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Aluminum (Al^{13})

Properties

Aluminum is a silvery-white metal with an atomic mass of 26.98 u. Al has a density of 2.7 g/cm^3, a melting point of 660 ^{o}C and a resistivity of 2.65 µOhm cm. It is relatively soft, ductile, durable and malleable. Al has a Brinell hardness of 160 – 550 MPa. The yield strength of pure aluminum is 7–11 MPa, while aluminum alloys have yield strengths ranging from 200 MPa to 600 MPa. Al is a good thermal and electrical conductor with thermal conductivity of 237 W/(m·K), having 59% the conductivity of copper, both thermal and electrical, while having only 30% of copper's density. The main alloying agents for Al are Cu, Zn, Mg, Mn, and Si (e.g., duralumin) with the levels of other metals in a few percent by weigh.

Although the great majority of aluminum compounds feature Al^{3+} centers, compounds with lower oxidation states (-1, -2, +1, +2) are also known and sometime of significance as precursors to the Al^{3+} species. Its standard electrode potential in respect to Al^{+3} is -1.66V. Aluminum is chemically resistant in ambient atmosphere and mineral acids due to the formation of protective oxide film on the surface, but dissolves readily in concentrated sulfuric acid, hydrochloric acid, hydrofluoric acid, sulfuric acid and bases. By mass, aluminum makes up about 8% of the Earth's crust. It is the third most abundant element after oxygen and silicon.

Plating Solutions

Aluminum can be electrodeposited from organic solutions, containing in g/l:

a) Example #1. Aluminum chloride – 250, lithium hydride – 6 in ethyl ether at temperature of 15 – 25 ^{o}C, current density of 10 – 40 mA/cm^2 with current efficiency of ~100% and plating rate of up to ~25 µm/hour.
b) Example #2. Aluminum chloride – 10, nitrobenzene – 55, benzene chloride – 25 in formamide at temperature of 45 – 50 ^{o}C, current density of 80 – 100 mA/cm^2 with current efficiency of 70%.
c) Example #3. Aluminum bromide – 75, hydrogen bromide – 12, paraffin – 17 in xylene at temperature of 15 – 25 ^{o}C, current density of 10 mA/cm^2 with current efficiency of 70% and plating rate of 9 - 10 µm/hour.

Aluminum can be electrodeposited from molten salts, consisting of:

a) Example #1. Aluminum chloride – 58 wt. % and tetraethyl ammonium – 42 wt. % melted at 100 - 110 ^{o}C with plating temperature of 50 – 70 ^{o}C and current density of 1000 – 1500 mA/cm^2.
b) Example #2. Aluminum and sodium chlorides with molar ratios of 1:1, 3:2, 2:1 at temperature of 175 - 250 ^{o}C and current density of 2 – 5 mA/cm^2. The current density can be increased by ~100x with addition of fluorides and iodides.

Aluminum can be also electrodeposited from ionic liquids, for example, 1-butyl-3-methyl-imidazolium chloride ((Bmim)Cl)/$AlCl_3$ (40/60 mol %). Thick (20 µm) aluminum coatings can be electrodeposited on brass substrates at different temperatures and mixing conditions (mechanical stirring and sonication) [1].

Applications

Aluminum and its alloy are vital to the aerospace industry and important in transportation and building industries, such as building facades and window frames. Other major uses for aluminum are in packaging (cans, foil, frame etc.), electrical parts (conductor alloys, motors and generators, transformers, capacitors, etc.), a wide range of household items from cooking utensils to furniture. Aluminum is also capable of superconductivity. It is the most common material for the fabrication of superconducting qubits [2].

References:

1. E. Berretti et al. *Materials* **9**(9), 719, 2016.
2. M.H. Devoret, R.J. Schoelkopf. *Science* **339** (6124), 1169–1174, 2013.

CONTACT NANO3D SYSTEMS LLC TO FORMULATE ALUMINUM PLATING SOLUTION PER YOUR REQUIREMENTS