

# A numerical study of the dynamic inelasticity under compression-shear ramp wave loading\*

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***Jow Ding<sup>1</sup>, C. Scott Alexander<sup>2</sup>, & Jim Asay<sup>2</sup>***

***<sup>1</sup>Washington State University***

***<sup>2</sup> Sandia National Labs***

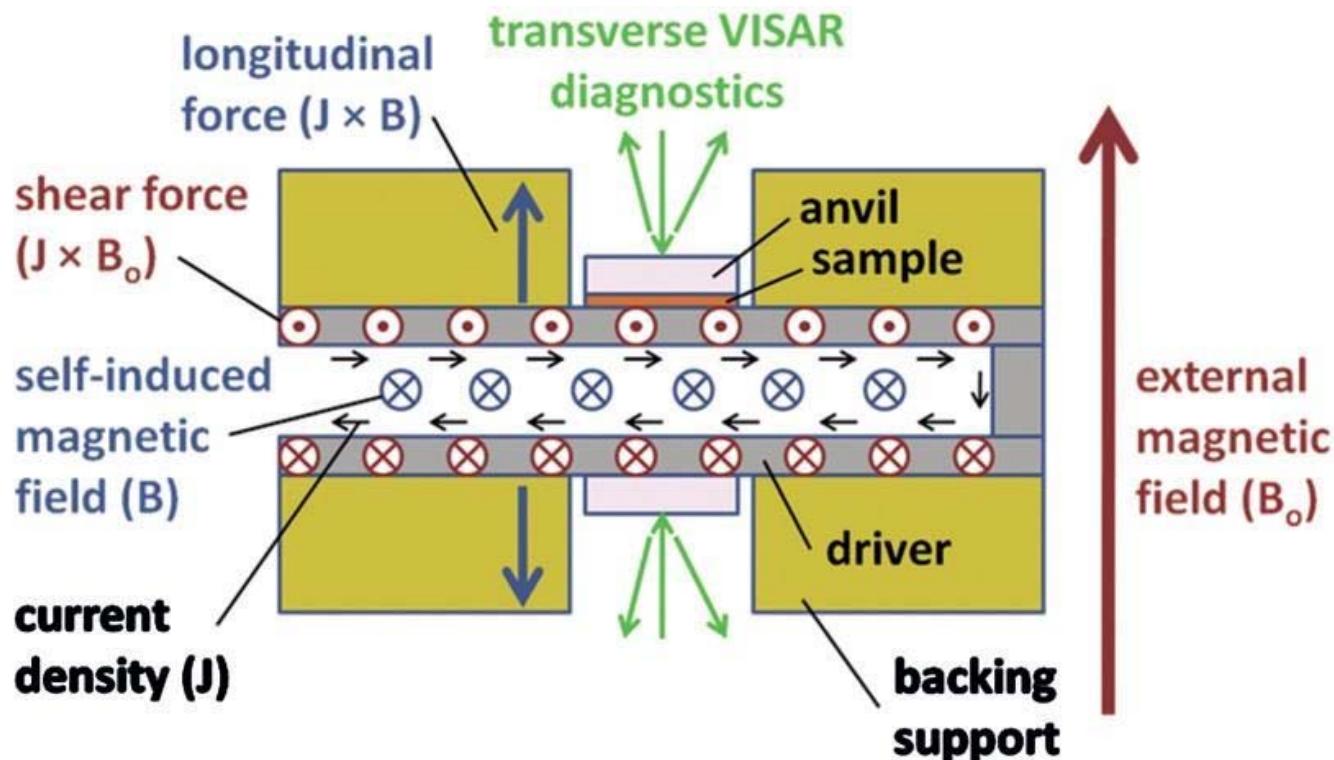
**\* Work sponsored by Sandia National Labs**

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# MAPS (Magnetically Applied Pressure Shear) Experiments



(Alexander, Asay, & Haill, JAP, 126101, 2010.)

Load Panel: Molybdenum  
Anvil: Zirconia

Main focus of the experiments: material strength under high pressure

# Strength Model

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$$\dot{\sigma}'_{ij} = 2G\dot{\varepsilon}'_{ij}$$

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$$\dot{\varepsilon}'_{ij}^p = \dot{\bar{\varepsilon}}^p (\sigma'_{ij} / |\sigma'_{ij}|) \quad \text{and} \quad \dot{\bar{\varepsilon}}^p = A[\sigma_{\text{effective}} - \sigma_{th}]^2$$

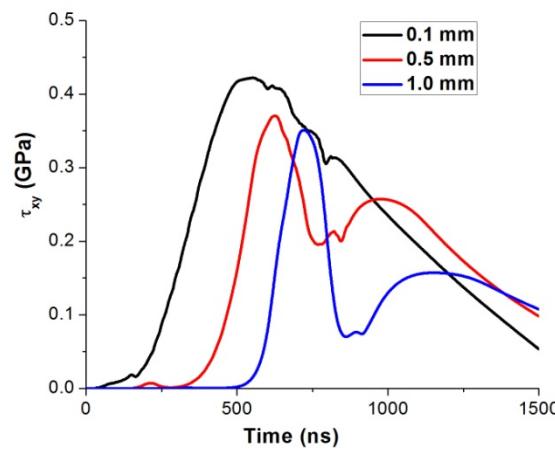
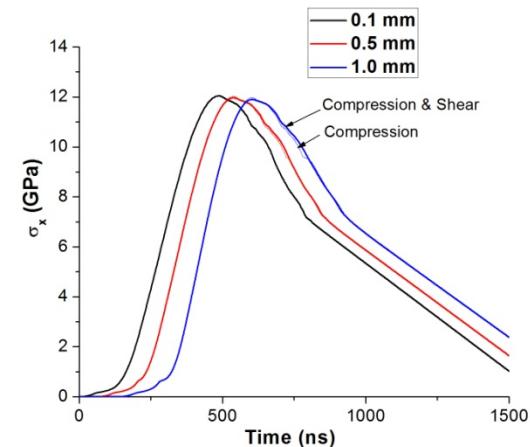
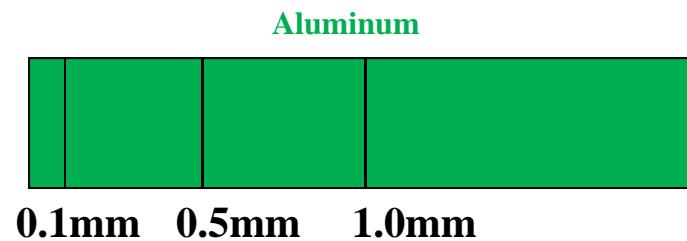
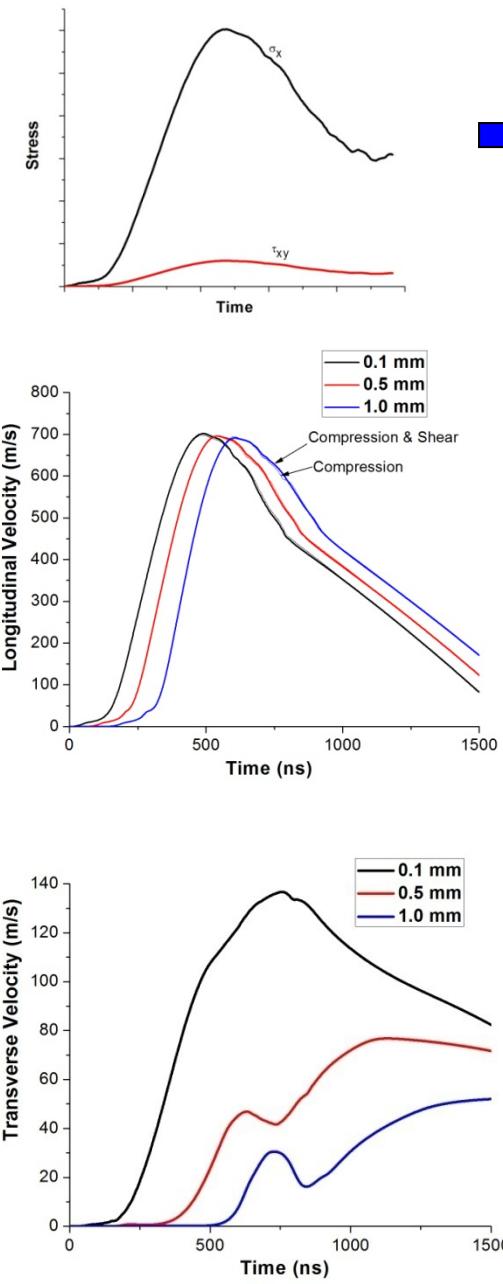
$$\left( \dot{\bar{\varepsilon}}^p = \left( \frac{2}{3} \dot{\varepsilon}'_{ij} \dot{\varepsilon}'_{ij} \right)^{1/2}, \sigma_{\text{effective}} = |\sigma'_{ij}| = \left( \frac{3}{2} \sigma'_{ij} \sigma'_{ij} \right)^{1/2} \text{(strength)}, \sigma_{th} \text{ :threshold effective stress} \right)$$

