Electrodeposition of NiW, NiWMo and NiMo Alloy Thin Films and NiW Nanowires

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Tungsten and molybdenum alloys with iron-group metals, particularly NiW and NiMo alloys, are well known to possess outstanding functional properties such as thermal, wear and corrosion resistance, high microhardness, and excellent catalytic activity towards hydrogen evolution. They have been electrodeposited as thin films, and rarely as nanowires, despite the potentially superior properties and applications that nanowires can offer. The research presented is the first demonstration of NiW nanowires.

The electrolytes for deposition of NiW, NiWMo and NiMo alloy thin films and NiW nanowires were developed. One challenge in depositing these alloys is in reaching a high amount of W or Mo. Both W and Mo cannot be electrodeposited from aqueous electrolytes, but require Ni ions to induce their reduction, while at the same time depositing Ni. This research shows that it was possible to deposit NiW alloys with W content in the range of 40 to 60 wt % using direct current of 2-50 mA/cm^2, current efficiency being 7-62 %. NiWMo alloys with Mo content in the range of 48 to 70 wt % pushed the combined Mo+W content to the high range of 60 to 79 wt %. Replacement of W for Mo in the electrolyte for NiW alloy resulted in NiMo alloy deposition with 69 to 82 wt % of Mo in the deposit. The trade-off for comparatively high refractory metal content is a very low current efficiency for NiWMo and NiMo alloys between 0.5-2 %, and needs to be significantly improved in future. Deposition of NiWMo and NiMo alloys required higher values of current densities (200-300 mA/cm^2) than for NiW (2-50 mA/cm^2).

The NiW nanowires with diameters from 40 nm to 250 nm and length of 6 µm had W contents from 33 wt % to 54 wt %. The nanowires were deposited into polycarbonate templates and released by dissolution of the membrane in dichloromethane. Transmission electron microscopy (TEM) and scanning electron microscopy (SEM) showed that the NiW nanowires had a bumpy morphology even when deposited under direct current. The dimension of bumps and W content depended on both the membrane pore diameter and deposition conditions.

Ultrasonic treatment of NiW nanowires was conducted in order to examine their mechanical robustness. Results demonstrated that using pulse current instead of direct current results in less broken NiW nanowires, and thus more robust wires.