MHD Electrolyte Flow within an Inter-electrode Gap Driven by a Sinusoidal Electric Field and Constant Magnetic Field

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Introduction: Pulsed electrochemical machining (PECM) allows micro-scale geometries with excellent finishes for high performance materials. Magnetic fields assist electrolyte flow in the inter-electrode gap (IEG), creating a complex magnetohydrodynamic (MHD) flow [1].

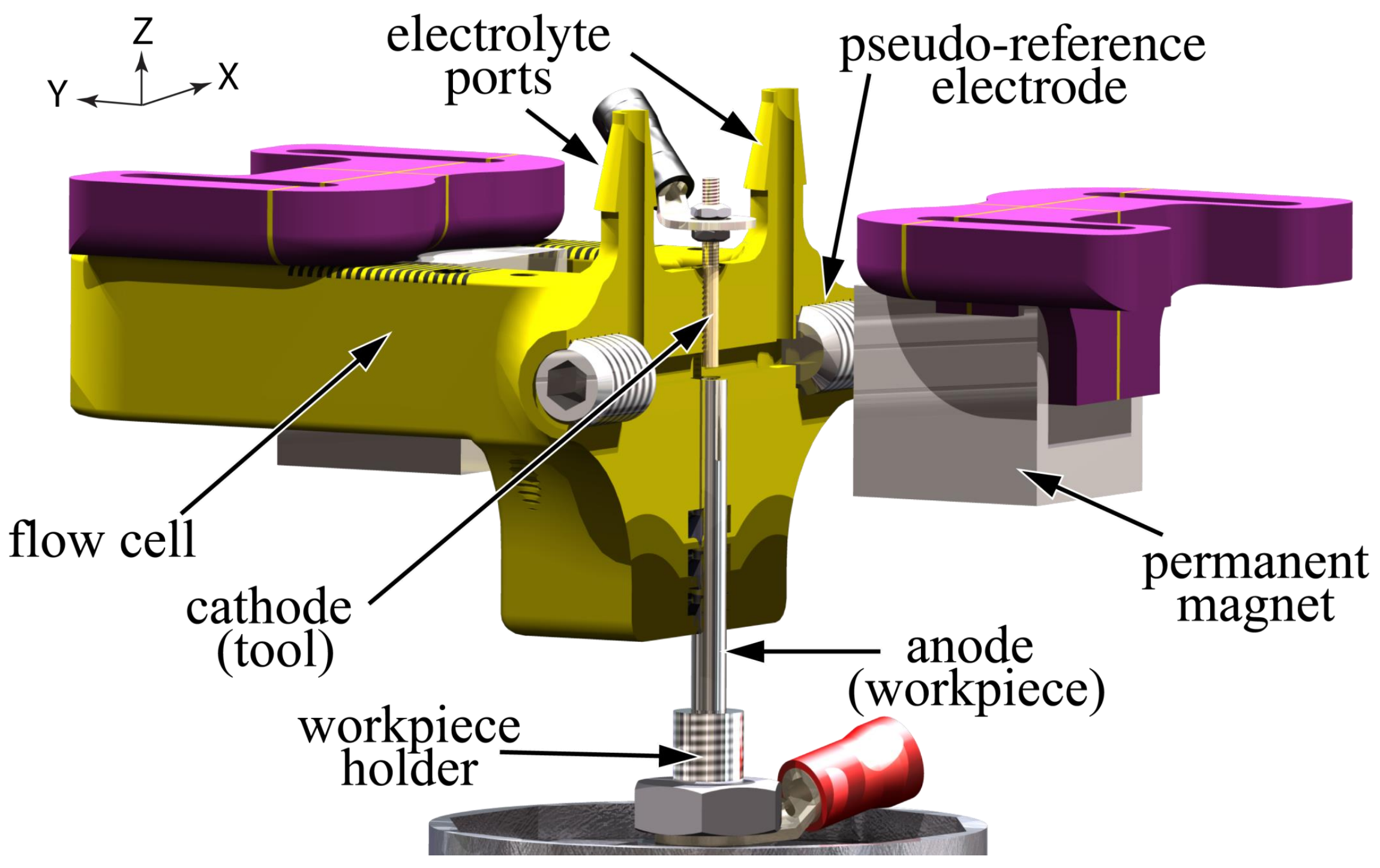

Figure 1. EIS Flow cell w/ magnets

	Value	Units
Anode	7075	Al
Electrolyte	$NaNO_3$	20%
IEG	390	µm
B-Field	0.053-935	mT
E-Field Frequency	0.25-250k	Hz

