

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

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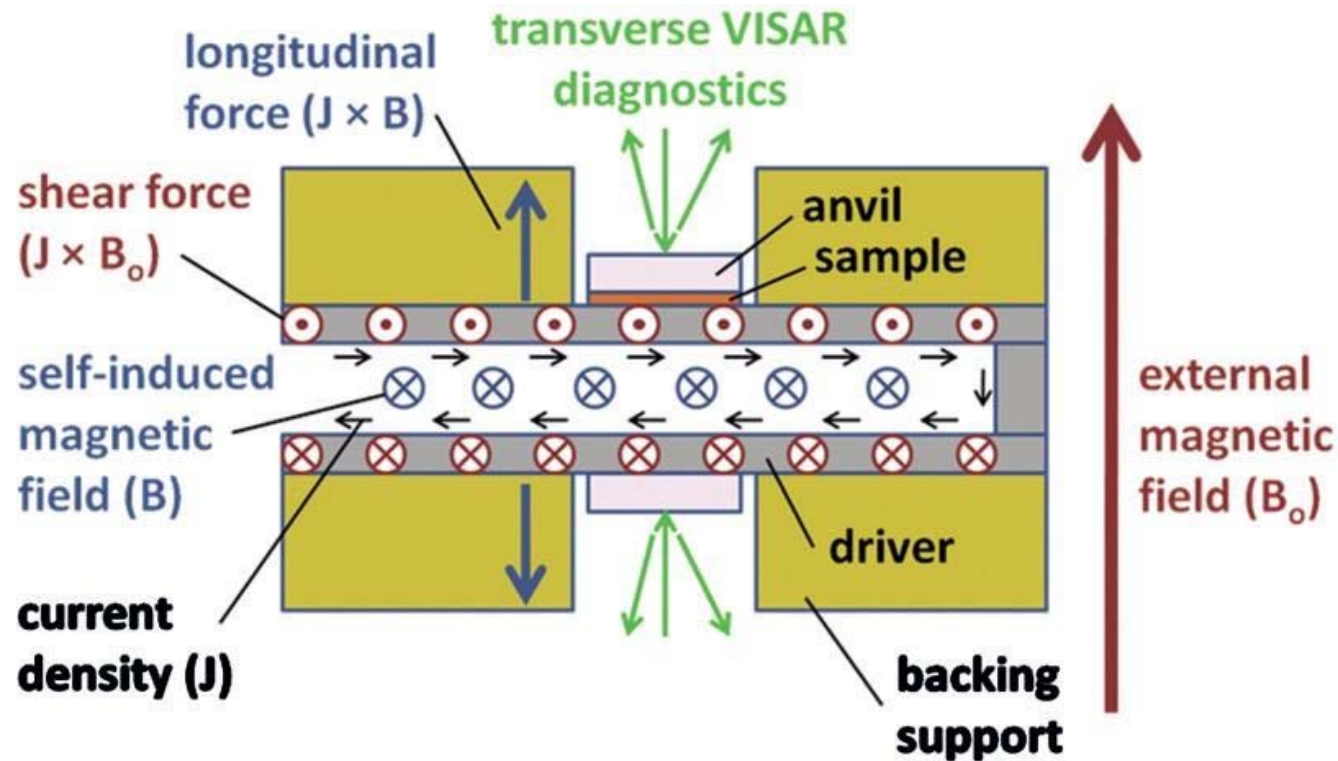
*** Work sponsored by Sandia National Labs**

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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

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

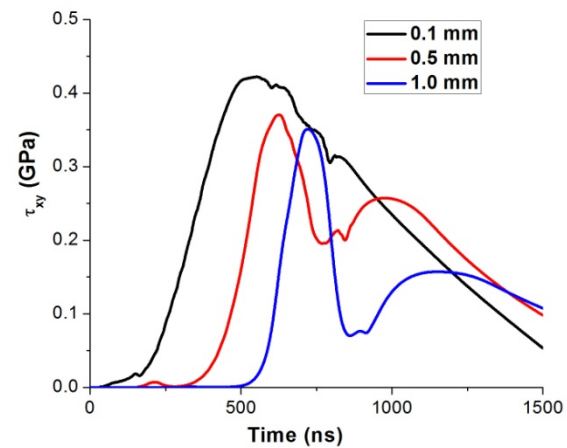
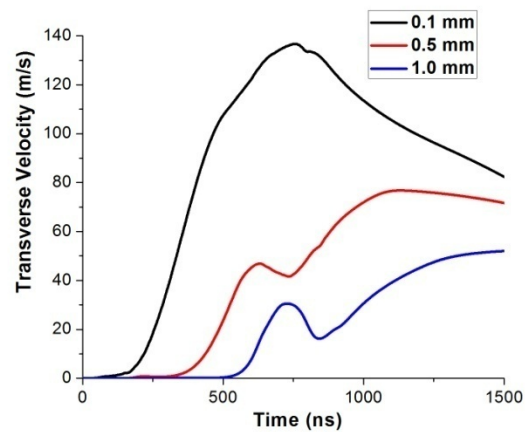
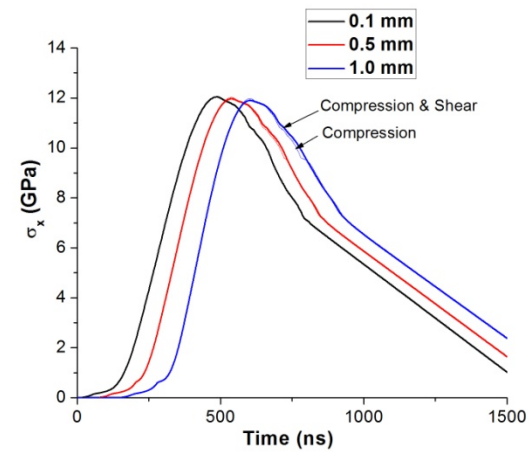
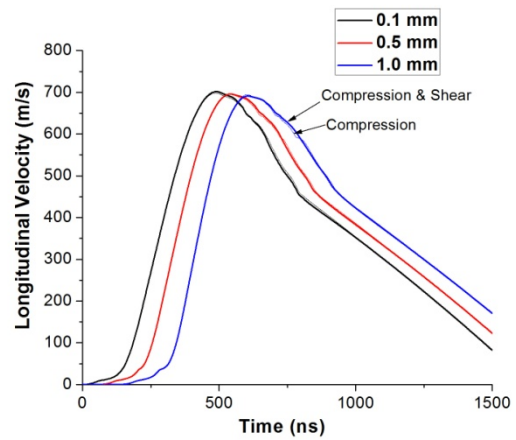
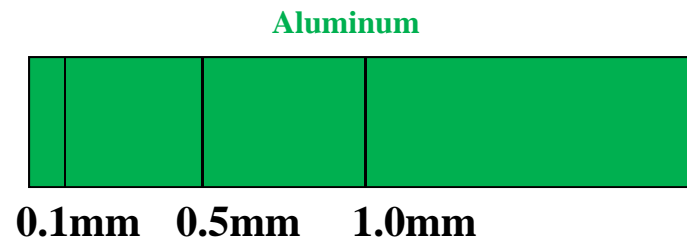
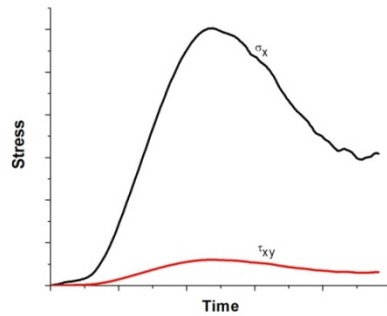
$$\dot{\varepsilon}_{ij}^p = \dot{\bar{\varepsilon}}^p (\sigma_{ij}' / |\sigma_{ij}'|) \quad \text{and} \quad \dot{\bar{\varepsilon}}^p = A[\sigma_{\text{effective}} - \sigma_{th}]^2$$

