity plots are unexpected
- Normalized conductivity is a reflection of lifetime
  - After 0.05ns is reflection of lifetime in undoped region
- Fig 1 implies structural damage in II Ge + PLM is greater than damage from II Ge + II Te + PLM
- *Fitting Equation*: $\sigma = A_{short}e^{-t/(T\ short)} + A_{long}e^{-t/(T\ long)}$
  - t = time | A = ratio of charge carriers | T = lifetime |
  - short/long = represents if carriers are in doped/undoped region
- The expectation is that pre-amorphization + hyperdoping leads to a much higher lifetime than when just pre-amorphized
  - Reality shows that while pre-amorphization does help in doped region, it has far less impact (only 24% increase)

What does pre-amorphization and annealing do?

- In general, increasing annealing temperature for Ge:Te that is pre-amorphized and hyperdoped improves lifetime
- The most effective annealing temperature is unknown
  - While trend indicates that higher annealing leads to higher lifetime, trend is not linear.
- Samples in Fig 5 pre-amorphized saw benefits up to 350C
  - Decreased at 450C potentially due to crystallization
- It would be useful to study hyperdoped Ge with annealing to compare to other annealed samples

Fig 4 & 5 representing normalized conductivity comparisons of samples that were pre-amorphized and hyperdoped(left) and those that were only pre-amorphized (right) across different annealing temperatures.



Conclusion and Next Steps

Overall, the predictions for the experiment do check out. Pre-amorphization and annealing do have positive impacts, but it is nothing revolutionary. Changes are noticeable but results indicate that dopant tails are not as impactful of a factor as initially thought. Next, we want to test the THz conductivity of these sample with infrared excitation at 2500 nm. At this level, only tellurium absorb the light which may provide interesting results. Additionally, we can test germanium that is hyperdoped with tellurium and annealed in order to better characterize what pre-amorphization does.

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