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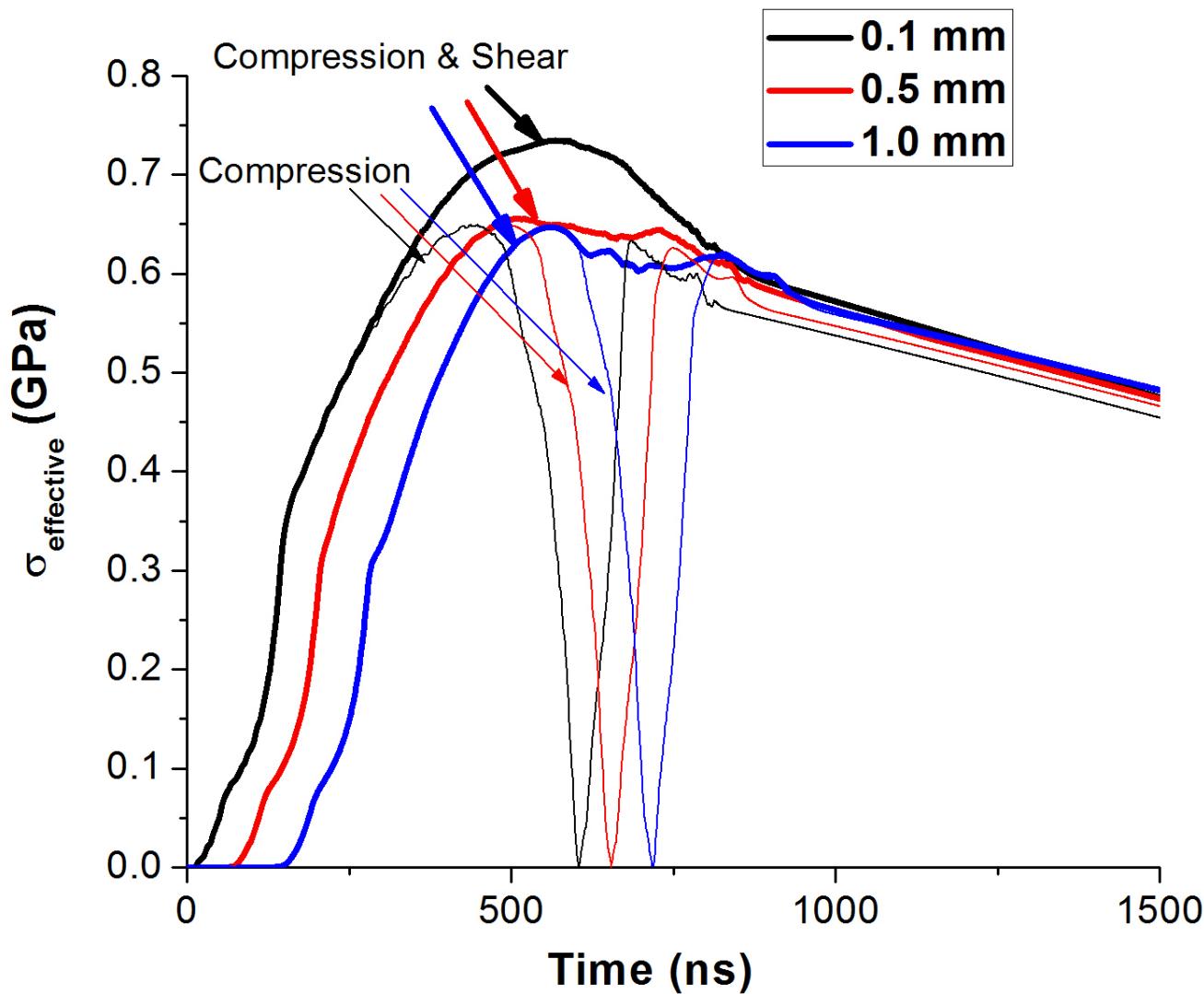
$$G = G_0 \left[ 1 + \left( \frac{G'_P}{G_0} \right) \frac{P}{\eta^{1/3}} + \left( \frac{G'_T}{G_0} \right) (T - T_0) \right] \quad \text{(Steinberg, Cochran, and Guinan, JAP, 1980)}$$

$$\sigma_{th} = \sigma_{th_0} [1 + \beta (\bar{\varepsilon}^p + \bar{\varepsilon}'^p)]^n [1 + \left( \frac{G'_P}{G_0} \right) \frac{P}{\eta^{1/3}} + \left( \frac{G'_T}{G_0} \right) (T - T_0)]$$

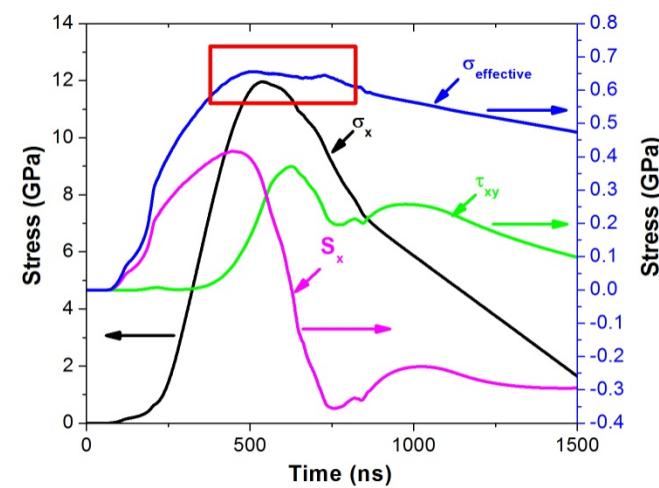
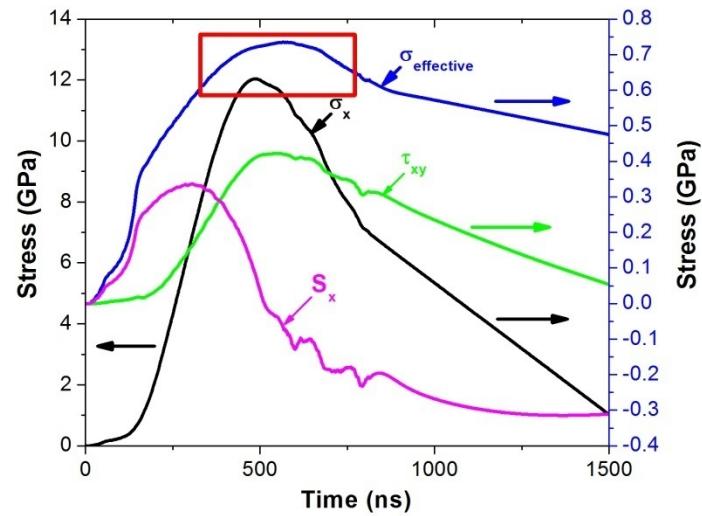
# Simulation of In-Situ Material Response