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

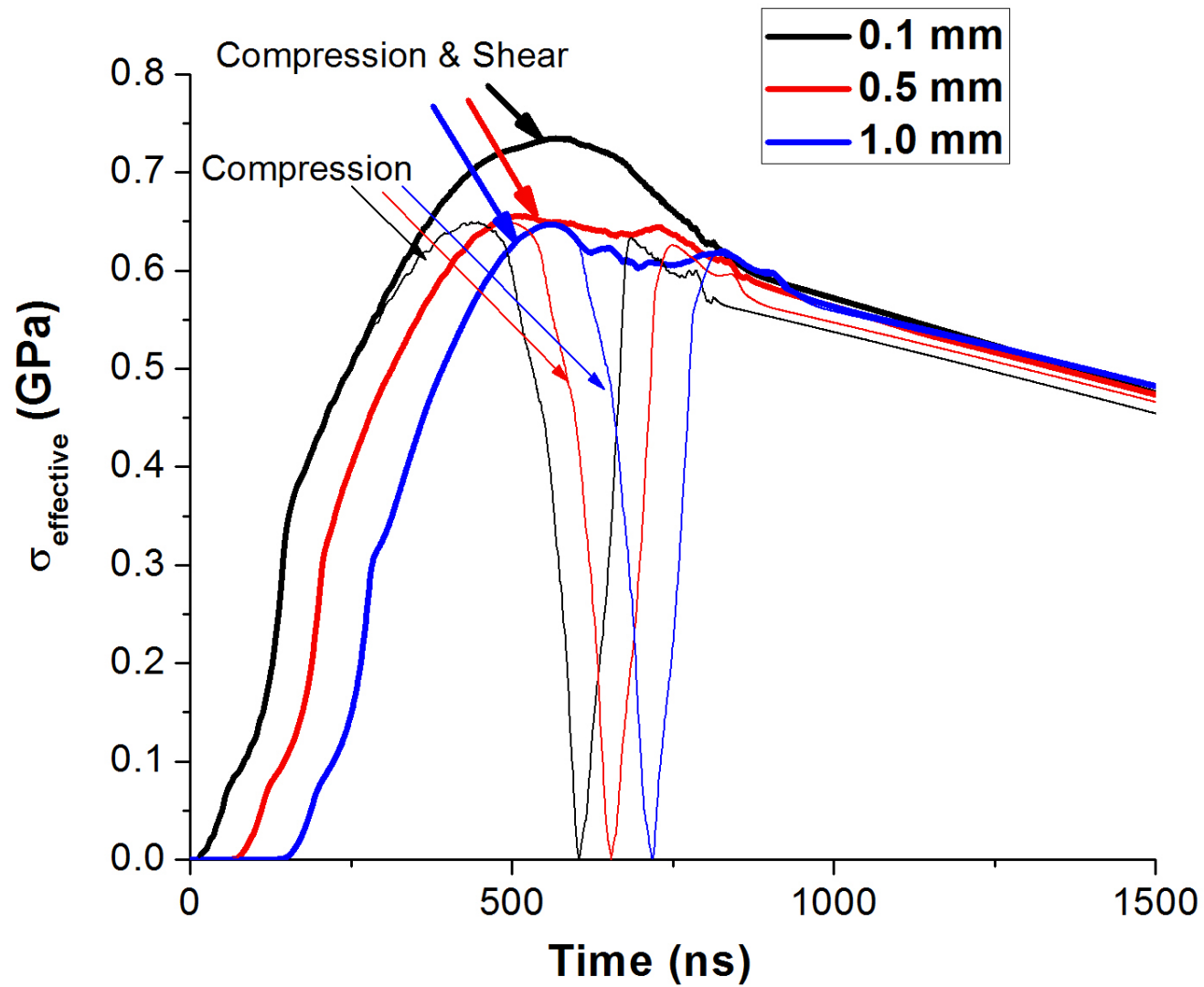
$$G = G_0 \left[1 + \left(\frac{G_P'}{G_0} \right) \frac{P}{\eta^{1/3}} + \left(\frac{G_T'}{G_0} \right) (T - T_0) \right] \quad (\text{Steinberg, Cochran, and Guinan, JAP, 1980})$$