Table 1. EIS Conditions

Computational Methods: First the E-field is solved, then the Lorentz force and fluid velocity are solved simultaneously using the Navier-Stokes equations for incompressible laminar flow [2],

$$\mathbf{J} = \sigma\mathbf{E} + (\sigma\mathbf{u} \times \mathbf{B}) + \frac{\partial \mathbf{D}}{\partial t}, \qquad \mathbf{F} = \mathbf{J} \times \mathbf{B},$$

$$\rho\frac{\partial \mathbf{u}}{\partial t} + \rho(\mathbf{u} \cdot \nabla)\mathbf{u} = \nabla \cdot \left[-p\,\mathbf{I} + \mu\left(\nabla\mathbf{u} + (\nabla\mathbf{u})^{\mathrm{T}}\right)\right] + \mathbf{F}$$

Fig. 2 shows a COMSOL 5.2™ simulation of flow cell IEG.

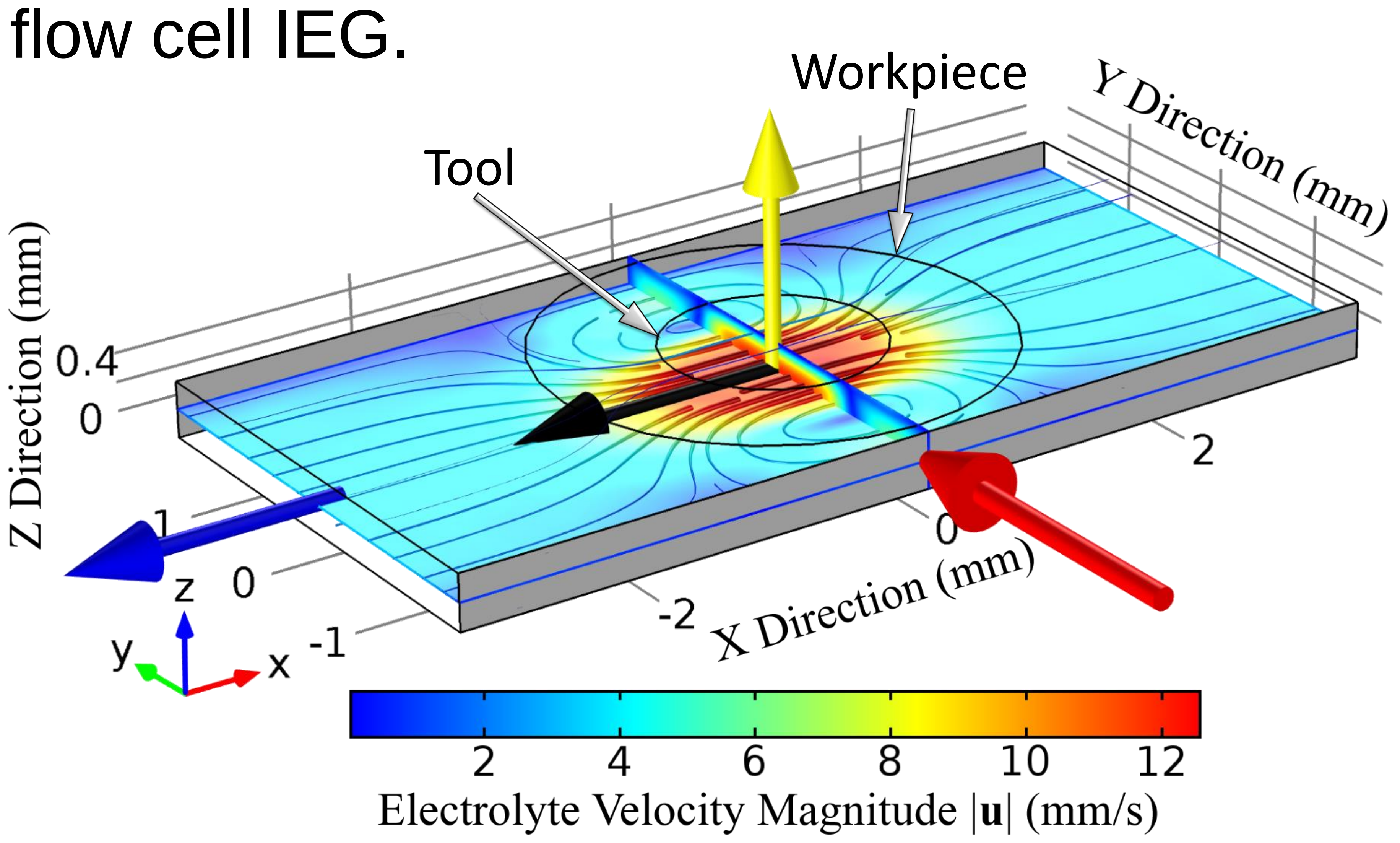

Figure 2. IEG MHD flow velocity magnitude |**u**|

Results: Electrochemical impedance spectroscopy (EIS) measures conductance as a function of B-field magnitude and E-field frequency in Fig. 3. MHD simulation results in Fig. 4 show |**u**| also as a function of B-field magnitude and E-field frequency.

