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Fundamentals of Transmission Electron Microscopy in Earth and Planetary Sciences

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Over the last decade, advances in the analytical power of transmission electron microscopy (TEM) and associated targeted sample preparation methods have made it possible to perform imaging and spectroscopy studies of geologic and astromaterials samples with single atom sensitivity. The elemental composition and atomic ordering, or lack thereof, of nearly any sample can be imaged, so that we can identify what a sample is and how it formed. With TEM, we can learn whether dust grains that condensed around stars older than the Sun are single crystals of the mineral phases predicted by equilibrium phase condensation models, observe damage to regolith grains on airless bodies due to the accumulation of solar wind He, tease out the interactions of minerals, water, and organic matter in Archean rocks and returned asteroid samples, and constrain the strength of the local magnetic fields at the time of crystallization of Fe-rich minerals in the early Solar System. Furthermore, dynamic in situ experiments are possible to investigate how individual samples change at reduced or elevated temperatures, and respond to exposure to water, reactive gases, particle irradiation, or applied stress or strain. Transmission electron microscopy is without doubt one of the most versatile and powerful modern analytical methods available to geoscientists. Our goal is to provide a concise, basic grounding in transmission electron microscopy theory, methods, and applications for all geologists and planetary scientists, to make the state-of-art methods accessible to the broadest community.