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

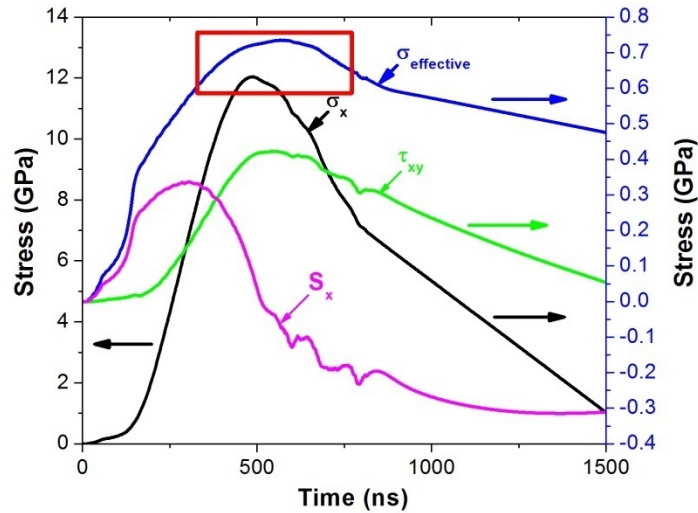
Simulation of In-Situ Material Response



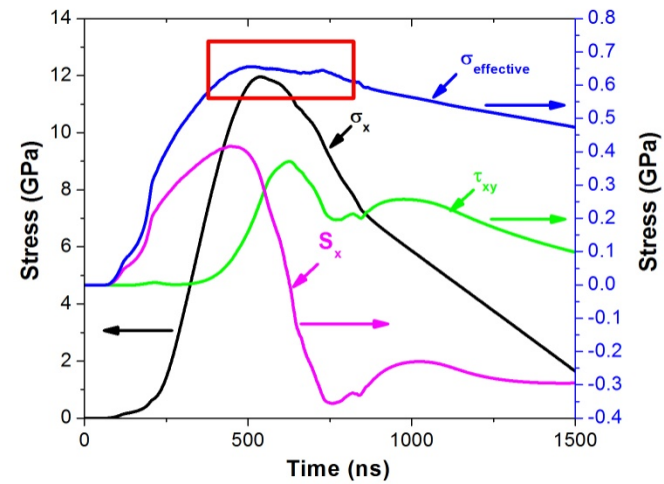
Simulation of In-Situ Material Response



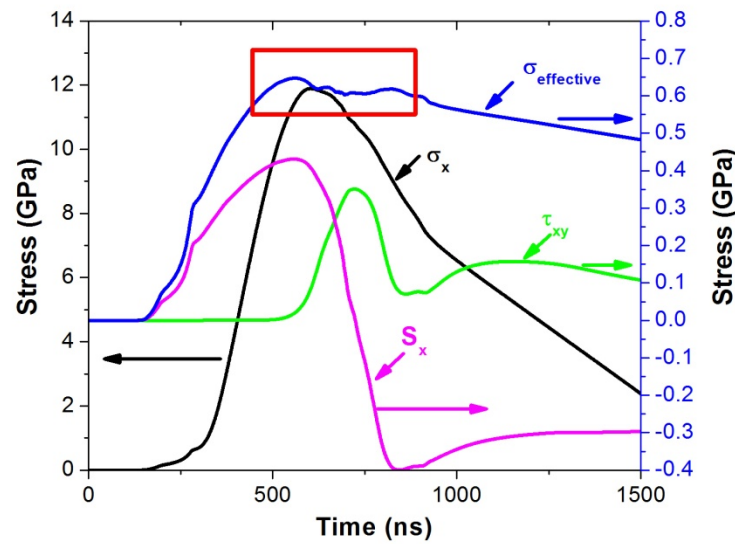
Simulation of In-Situ Material Response



0.1 mm

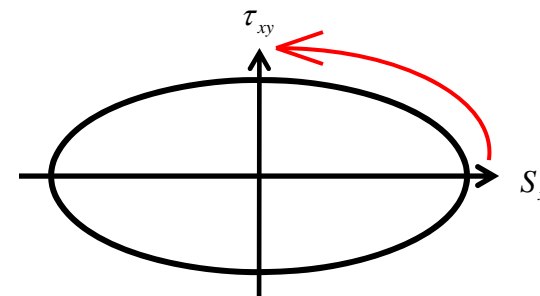


0.5 mm

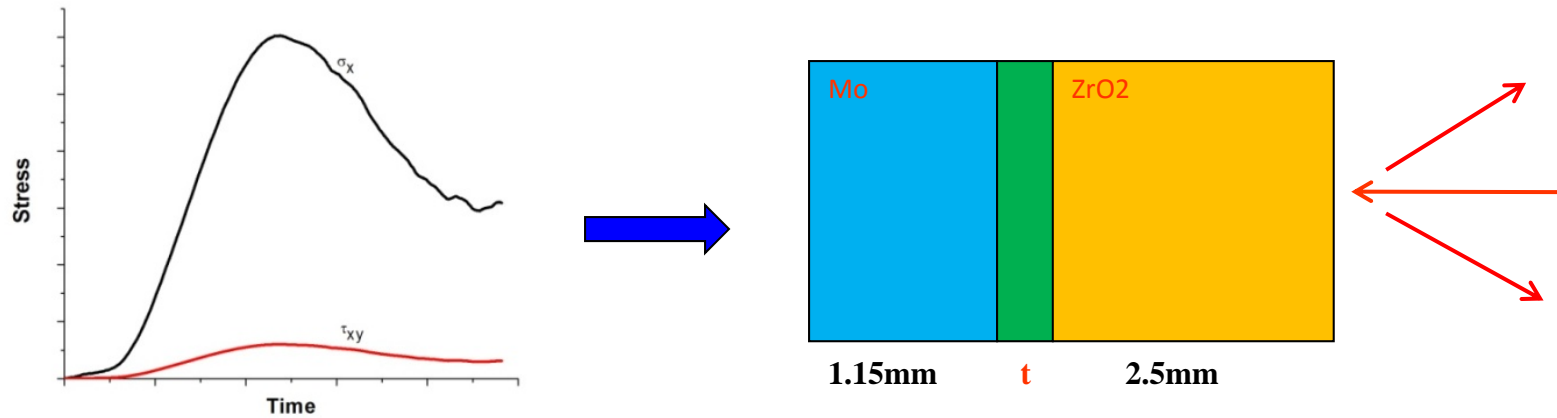


1.0 mm

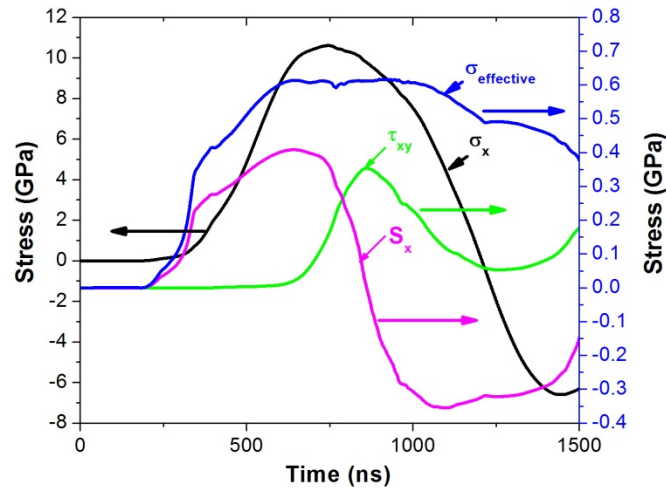
$$\sigma' = \begin{bmatrix} \frac{2}{3}(\sigma_x - \sigma_y) & \tau_{xy} & 0 \\ \tau_{xy} & -\frac{1}{3}(\sigma_x - \sigma_y) & 0 \\ 0 & 0 & -\frac{1}{3}(\sigma_x - \sigma_y) \end{bmatrix} = \begin{bmatrix} S_x & \tau_{xy} & 0 \\ \tau_{xy} & -\frac{1}{2}S_x & 0 \\ 0 & 0 & -\frac{1}{2}S_x \end{bmatrix}$$



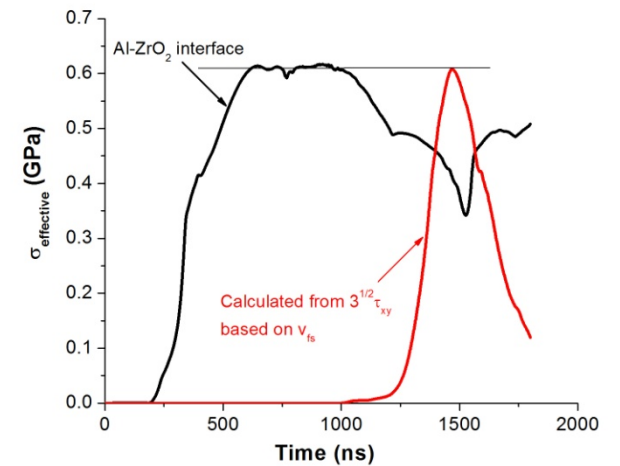
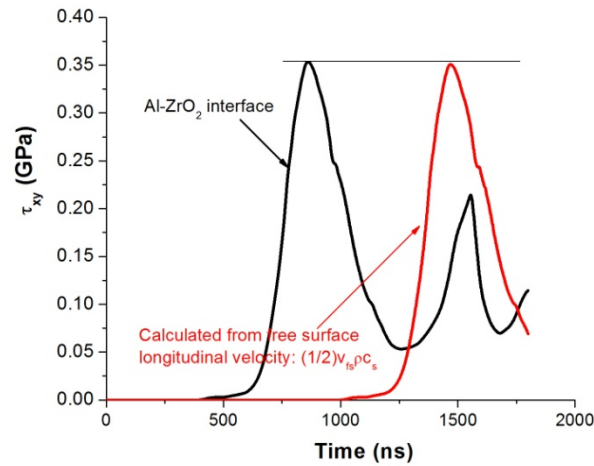
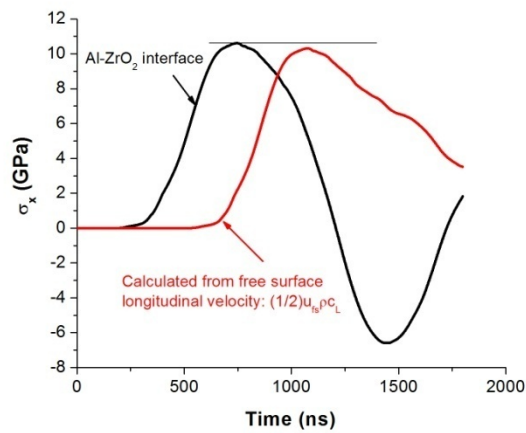
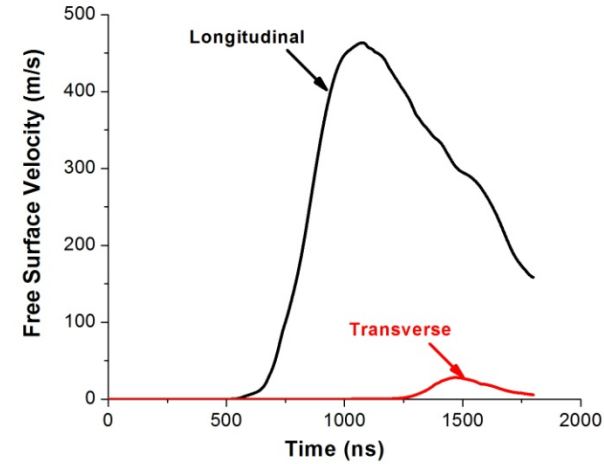
Simulation of The Experiments