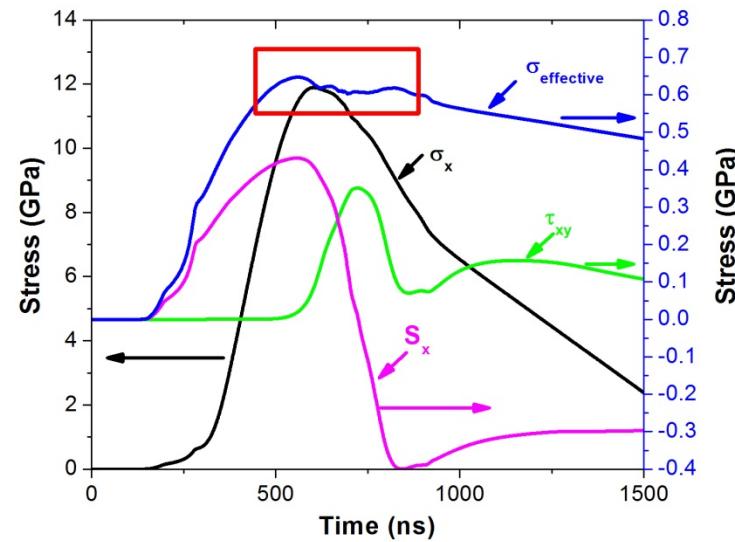
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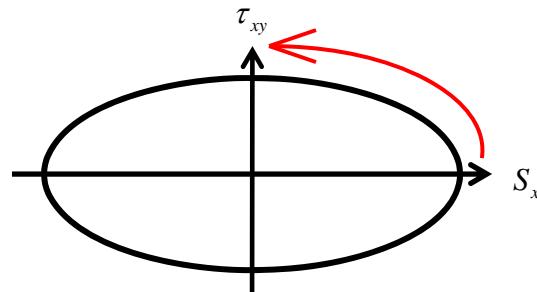


**0.1 mm**



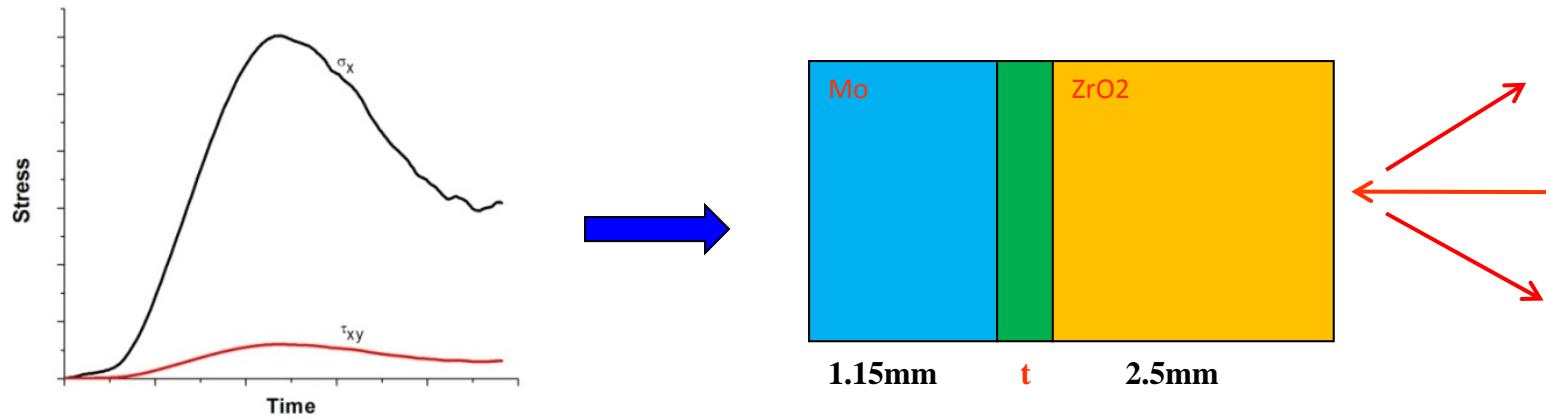
**1.0 mm**

$$\sigma = \begin{bmatrix} \frac{2}{3}(\sigma_x - \sigma_y) & \tau_{xy} & 0 \\ \tau_{xy} & -\frac{1}{3}(\sigma_x - \sigma_y) & 0 \\ 0 & 0 & -\frac{1}{3}(\sigma_x - \sigma_y) \end{bmatrix} = \begin{bmatrix} S_x & \tau_{xy} & 0 \\ \tau_{xy} & -\frac{1}{2}S_x & 0 \\ 0 & 0 & -\frac{1}{2}S_x \end{bmatrix}$$

