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From Inhomogeneity to Insight: Neutron Imaging in Modern Materials Science

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Inhomogeneity is a defining feature of real-world materials - whether in composition, phase, strain, or defect distribution - and plays a central role in determining their mechanical and functional behavior. Neutron imaging, with its unique ability to penetrate dense structural materials, has evolved into a powerful, non-destructive tool for visualizing such internal complexity across macroscopic volumes.

Recent advances in instrumentation and methodologies have extended its capabilities far beyond conventional attenuation contrast, enabling the exploitation of imaging modalities previously accessible only through neutron scattering techniques. Notably, **diffraction contrast** allows for spatially resolved characterization of texture, strain, and crystallographic phase distributions, while **inelastic scattering contrast** facilitates the probing of temperature fields during in-situ processing.

In some cases, these contrast mechanisms can be complemented by **Digital Volume Correlation** (DVC) applied to X-ray or neutron computed tomography data, allowing the quantification of internal deformation fields under load.

Together, these emerging techniques make it possible to visualize not only bulk structures, but also to resolve heterogeneities, including cracks and pores, track localized deformation, and even detect the early onset of plasticity —bridging the gap between microstructural behavior and macroscopic performance. This **multi-modal approach** holds particular promise for advancing the understanding of hydrogen embrittlement in metallic alloys, a long-standing challenge in structural materials research.

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