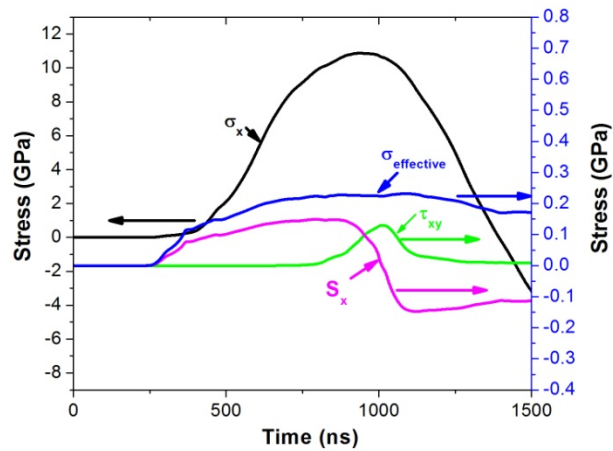
Simulation of The Experiments



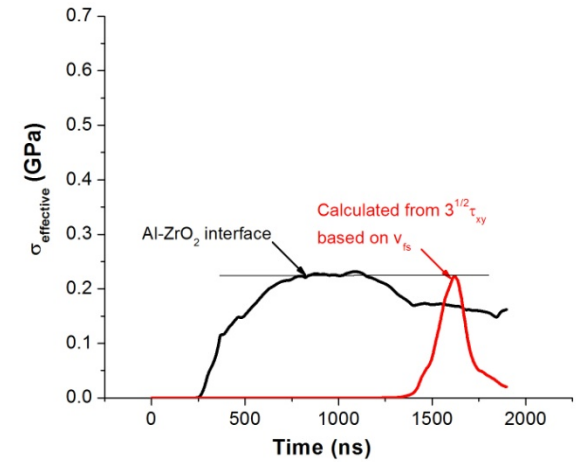
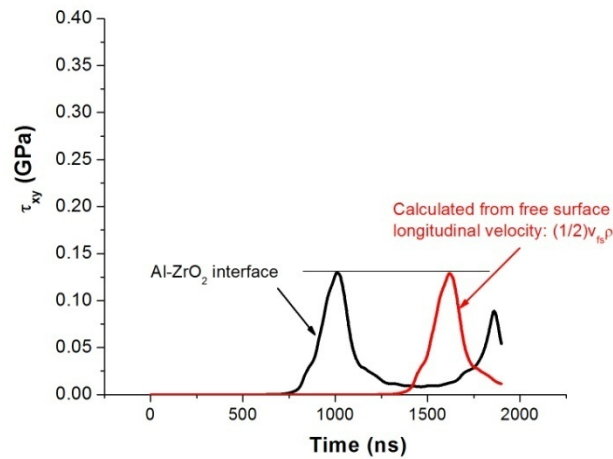
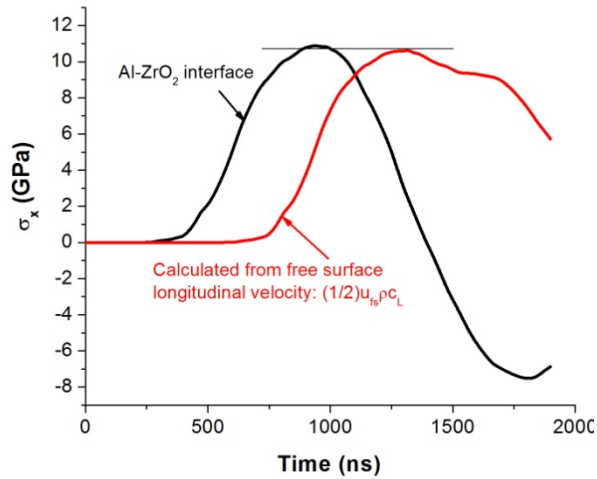
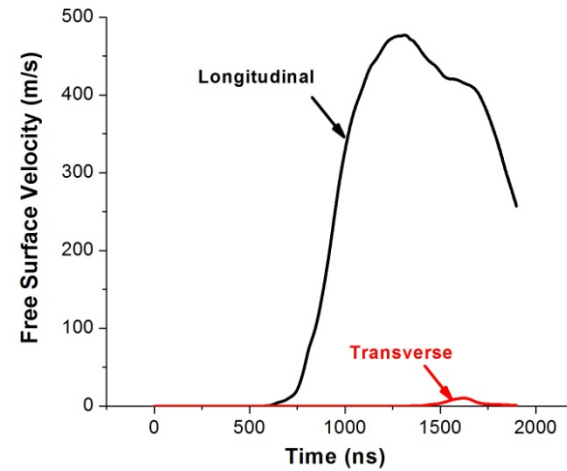
Al-ZrO₂ interface (t = 0.1mm)