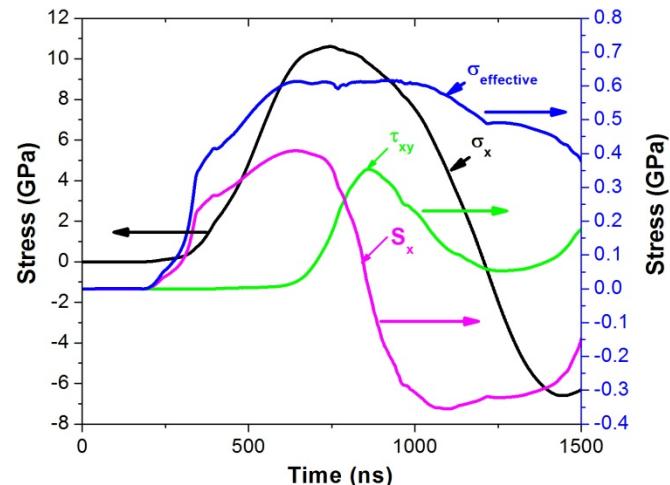


# Simulation of The Experiments

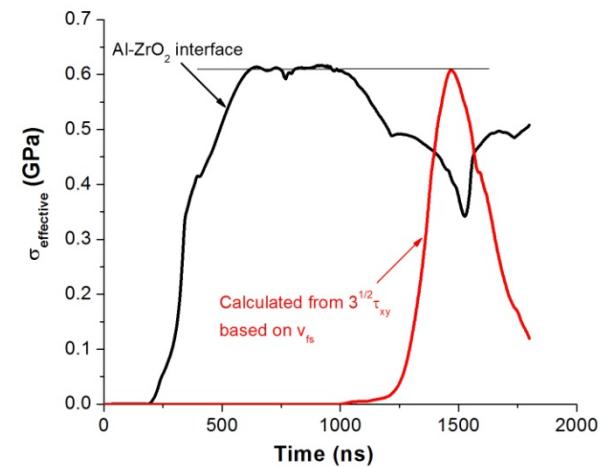
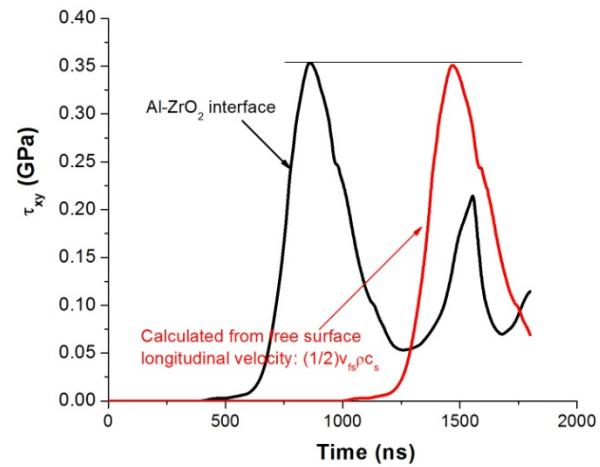
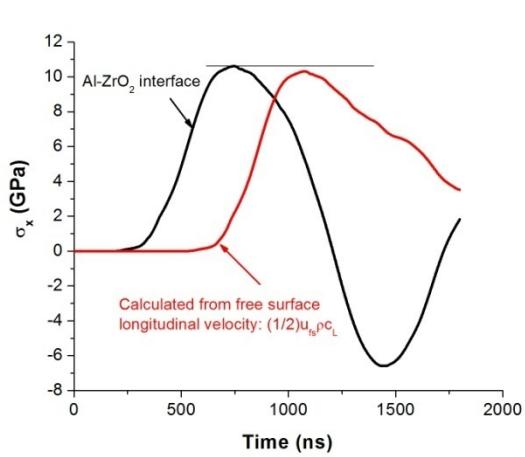
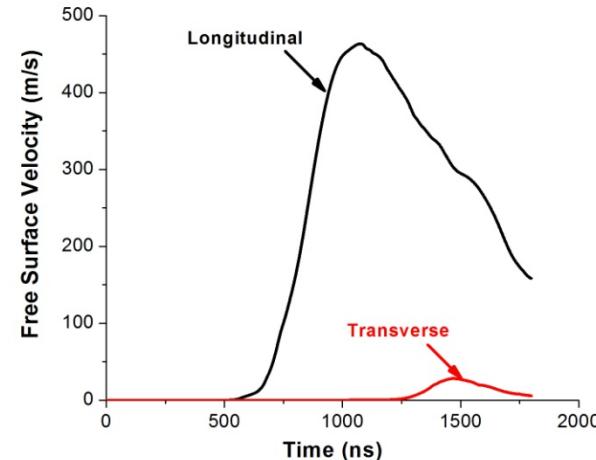
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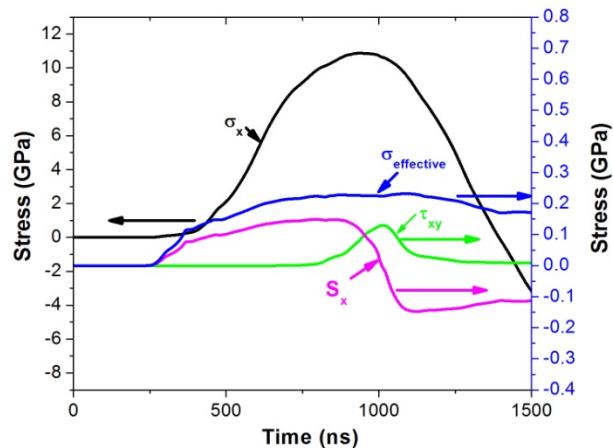
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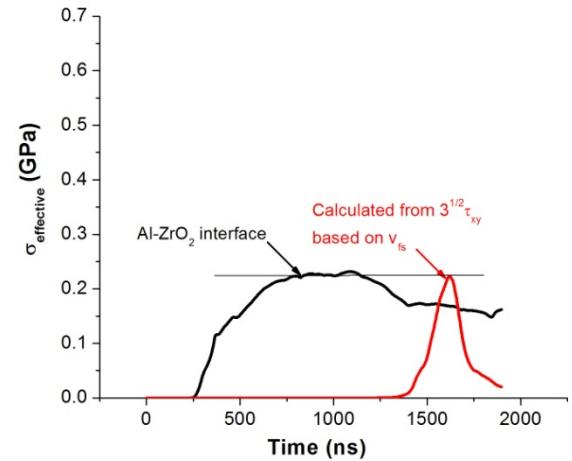
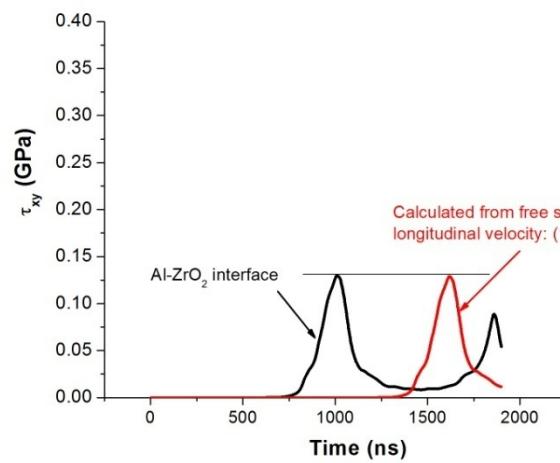
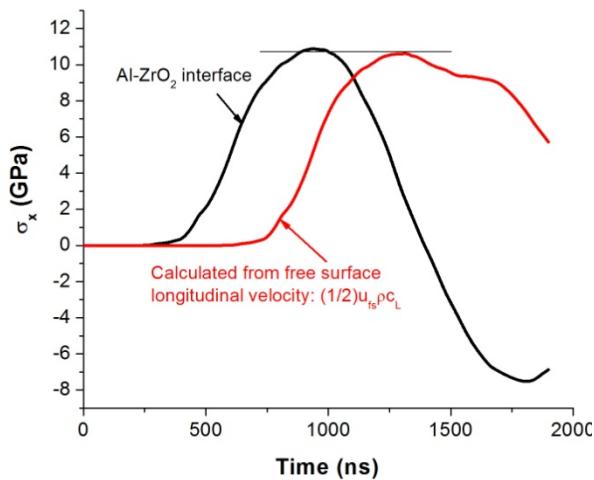
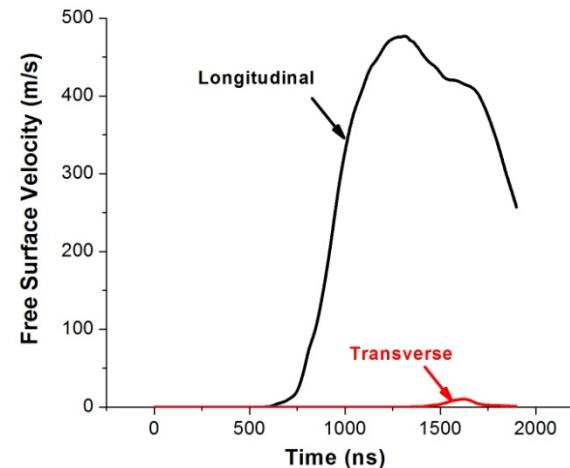
Al-ZrO<sub>2</sub> interface (t = 0.1mm)



