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Elastic and plastic properties of fcc Fe-Mn based alloys

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High Mn steels exhibit an excellent combination of high strength and extraordinary ductility, which make these steels interesting as lightweight steels with advanced crash resistance and high formability in the automotive industry. This outstanding property combination is enabled by several deformation mechanisms, namely dislocation glide, transformation induced plasticity and twinning induced plasticity. The deformation mechanisms are affected by the stacking fault energy, which is dependent on temperature and chemical composition.

The influence of the chemical composition on the elastic properties of fcc Fe-Mn alloys with additions of C, Al, Cr, Co, Ni and Cu was investigated by combinatorial thin film approach and *ab initio* calculations.

The influence of C and Mn content on the Young's modulus of Fe-Mn-C alloys has been studied experimentally and theoretically. Combinatorial thin film and bulk samples were characterized regarding their structure, texture and Young's modulus. The experimental lattice parameters change marginally with addition of C and are consistent with *ab initio* calculations. C has no significant effect on the Young's modulus of these alloys within the composition range studied here. The comparison of thin film and bulk samples results reveals similar elastic properties for equivalent compositions.

The influence of the Al concentration in Fe-Mn alloys on their elastic properties has been investigated on combinatorial Fe-Mn-Al thin films deposited with different substrate bias potentials to analyze the effect on the phase formation, microstructure, texture and elastic properties. With higher substrate bias potentials fine polycrystalline structure with γ-Fe, α-Fe and β-Mn phases was obtained while with lower substrate bias potentials the γ-Fe phase was prominent and a preferred growth direction in <111> is observed. With addition of Al into the Fe-Mn matrix, the lattice expands as the Al concentration increases. This is consistent for calculations and experiments. Neither the Al content nor the substrate bias potential influence the Young's modulus values significantly.

Ab initio calculations were performed to predict the lattice parameter, B/G ratio and Young's modulus of fcc Fe-Mn-X (X = Cr, Co, Ni and Cu) and combinatorial thin films were synthesized and analyzed regarding the structure and elastic properties. Both the calculations and experiments indicate that with addition of element X in Fe-Mn alloys the lattice parameter and Young's modulus values were marginally affected. Generally very good agreement is obtained between the predictions and the experimental data. Additions with Cr and Co seem to exhibit no substantial effect on the B/G ratio, while with additions of Cu and Ni the B/G ratio is increased. The trends in B/G may be understood by considering the changes in shear modulus induced by the variation in valence electron concentration (VEC). As the VEC is increased, more pronounced metallic bonds are formed, giving rise to smaller shear modulus values.

The effect of the chemical composition on the plastic properties was studied by nanoindentation technique for selected fcc Fe-Mn-C-Al alloys with varying Al concentration. Bulk samples have been electrochemically polished and analyzed locally in their chemical composition, local mechanical properties and topography. The indentation stress-strain curves were determined based on the load-displacement data of the indentations. The curves exhibit a scattering with a maximum deviation in stress by 0.680 GPa and in strain by 0.004. With increasing Al concentration a decreased yielding was observed which might be explained by weaker dynamic Hall-Petch strengthening. The sample with higher Al contents exhibits a pronounced pile-up in comparison with the sample with lower Al concentrations.

The experimental and calculated results of the phase formation, lattice parameter and the Young's modulus values are in good agreement and emphasize the combined experimental and theoretical approach is a valuable research strategy for future design of multi-component high Mn steels. The use of the nanoindentation technique to study the plastic properties of high Mn steels is a powerful method for describing the deformation behavior locally especially in combination with investigations of the local microstructure and texture.