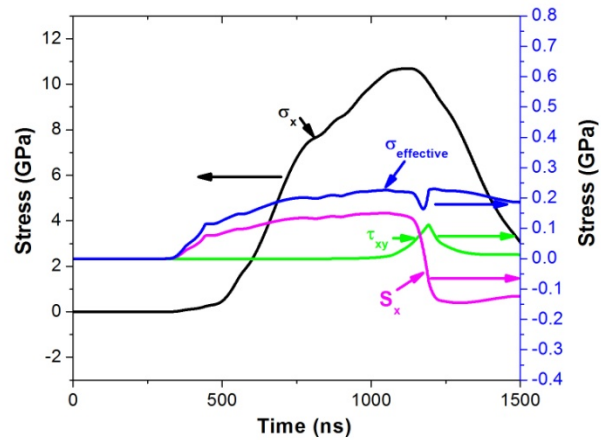
Simulation of The Experiments



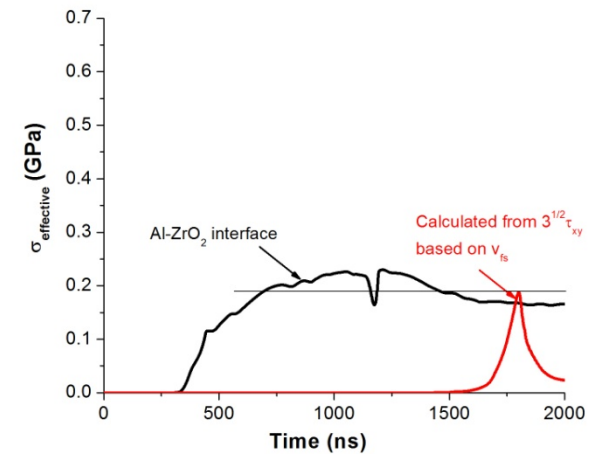
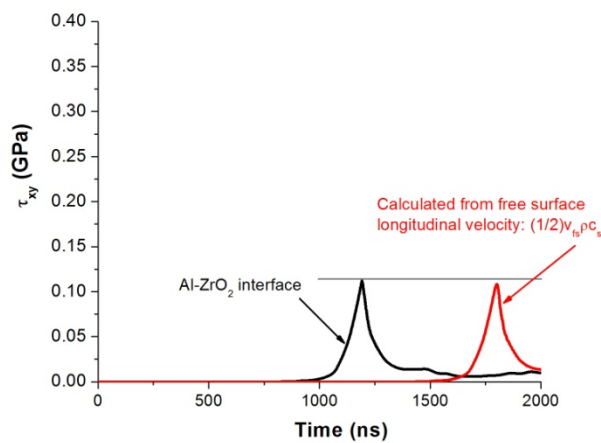
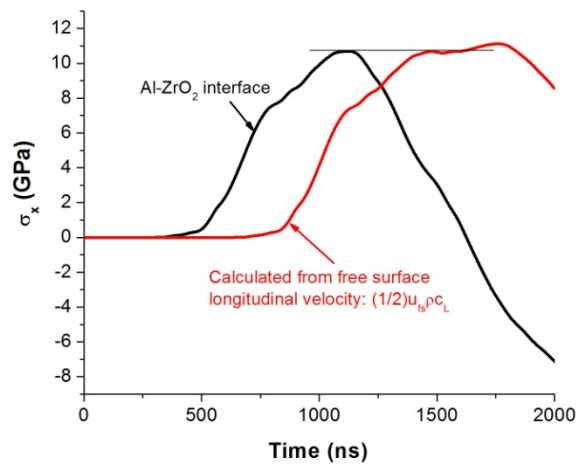
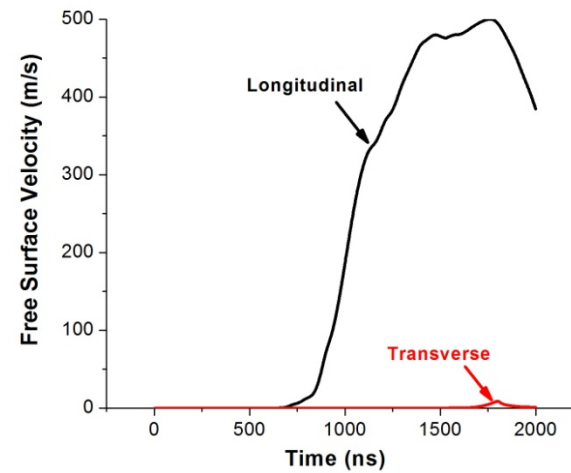
Al-ZrO₂ interface ($t = 0.5\text{mm}$)



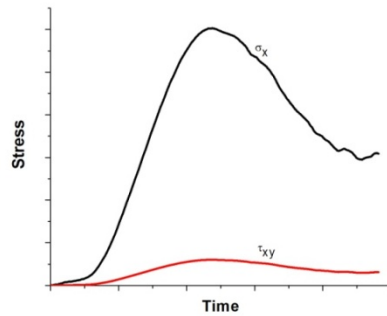
Simulation of The Experiments



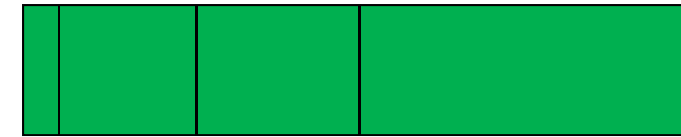
Al-ZrO₂ interface (t = 1.0mm)



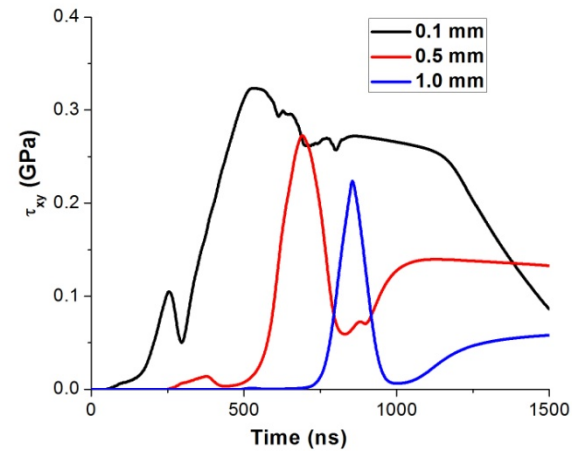
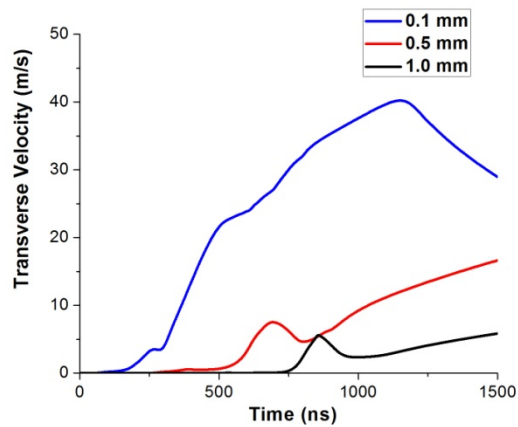
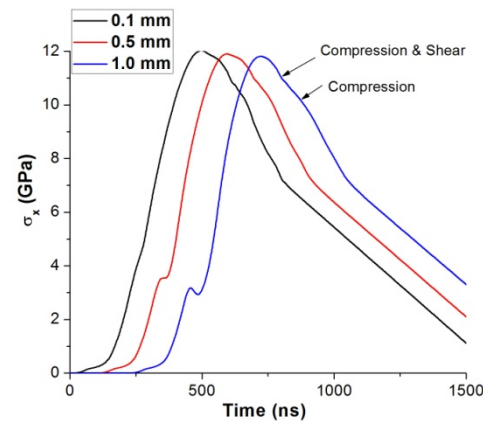
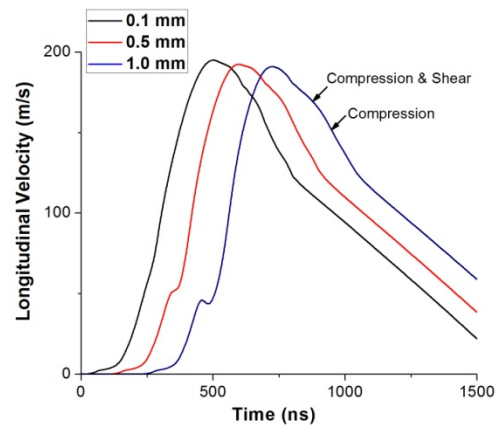
Simulation of In-Situ Material Response