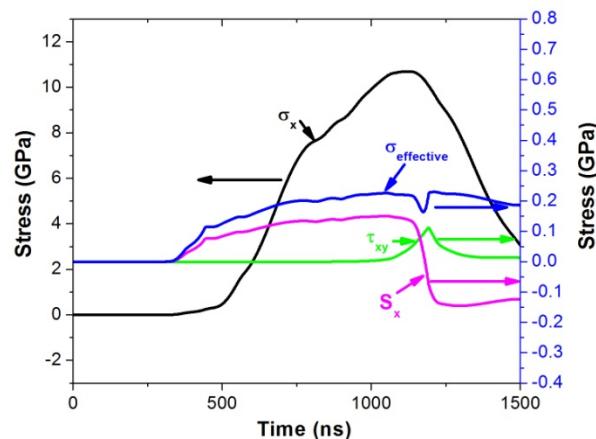
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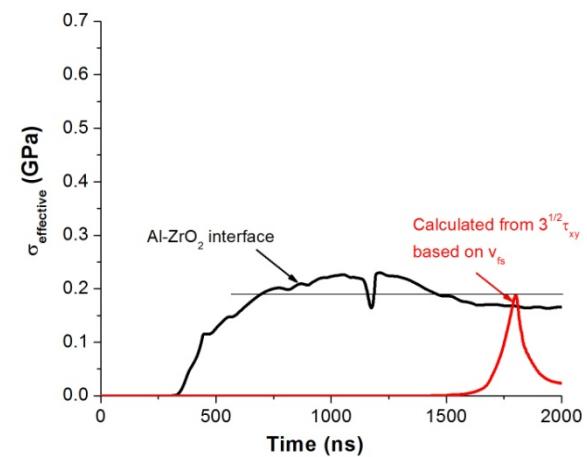
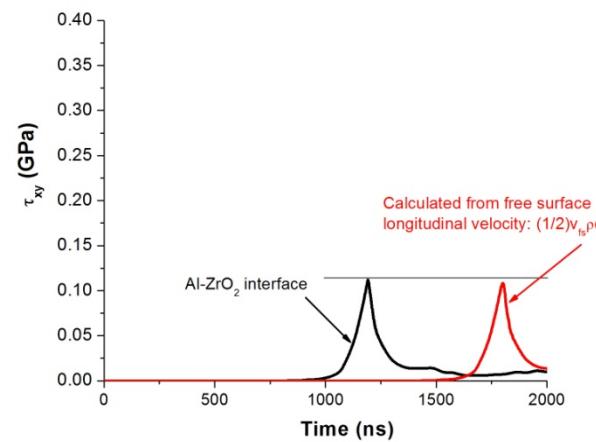
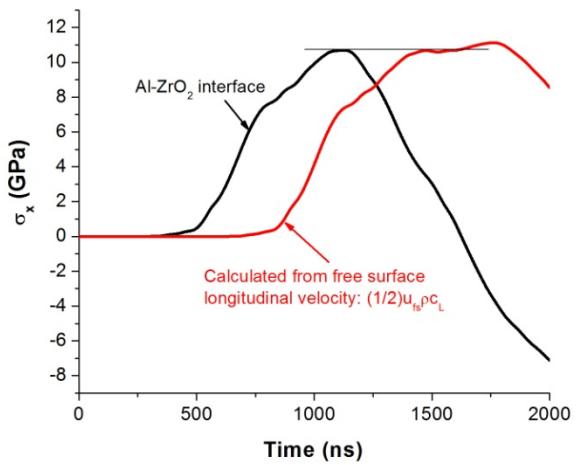
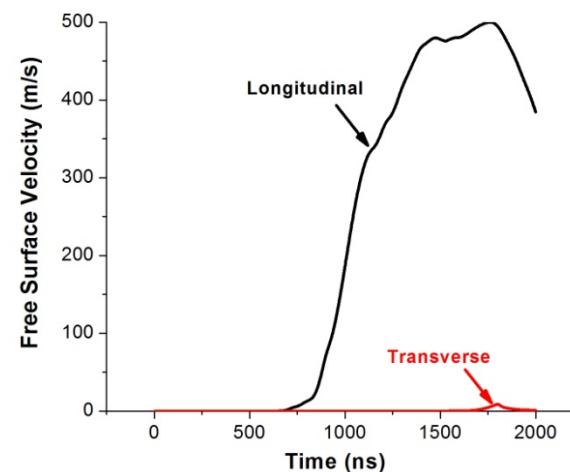
Al-ZrO<sub>2</sub> interface (t = 0.5mm)



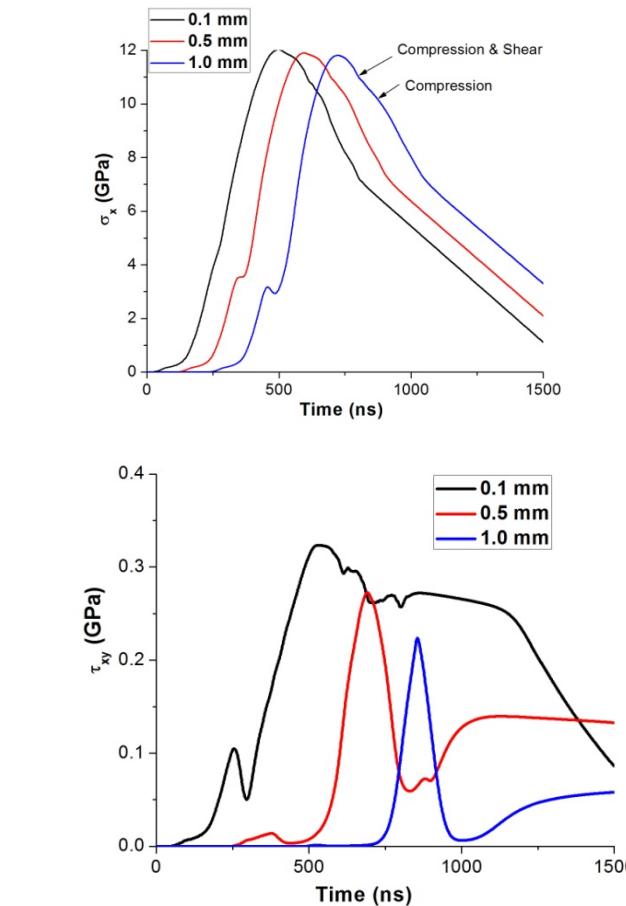
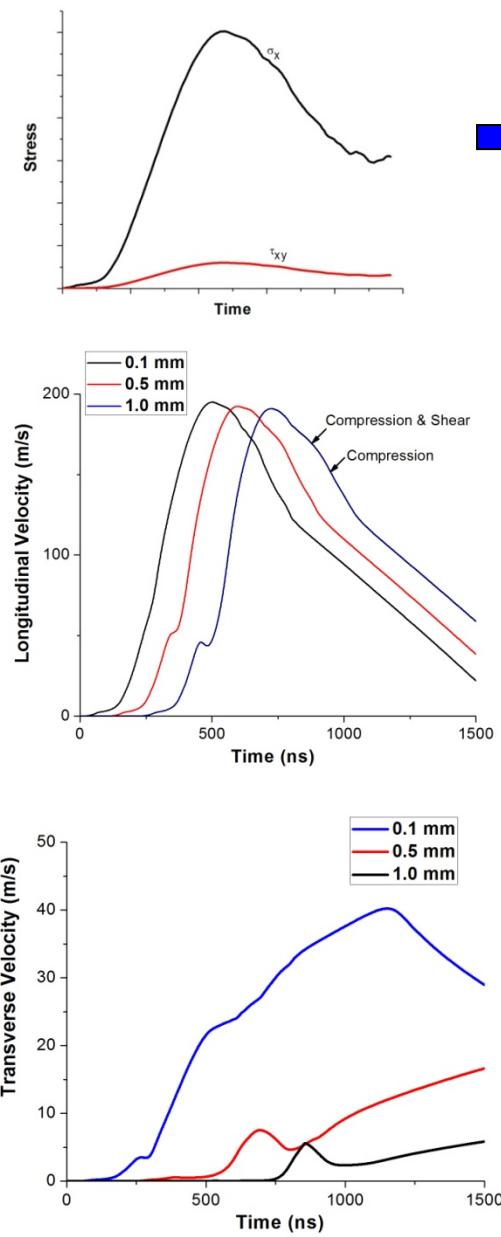
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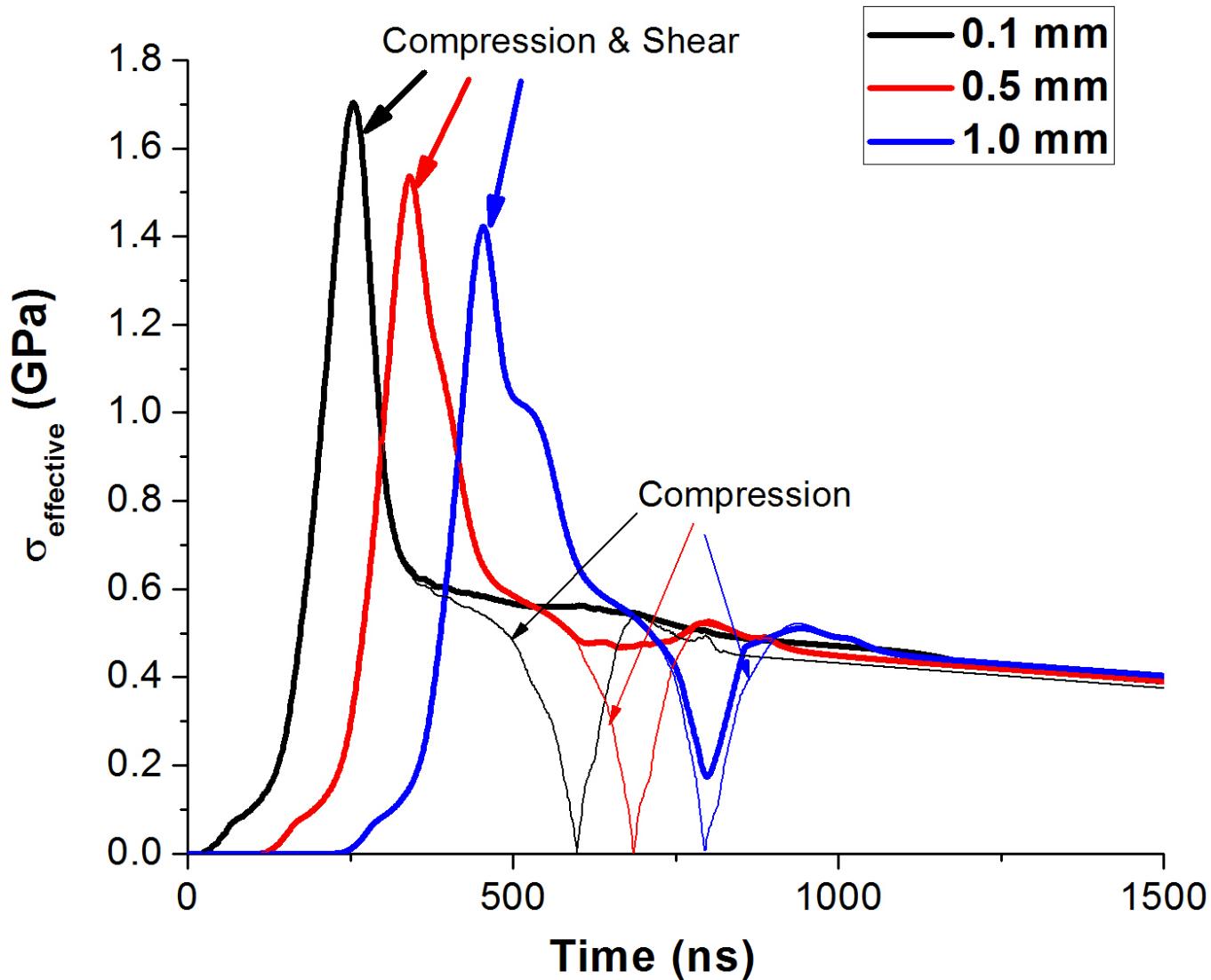
Al-ZrO<sub>2</sub> interface (t = 1.0mm)