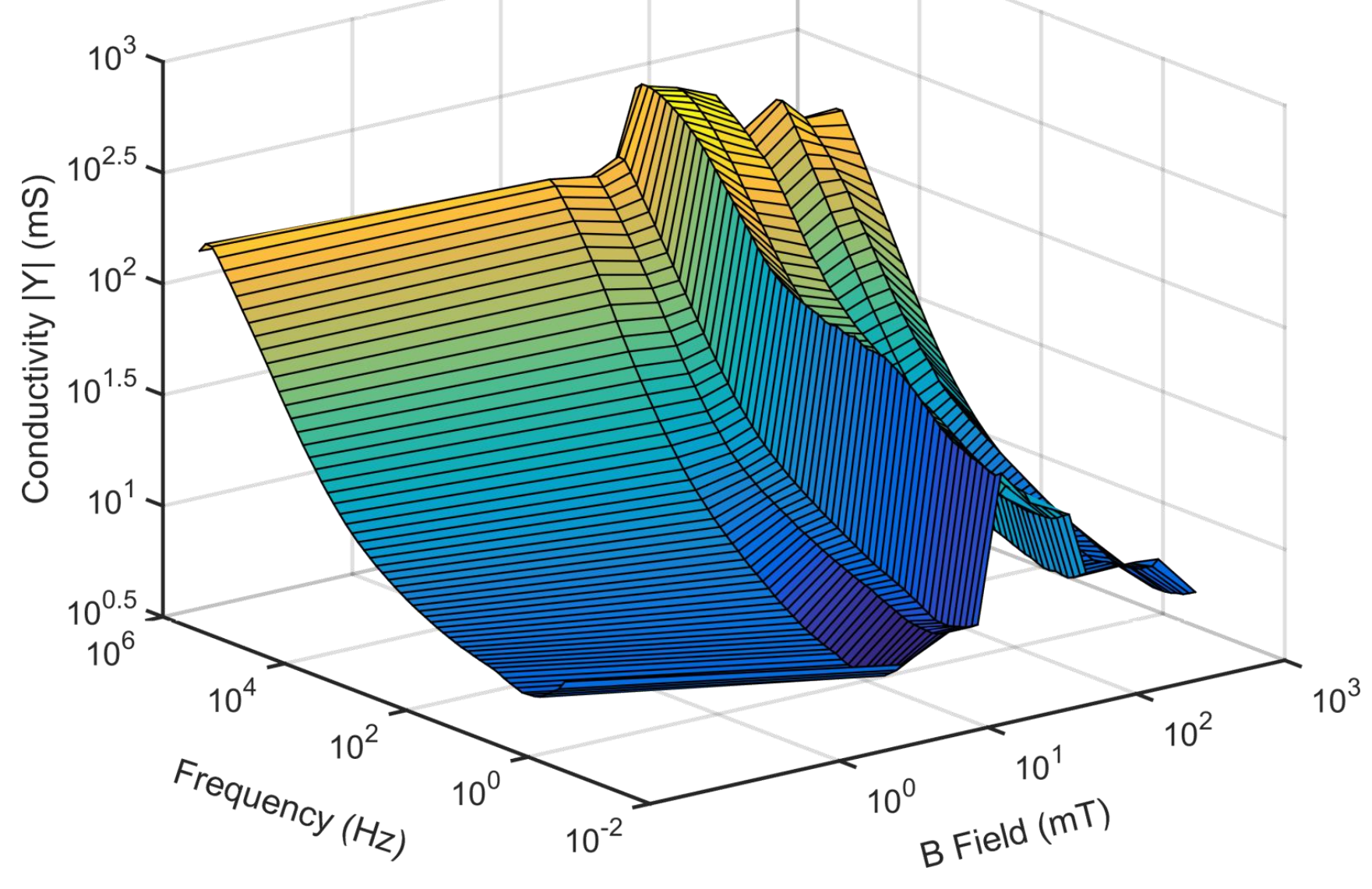

Figure 3. EIS |*Y*|

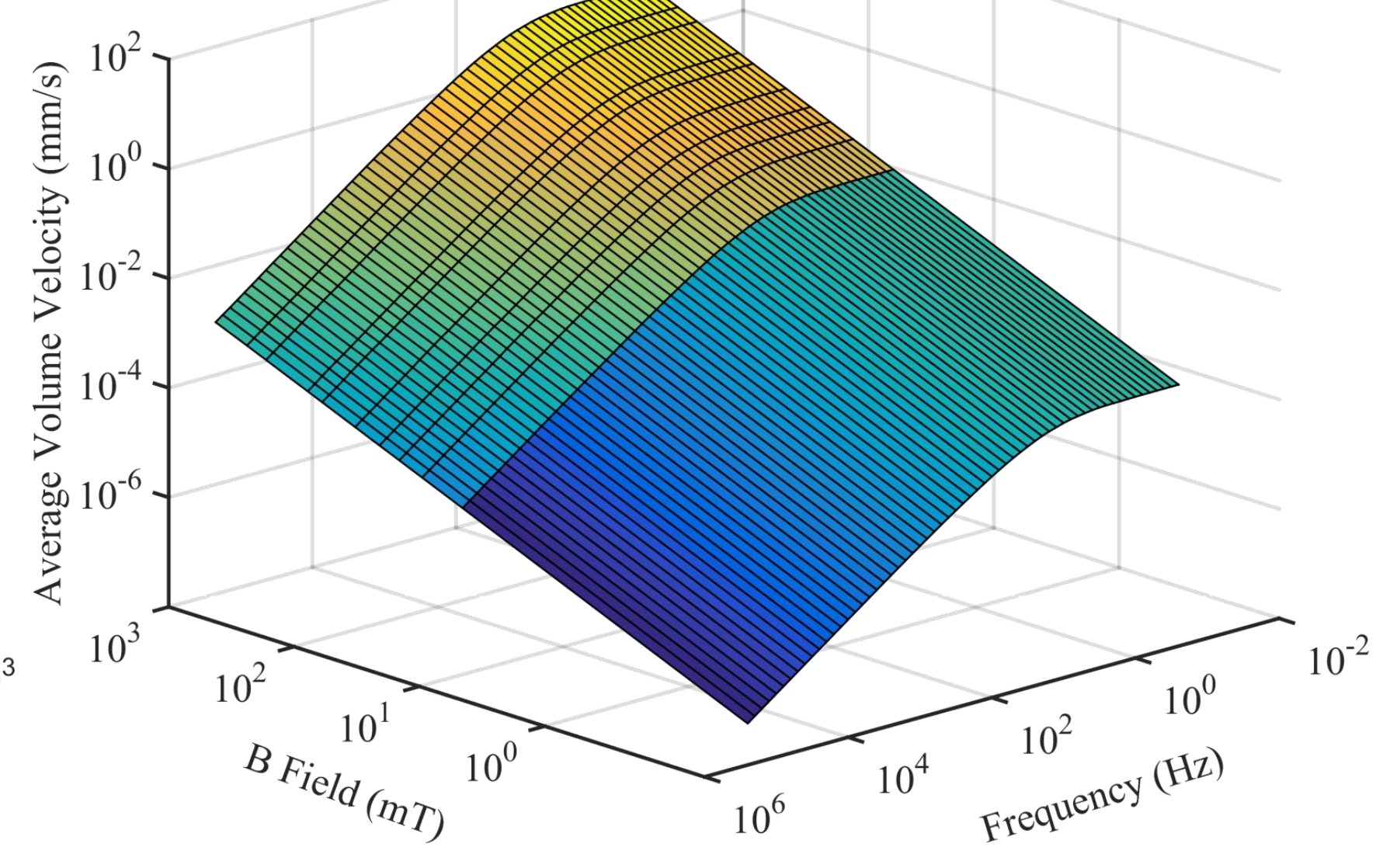

Figure 4. MHD |**u**|

The velocity results from the EIS combined with the MHD in Fig. 5.