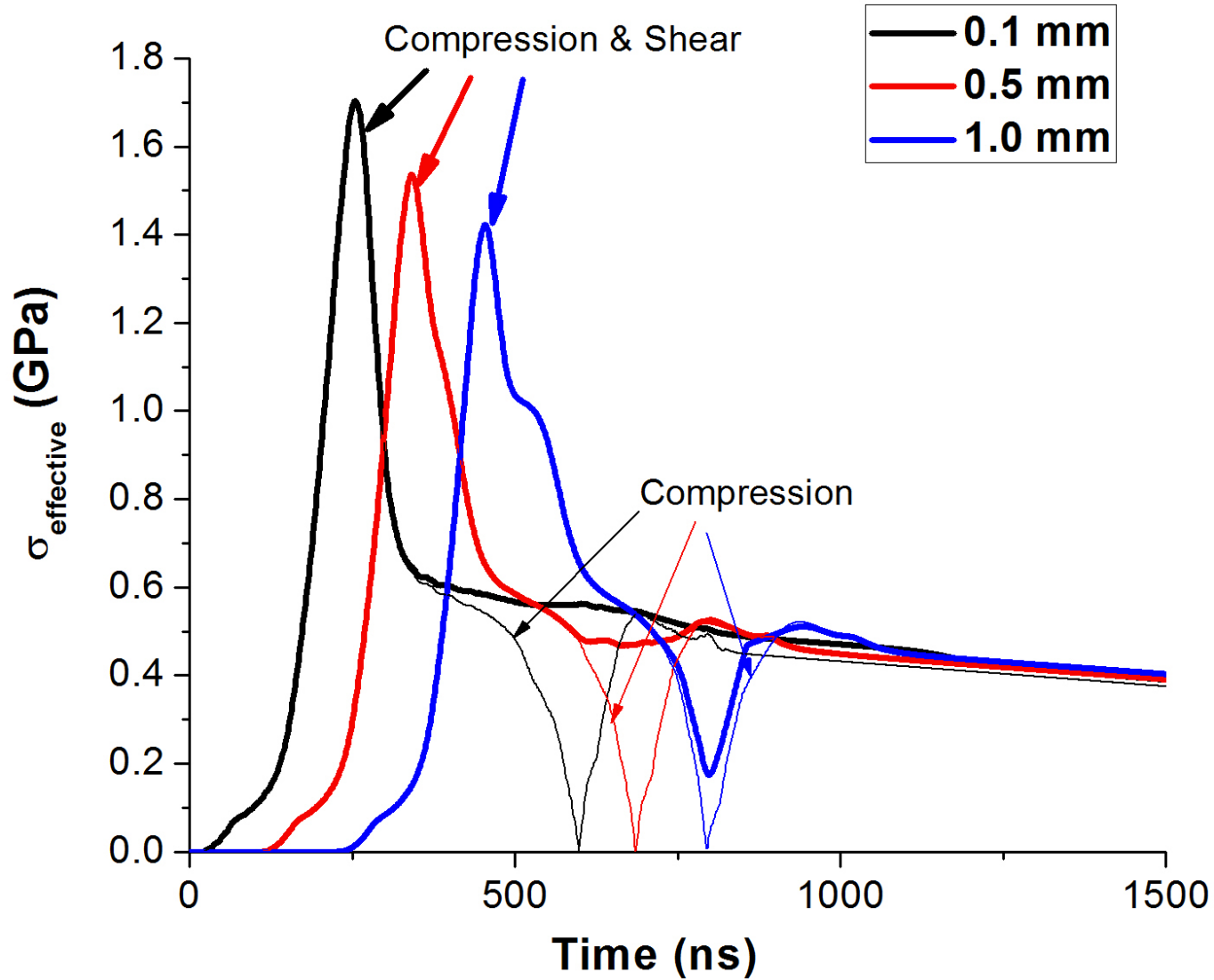
Tantalum



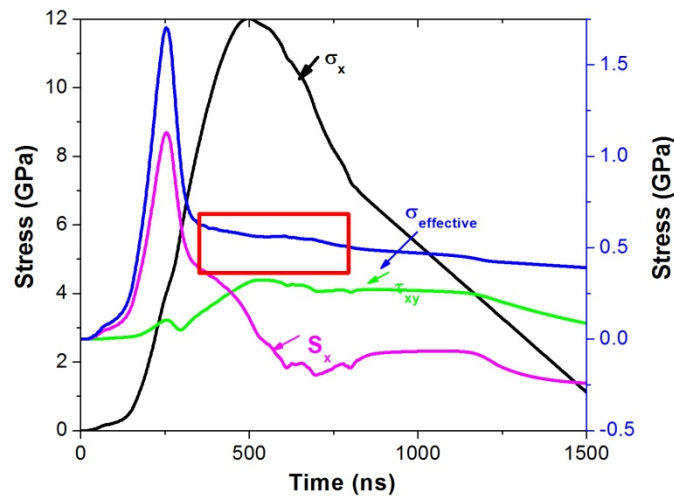
0.1mm 0.5mm 1.0mm



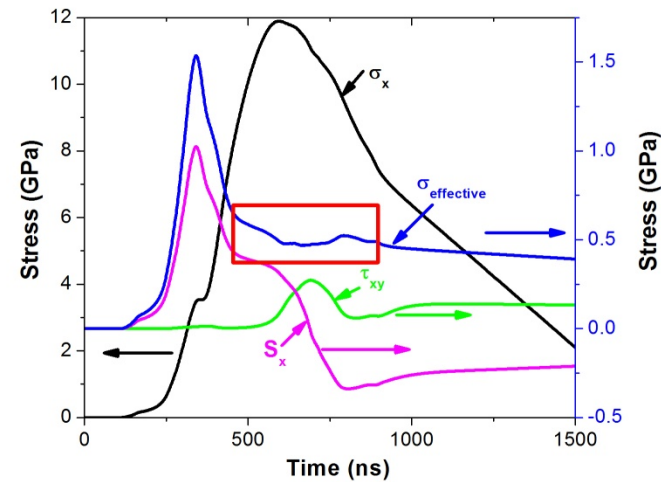
Simulation of In-Situ Material Response



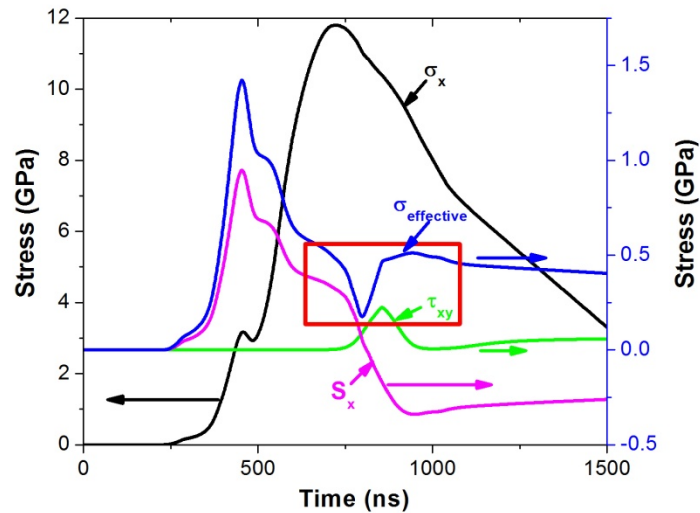
Simulation of In-Situ Material Response



0.1 mm

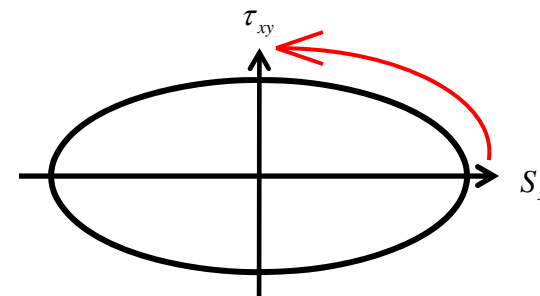


0.5 mm