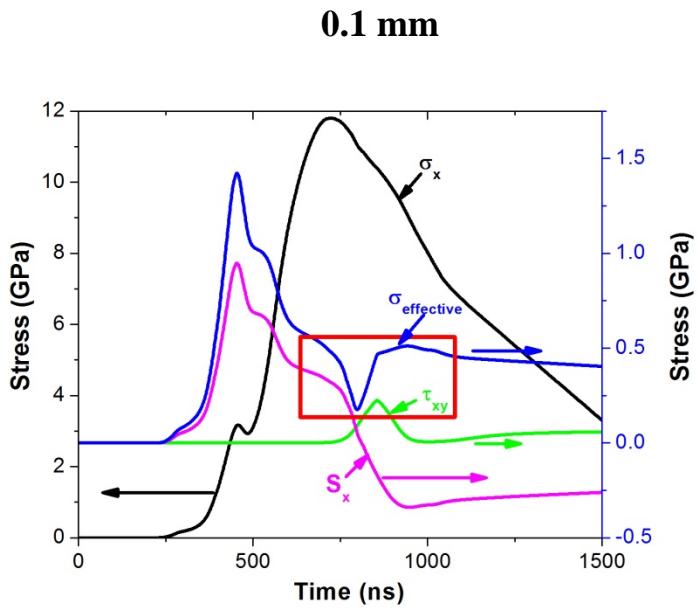
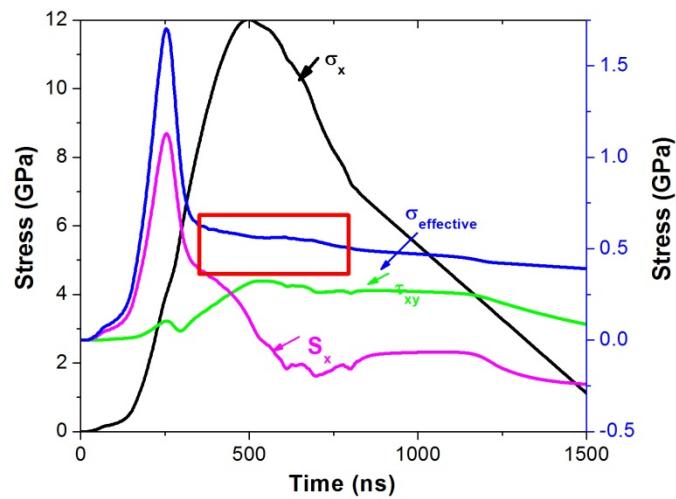
# Simulation of In-Situ Material Response



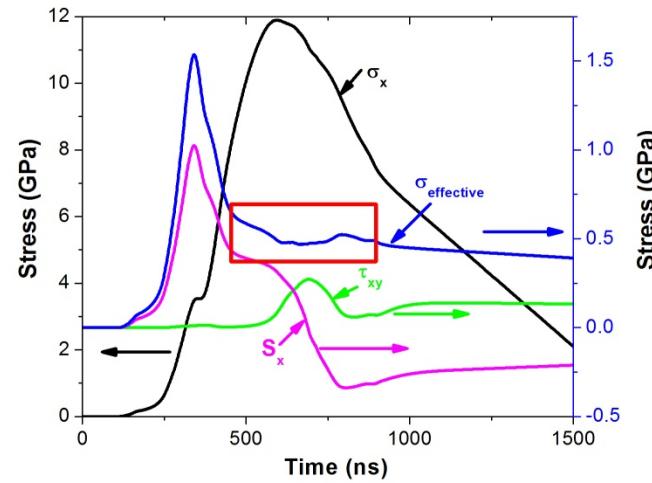
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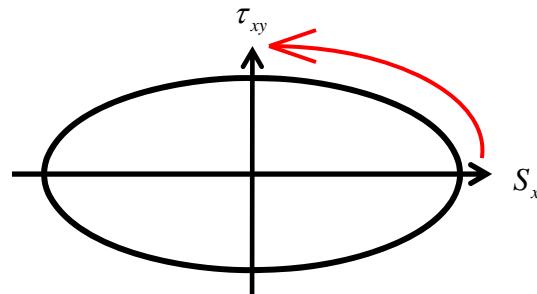