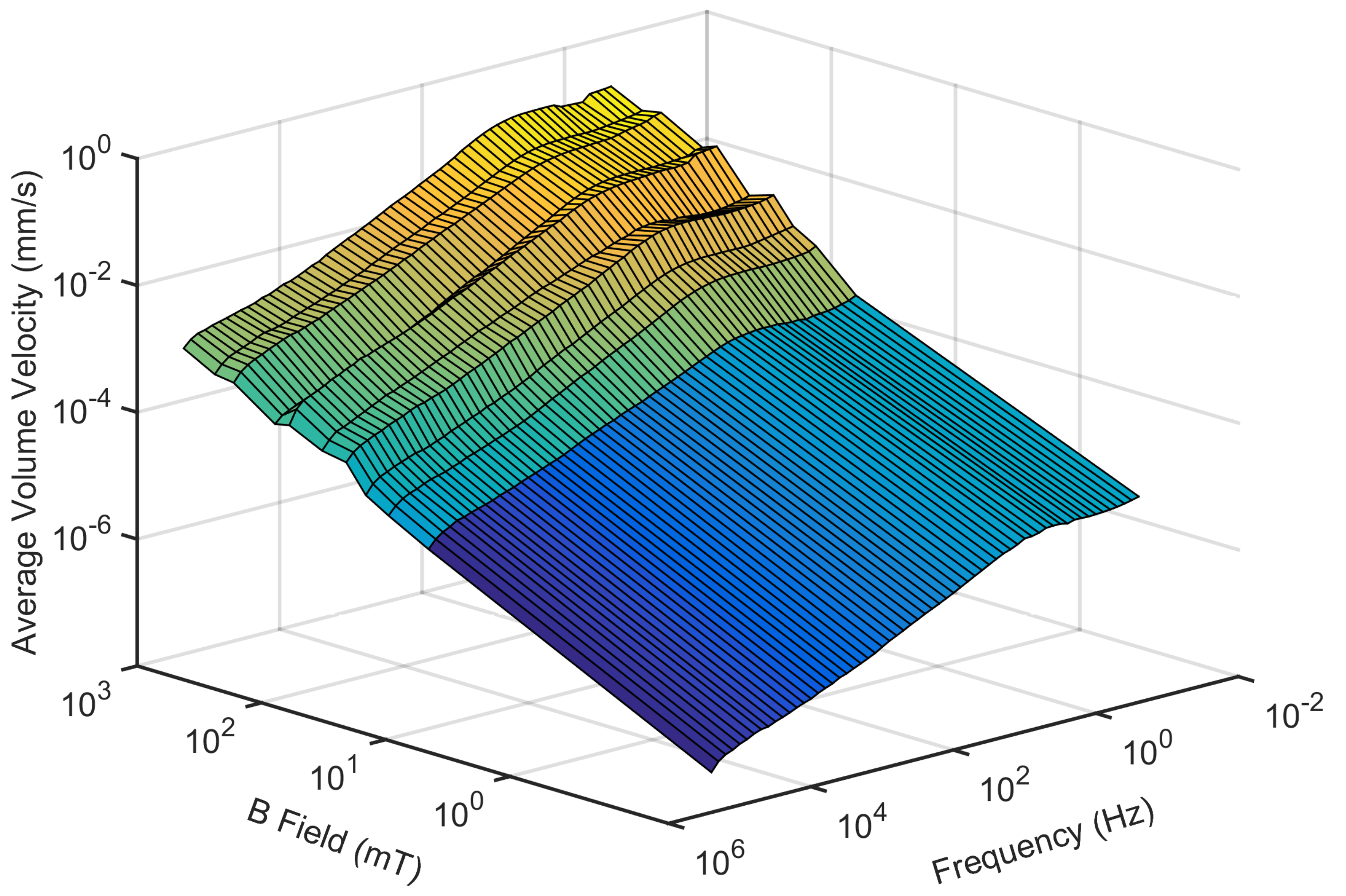

Figure 5. EIS |*Y*| Combined with MHD |**u**|

Conclusions: The EIS results suggest operating at a high frequency to maximize conductivity. The MHD suggests minimizing frequency and maximizing the magnetic field to maximize electrolyte |**u**|. Combining EIS with MHD suggests an optimum E-field frequency to maximize electrolyte |**u**|.

References:

1. O. Lioubashevski, Magnetic field effects on electrochemical processes: a theoretical hydrodynamic model, J. Phys. Chem. B, 108, (2004) 5778-5784
2. L. Aoki, An MHD Study of the Behavior of an Electrolyte Solution using3D Numerical Simulation and Experimental results, Proceeding of COMSOL conference. Boston, Volume, (2013)

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