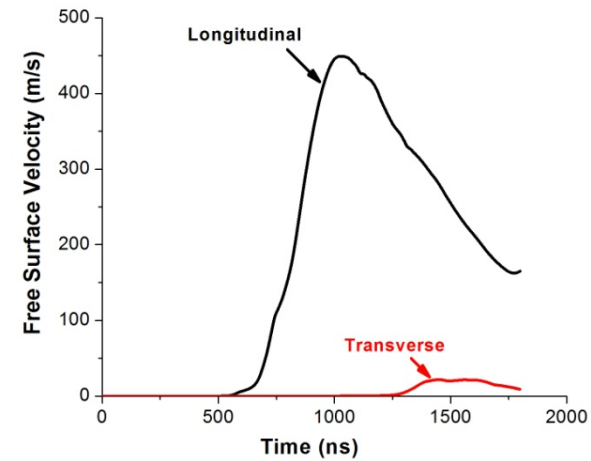
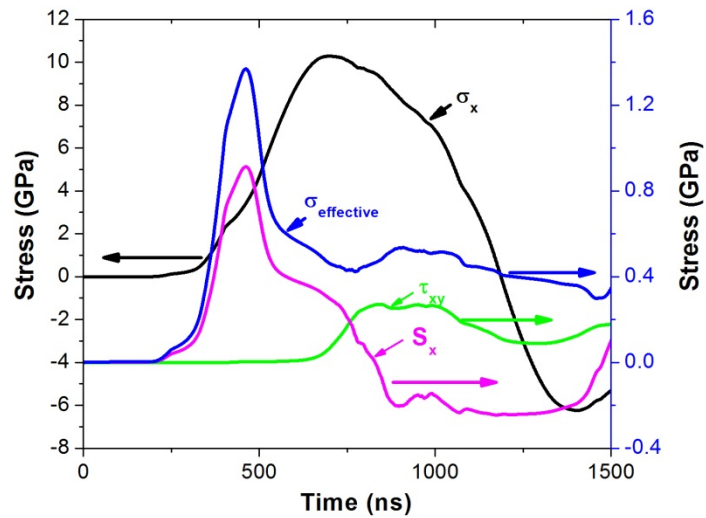


1.0 mm

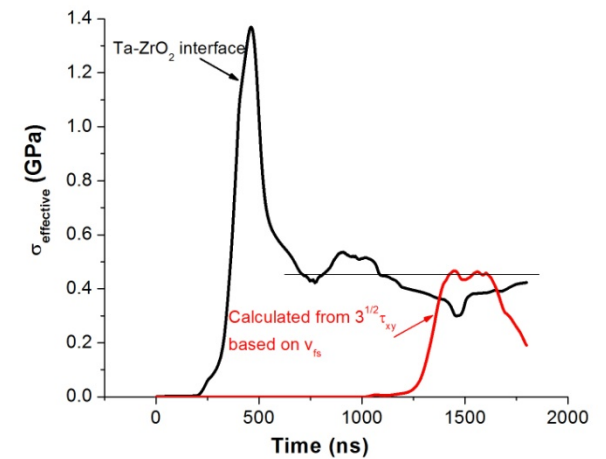
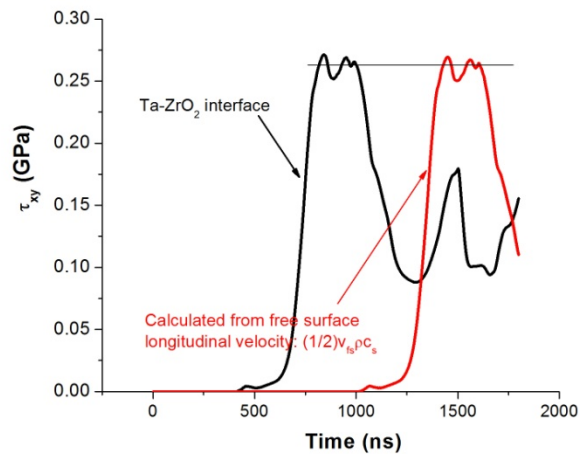
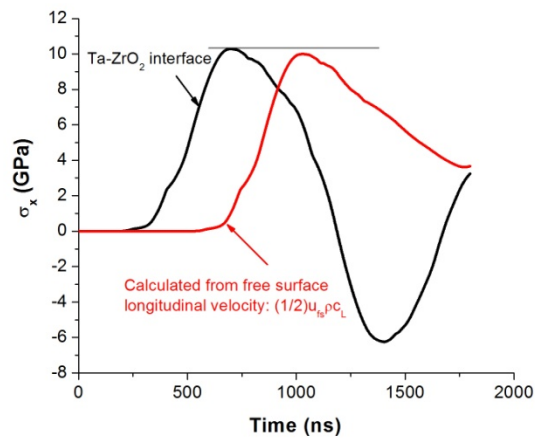
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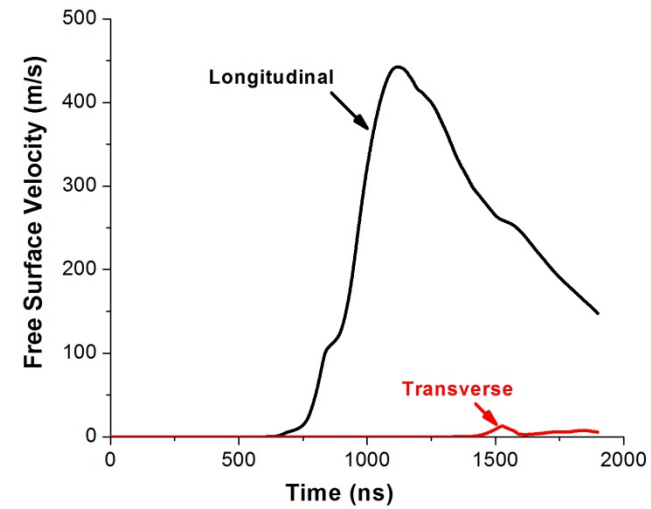
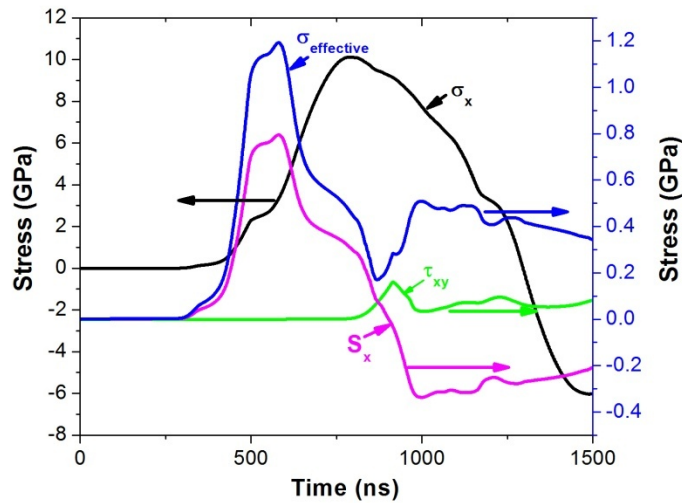
Simulation of The Experiments



