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Title: Interatomic Forces. Practical methods beyond EAM

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For 25 years the embedded atom method, and related techniques (EAM), have been the workhorse of molecular dynamics. While applications to radiation damage, plasticity and surfaces in elements have been successful, alloys, magnetism, and phase transitions remain troublesome. Two strands of improvement have been tried: the principled inclusion of "missing" physics and the pragmatic inclusion of extra degrees of freedom or more complex fitting functions. In fitting a successful interatomic potential one has to compromise the accuracy of some properties to get a good reproduction of others. This can lead to poor transferability, and one must also be aware that certain failings of the potential, such as phase stability, can make it useless. I will discuss some of the issues involved in fitting, and the difference between a useful interatomic potential and a good simple theory of bonding. I will review some recent work in going beyond EAM. In the case of ferromagnetism (Fe) and covalent bonding (FeC) missing physics can be incorporated in the EAM form, although the interpretation of the functions must be changed. I will show that a return to earlier ideas of screened pairwise potentials opens to possibility of understanding the fantastically complex structures observed under pressure in the alkali and alkaline earth metals. Finally, I will lay out the ongoing challenges to modelling, and what questions MD can realistically hope to answer. especially in treating multicomponent and inhomogeneous nanostructured materials. Twinning hierarchy, shape memory, and superelasticity demonstrated by molecular dynamics Zelazny, Richardson and Ackland PRB 2011 Rescaled potentials for transition metal solutes in alpha-iron Hepburn, Ackland and Olsson Phil.Mag 89 34-36 3393 (2009) Metallic-covalent interatomic potential for carbon in iron Hepburn and Ackland Physical Review B, 78, 16, 165115 (2008)