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המחלקה להנדסת חומרים
אוניברסיטת בן-גוריון בנגב
Department of Materials Engineering
Ben-Gurion University of the Negev

Seminar @ Materials Engineering Department

Thursday, July 2th, 2026, 11:00-12:00 | *Hall 015, Building 51 (Marcus Campus)*

PhD Concluding Seminar

Shock Wave Study of Precipitate Strength in Multicomponent Ni-Based Alloys

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Understanding how nanoscale precipitates govern strength is essential for designing precipitation-hardened Ni-based multicomponent alloys, particularly as alloy complexity increases from conventional binary and ternary systems toward high-entropy compositions. In this context, the present PhD work examines the geometry, concentration, and individual strength of Ni_3Al-based precipitates in Ni-based binary (88.5% Ni, 11.5% Al), ternary (79.3% Ni, 10.2% Al, 10.5% Fe), quaternary (71.5% Ni, 8.72% Al, 10.0% Fe, and 9.75% Cr), and quinary (56.60% Ni, 12.92% Al, 9.70% Fe, 9.90% Cr, and 10.92% Co) alloys. Results for the 2- and 3-component systems have been published in the Journal of Alloys and Compounds[a], whereas the 4- and 5-component alloys extend the study to higher alloy complexity. Transmission electron microscopy characterization of homogenized and aged samples was combined with planar impact testing to determine precipitate strength characteristics, including the Peierls stress. Detailed analysis of the experimental results reveals significant differences in precipitate structure among these alloys. In the binary Ni–Al alloy, the precipitates are predominantly small, dense Ni_3Al spheres with an average diameter of ~4 nm. Increasing the number of alloying components from 2 (Ni–Al) to 5 (Ni–Al–Fe–Cr–Co) results in larger, looser spherical precipitates. A key finding of this study is that the small precipitates exhibit superior strength, approximately 40% higher than that of the larger ones. The latter are identified as regions of Ni-based solid solution densely populated by tiny (~2 nm) islands of the ordered Ni_3Al phase. These results clarify the precipitation-hardening features of 2-, 3-, 4-, and 5-component Ni-based alloys and provide a basis for optimizing their design and processing for engineering applications. With the addition of each subsequent element—Fe, Cr, or Co—to the Ni–Al alloy, the ordered phase becomes increasingly diluted by these atoms, as also evident from TEM-EDS mapping. A high concentration of Ni_3Al precipitates (>50–70%) in high-entropy Ni-based alloys can hinder dissolution even at temperatures above the alloy melting point, as observed in the homogenized state of the Ni–Al–Fe–Cr and Ni–Al–Fe–Cr–Co alloys. The systematically calculated precipitate strength (Peierls stress) in the Ni–Al, Ni–Al–Fe, Ni–Al–Fe–Cr, and Ni–Al–Fe–Cr–Co alloys indicates that the contribution of the ordered phase to dynamic strengthening and resistance to dislocation motion under uniaxial loading decreases progressively with increasing alloy complexity. In the 4- and 5-component alloys, the improvement in mechanical properties, including dynamic properties, is therefore attributed primarily to solid-solution strengthening.

[1] I. Efremenkov, M. Aizenshtein, E. B. Zaretsky, S. Hayun (2024) "Strength of precipitates in Ni-Al and Ni-Al-Fe alloys, Journal of Alloys and Compounds, 983, 173864