HEAT DIFFUSION IN SHOCKED CHONDRITES: TOWARDS A BETTER UNDERSTANDING OF SHOCK MELTING FEATURES. J. Moreau[1], S. Schwinger[2]. [1]Department of Geosciences and Geography, University of Helsinki, Finland (juulia.moreau@helsinki.fi), [2]German Aerospace Center (DLR), Berlin, Germany.

Introduction: In recent years several studies have employed numerical modeling with the iSALE shock physics code [1] in order to investigate conditions of localized shock melting in ordinary chondrites [2–4]. The models showed high contrasts of post-shock temperatures between iron sulfides, or silicates, and metals (>400 K, [3]). Such temperature contrasts on the µm scale can be expected to be leveled quickly by heat diffusion. However, the process of heat diffusion is not implemented in the iSALE code and hence has not been considered in previous studies. Consequencetly, previous models failed to replicate melting of metals in eutectic mixtures with iron sulfides, or melting of metals with silicates, which is a commonly observed feature in shocked ordinary chondrites. To obtain a more realistic model of shock melting in ordinary chondrites, we simulated post-shock heat diffusion on the grain scale using 2-D post-shock temperature maps produced by the iSALE code as initial condition. To reproduce observed melting features, we implemented simplified textural models with different grain configurations typical of textural features in ordinary chondrites.

In addition we systematically investigated the effects of shock pressure, porosity, grain size and grain orientation relative to the direction of the shock wave on the degree of shock melting.

Methods: We set up 12 textural models and used the iSALE code to determine 2-D-maps of post-shock temperatures, following the procedure described in [3]. These maps were further processed using a 2-D heat diffusion code that exerts a finite difference solution for multi-phase meshes and heterogeneous thermal diffusivities with Dirichlet boundary conditions, update of phase thermal diffusivities according to current local temperatures and consideration of partial melting with change of state.

For simplification, the code only considers:

- post-shock heat diffusion, without consideration of heat diffusivity change with pressure
- even-spaced nodes of different materials (identical to the uncompressed state of the iSALE meshes)
- simplified eutectic properties (melting temperatures of 1261 K for iron or troilite phase in mixtures)

The distribution of temperatures, melt fractions and thermal diffusivities was recorded for each timestep of the diffusion model in order to track the change of

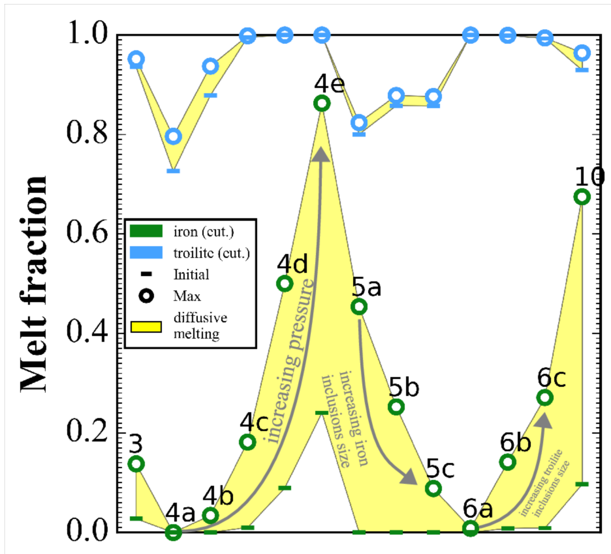

Fig 1. Melt fractions in models with intergrown iron and troilite grains in an olivine matrix. The model textures are either iron inclusions in troilite grains (models 3-5) or troilite inclusions in iron grains (models 6 and 10). The symbols represent the initial (shock melting) and maximum (diffusive melting) values of melt fraction for iron and troilite in each model. Yellow fillings between the initial and maximal values represent the contribution of heat diffusion to the melting of each phase. The effect of pressure and inclusion size on the degree of melting is illustrated by the gray arrows.

these properties with time.

Results: The consideration of heat diffusion has a significant effect on the modeled post-shock heat distribution and the resulting degrees of shock melting experienced by individual phases. In Fig. 1 we compile results of models representing mixtures of iron and troilite. As it has been observed in previous studies, we find that individual phases experience different degrees of heating by the shock wave due to their different shock wave impedances. Most notably, troilite is strongly heated and easily melted by shock, while shock heating of iron is limited. However, if iron is intergrown with strongly shock heated phases like troilite, as it is often observed in ordinary chondrite textures, iron can melt from the heat transfered by diffusion from neighboring grains.