**1.0 mm**

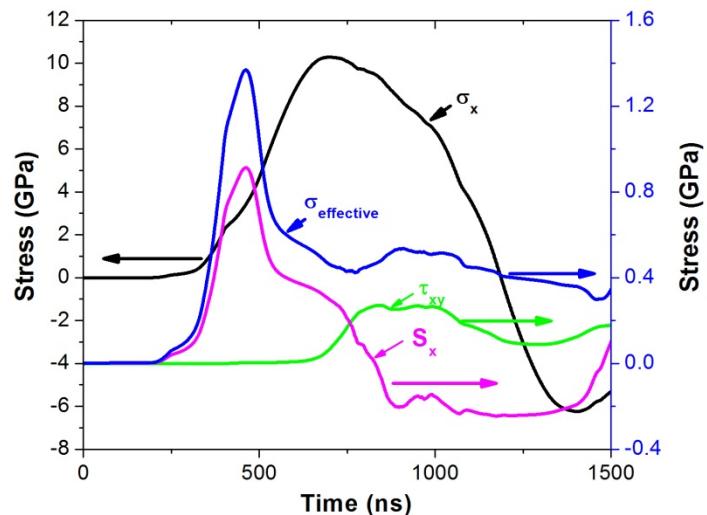


**0.5 mm**

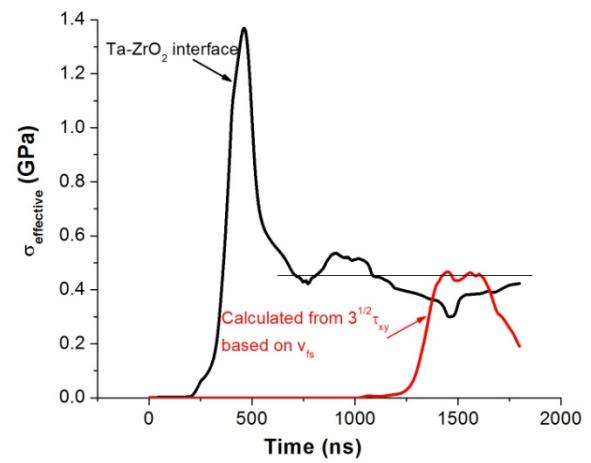
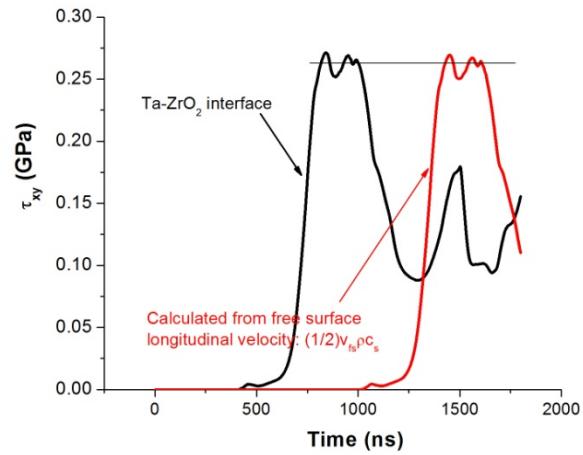
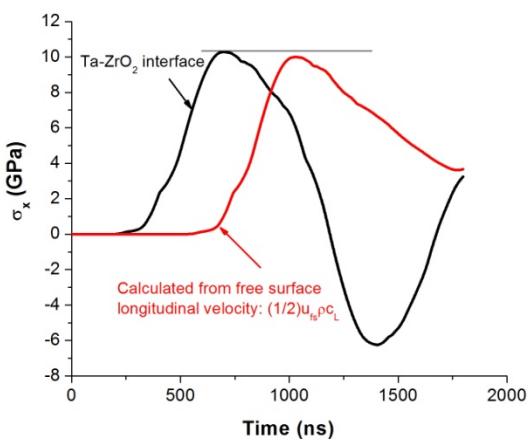
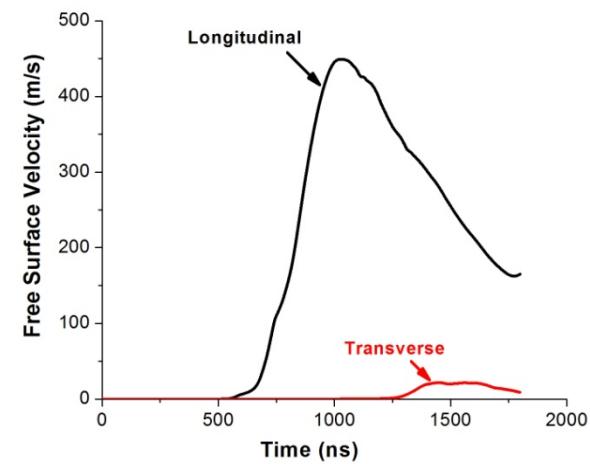
$$\sigma' = \begin{bmatrix} \frac{2}{3}(\sigma_x - \sigma_y) & \tau_{xy} & 0 \\ \tau_{xy} & -\frac{1}{3}(\sigma_x - \sigma_y) & 0 \\ 0 & 0 & -\frac{1}{3}(\sigma_x - \sigma_y) \end{bmatrix} = \begin{bmatrix} S_x & \tau_{xy} & 0 \\ \tau_{xy} & -\frac{1}{2}S_x & 0 \\ 0 & 0 & -\frac{1}{2}S_x \end{bmatrix}$$



