Summary Notes: Production and characterization of damage; experiments and supporting modeling

Hasegawa-san and Allain

- Defect Production
  - How quantitative can one make these investigations regarding defect evolution? density of defects, etc…
    - Number density of defects uncertainty is relatively low and TEM resolution is very good. Presence of very small defects may not be visible in some techniques and one needs to use caution.
    - Structures could depend on GB orientation and it is important to look at a number of grains to get the quantitative value of defect statistics.

  - Dudarev: Two experiments missing: 1) comparison of H and He thermal desorption curves for standardization 2) Induce dislocations via cold-worked W specimens; these can be well-controlled experiments, instead of irradiation effects, which can be complicated. To establish understanding on the basis of a standard modification and possible comparison to modeling.

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- Characterization
  - Mayer: First goal it must go step-wise, single type of defects generated in W for example, well-defined samples and experiments.
  - Need to have common samples in laboratories to ensure well-defined experimental results (Mayer). Define specific temperature regimes on damage.
    - Need to establish a methodology in our CRP to obtain W samples from same source. Perhaps IPP Garching (Meyer) can offer limited set of samples for testing.
  - Bas: pointed out the importance of GBs and defect evolution along and at GBs. characterization
  - Grain boundary characterization of irradiated-W is needed to understand diffusion behavior of H.

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- Surrogate Experiments (and Model Experiments)
  - G-H Lu: First step we need to understand what type of defects under neutron irradiation vs plasma-induced defects, trapping energy at these defects and migration of defects and therefore effect of these defects on hydrogen behavior. From modeling point of view one can look vacancy complexes, but as the number of defects evolve in complexity; models can also address these. If one can characterize these defects than you can compare with models.
  - How to design model experiments? can one connect fundamental, single-effect experiments to the more complex conditions of the fusion-materials interaction environment
    - Electron irradiation damage can be a model experiment for studies.
    - Damage below 0.01 dpa that result in separate cascades (Dudarev)
  - High-energy electron irradiation on cubic crystal; defects generated along crystallographic directions. Other issue: critical threshold energies and dpa can be clarified by this experiment. Use thin foils and use about 1.5 MeV electrons; paper in 1978 from France paper. dpa threshold damage lower than what is conventionally known. The displacement energy for W may be lower.

Hydrogen (tritium) retention in damaged tungsten; experiments and supporting modeling. Review of main problems to be addressed in the course of the CRP

Meyer and Hatano-san

- G-H. Lu: TDS is a good experimental tool for comparison with computational models due to trap energies, defect complexes, etc… (Hatano-san mentioned the importance of understanding possible artifacts introduced by temperature ramp yielding annealing and elimination of defects. Mayer: mentioned that TDS could be use but assignment of peaks directly to traps is not solely sufficient.
- C. Zhang: Commented/asked irradiation with hydrogen plasma vs hydrogen gas conditions are important.
  - Heavy ion combined with incident fluxes of H plasma (potentially modifying incident fluxes) could be good to understand effect of microstructure and hydrogen retention.
  - Measurement of TDS along with microstructure could be a good combination to elucidate on TDS spectra.
- Shimada: vacancy cluster migration energy: is this known by modeling? experiments may be difficult to discern complex vacancy clusters. Also pointed out the question of how deep in the bulk one needs to go for simulating conditions in high-dpa environments.

Hydrogen (tritium) retention in damaged tungsten; experiments and supporting modeling. Review of main problems to be addressed in the course of the CRP

Meyer and Hatano-san

- G-H Lu: MD can give you migration energies of vacancy clusters and its connection on rate theory.

- Mayer: Role of He effects on microstructure. He production in W is very low from transmutation point of view. Hatano-san: tritium can yield lots of He-3 production in solid state over 3 years. From: plasma He/H effects on surface are important.

- Grisolia: impurities of oxygen in machine should be accounted in context of the surface, sub-surface conditions (equally important to the consideration of He).

- Pelicon: Mentioned various methods to introduce hydrogen from various sources at various depths in materials in bulk scale: plasma, ion-beams, electrons, etc…

- Hatano-san: plasma can induce blisters and bubbles with hydrogen. One could introduce H in more controlled way use: gas, atoms. Gas exposure can be done at high temperature and you can study bulk properties very well (while avoiding irradiation)