Fig. 2 illustrates the thermal evolution of textures with iron inclusions in troilite, and vice versa. For the grain sizes assumed in our models (30-250 µm) the temperature contrasts between iron and troilite were typically leveled within ~400µs. Within this time period, iron melted progressively, while troilite experienced cooling and partial solidification. The heating and cooling rates of both phases are affected by the

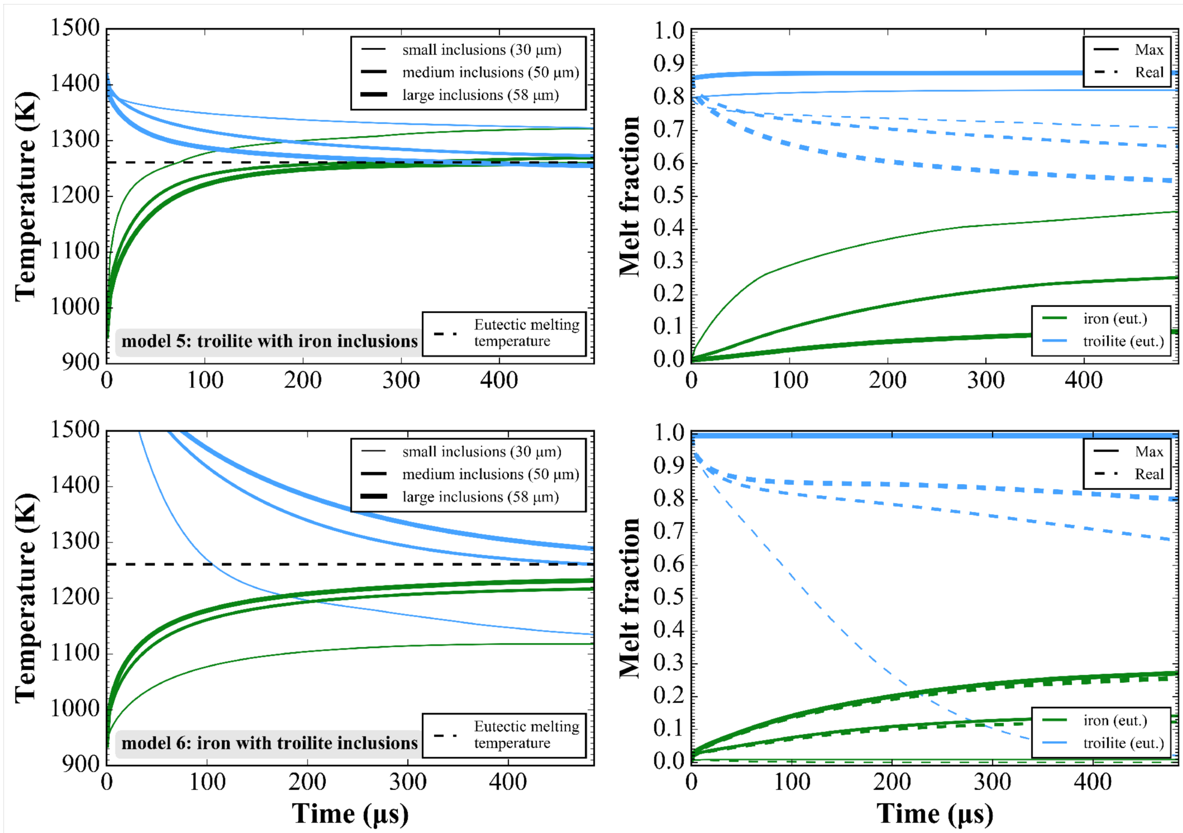

Fig 2. Temperatures and melt fractions as functions of diffusion time for iron or troilite inclusion sizes in eutectic mixtures. Different colors indicate different phases while different line thicknesses represent different inclusion sizes. Solid melt fraction curves represent maximal melt fractions recorded over diffusion time *t* without considering solidification, and dashed melt fraction curves represent the real melt fraction at time *t* considering solidification. Black dashed lines in the temperature diagrams indicate the eutectic melting temperature of an iron-troilite mixture.

size of the inclusions, since grain size influences both the initial distribution of heat introduced by the shock wave and the time scale of thermal equilibration by subsequent heat diffusion.

Discussion and conclusions: Our results indicate that iron melts not by initial shock heating but by diffusion of heat from adjacent, strongly shock heated phases. This is consistent with textural observations in ordinary chondrites like intermixed melting of iron and shock heated albite and the presence of iron metal in shock melt veins.

Our work also illustrates the importance of the time scales of shock heating and heat diffusion for the formation of shock melt features. For example, shock-darkening, the formation of veins by intrusion of iron metal and sulfide melts into silicate cracks [1-3, and references therein], might not occur if any of the phases cools down and solidifies before opening of the silicate cracks upon release of the shock wave. Hence, the shock wave duration and consideration of heat diffusion during the shock wave might be important for the understanding of shock melting in natural samples. In shock recovery experiments the time scale of the shock pulse is typically <1µs [5], so that the time scale of the shock pulse never exceeds the time scales relevant for heat diffusion. However, large scale impacts like asteroid collisions involve shock pulse durations of 100-1000ms [6], which exceeds the time scales of heat diffusion by several orders of magnitude. Hence, a better understanding of the formation conditions of melt features in ordinary chondrites requires further study considering heat diffusion and the associated changes in heat distribution during shock.

Acknowledgements: Our thanks to the iSALE developers, and Lars Kaislaniemi for sharing the idea for the diffusion code. This work is supported by the Academy of Finland and by the Deutsche Forschungsgemeinschaft (SFB-TRR170, subproject C4) and the Helmholtz association (project VH-NG-1017).

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