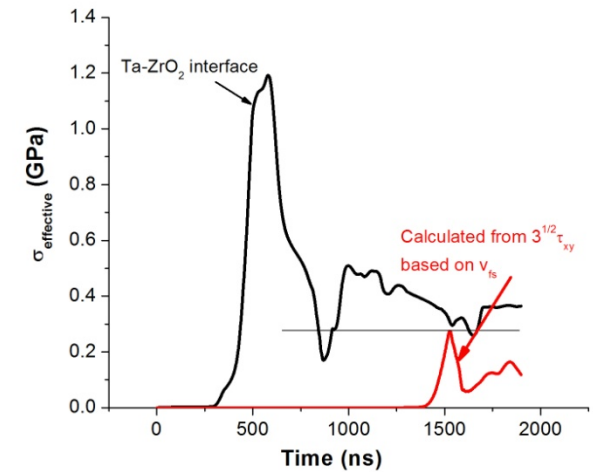
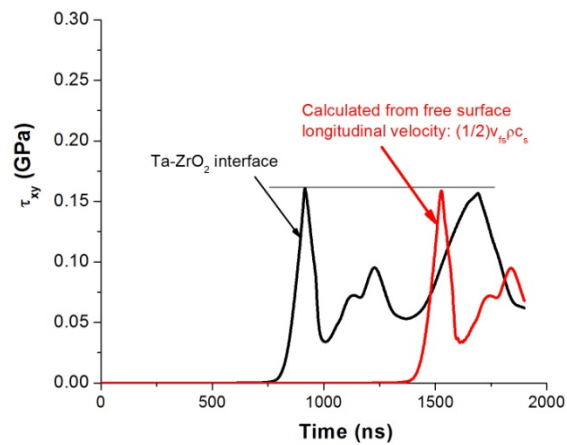
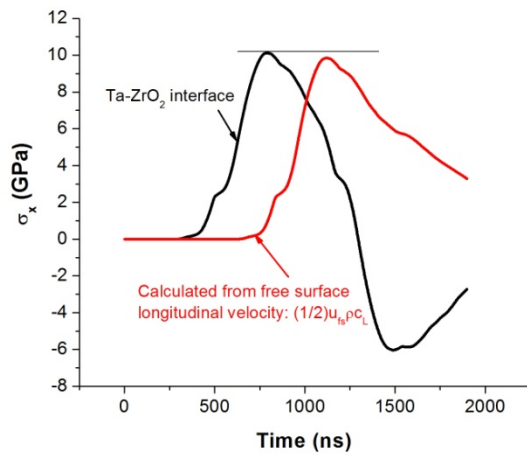
Ta-ZrO₂ interface (t = 0.1mm)



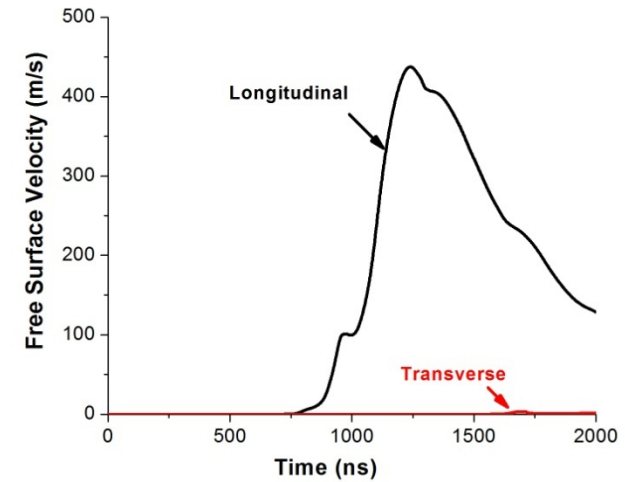
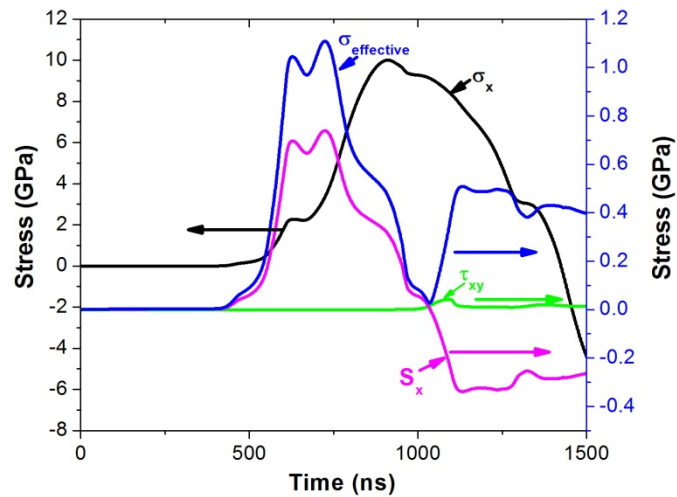
Simulation of The Experiments



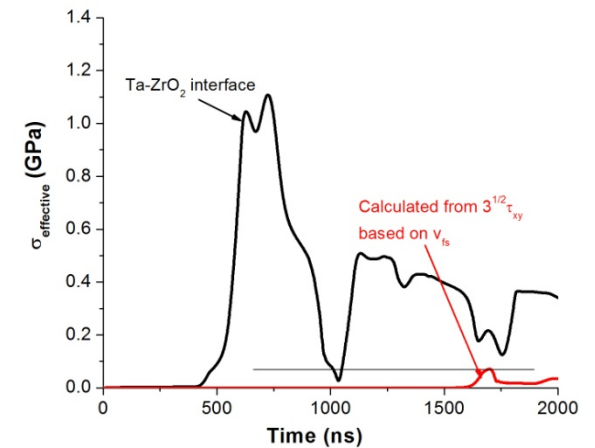
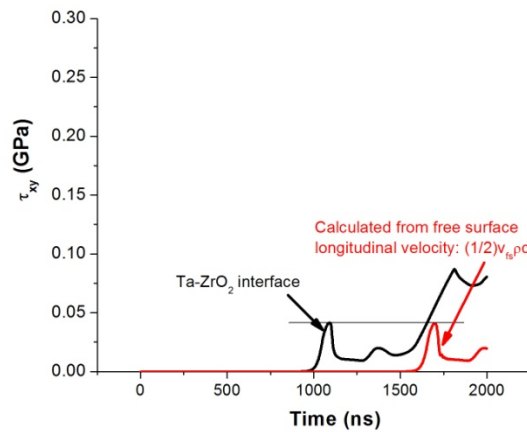
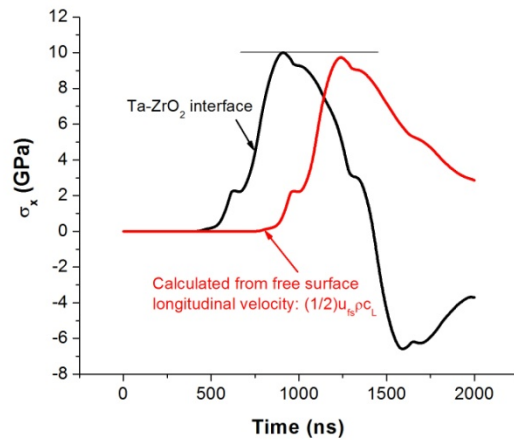
Ta-ZrO₂ interface (t = 0.5mm)



Simulation of The Experiments



Ta-ZrO₂ interface (t = 1.0mm)



Conclusions and Future Work

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.