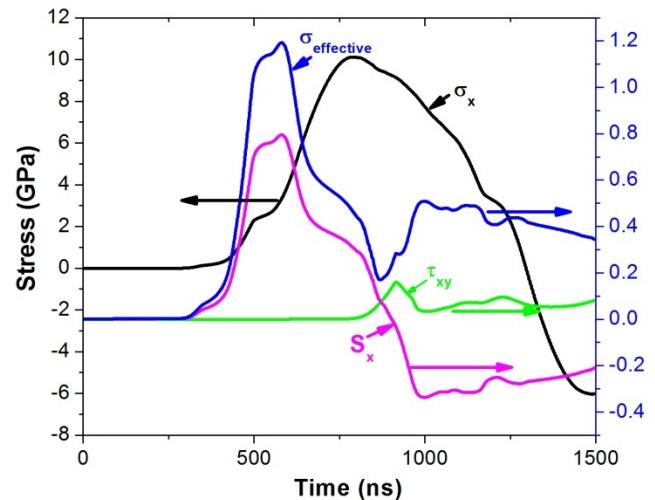
# Simulation of The Experiments



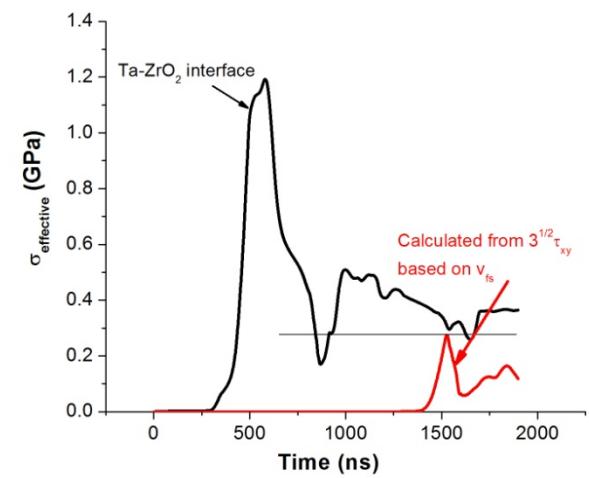
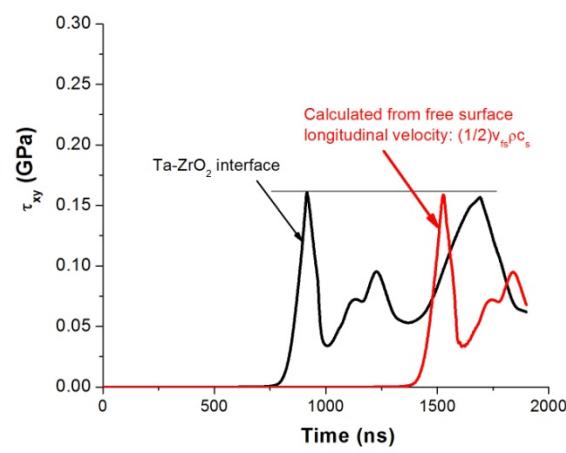
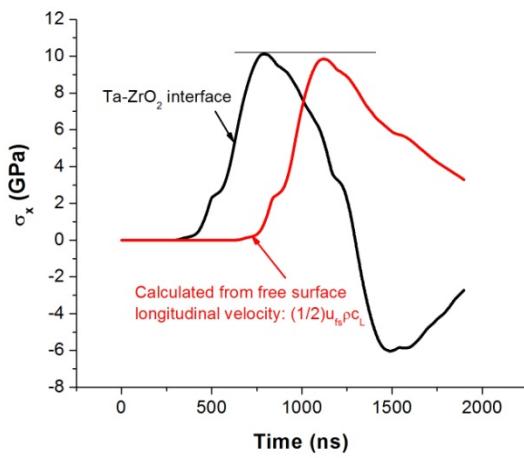
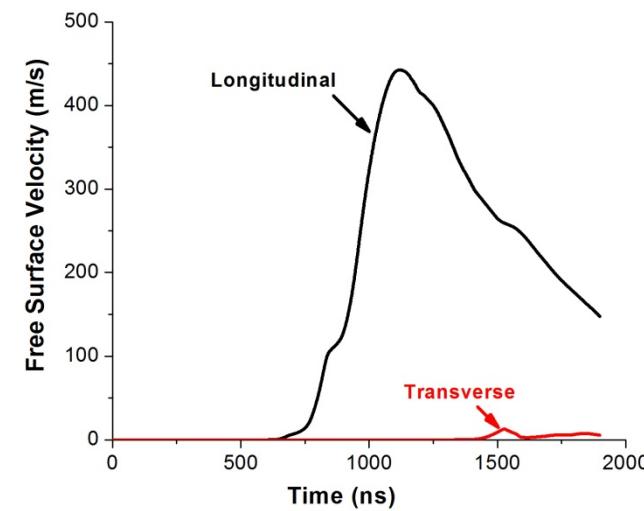
Ta-ZrO<sub>2</sub> interface (t = 0.1mm)



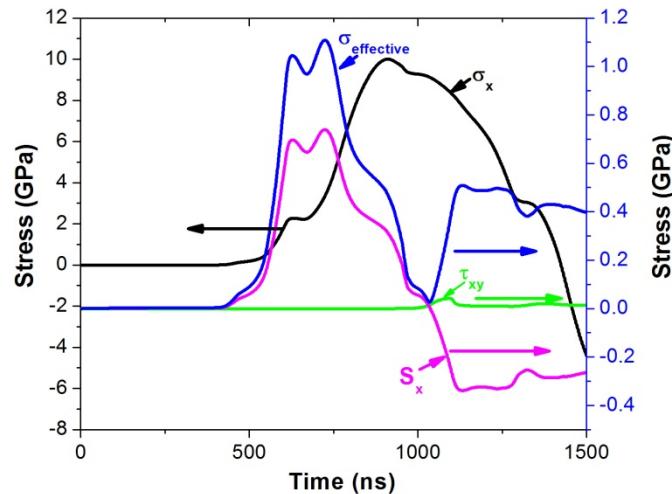
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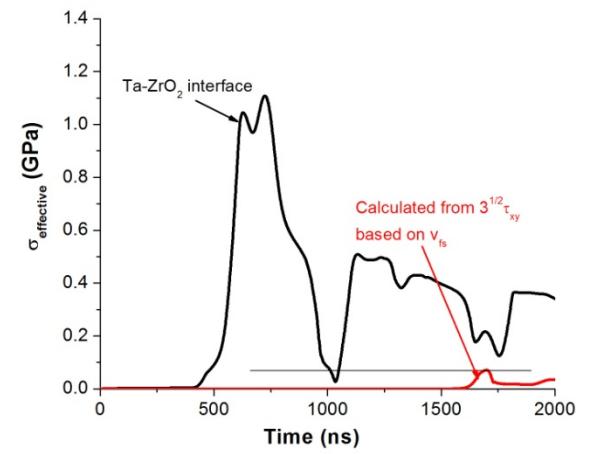
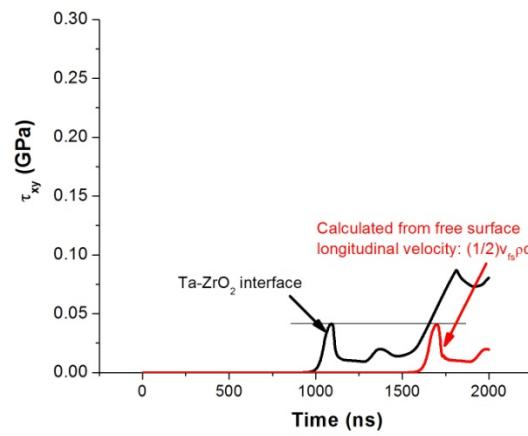
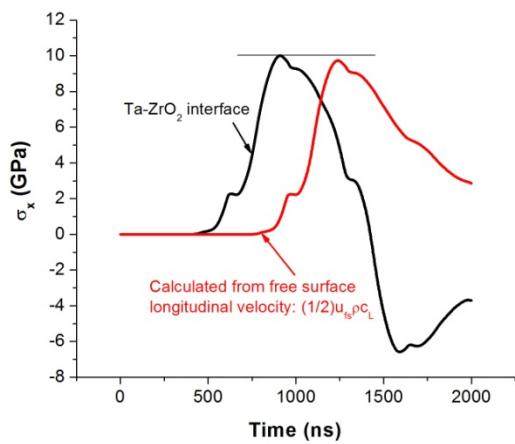
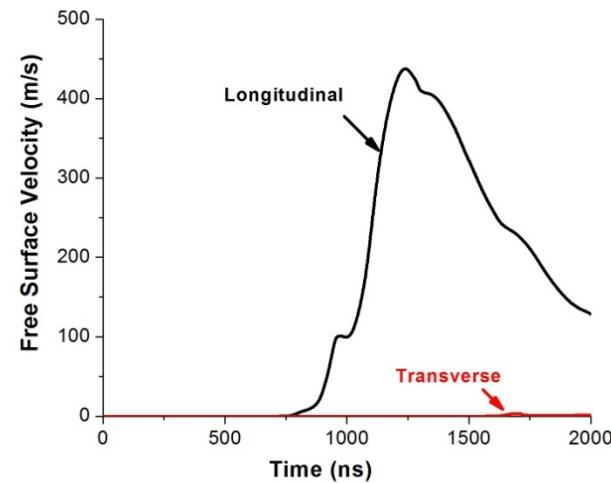
Ta-ZrO<sub>2</sub> interface (t = 0.5mm)



# Simulation of The Experiments



Ta-ZrO<sub>2</sub> interface ( $t = 1.0\text{mm}$ )



# Conclusions and Future Work

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## Conclusions

- Some preliminary insights were gained on the material response to large amplitude compression-shear ramp wave loading.
- The free surface velocities obtained from elastic anvil provide accurate information about the material state at the sample-anvil interface.
- The probe window and the probed material state are sensitive to the thickness of the sample.

## Future Work

- Study of more complicated material behavior.
- Optimization of test configuration.
- Inelastic response of anvil materials.