Gold Etching

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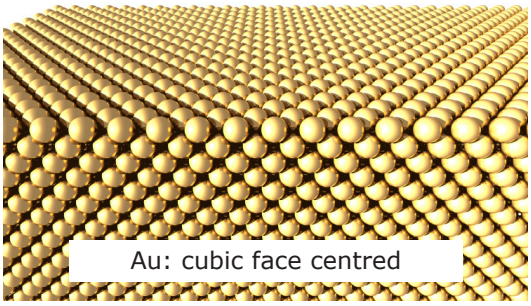
Concentrations

All chemicals concentrations mentioned in this chapter with a * refer to a conventional concentration listed in the last section of this document.

Gold

Gold has a very high density of 19.3 g/cm^3, its crystal structure is cubic face centred.


Au: cubic face centred

With a standard potential of 1.5, gold belongs to the noble metals. The electron configuration [Xe]4f^{14} 5d^{10} 6s^1 strongly prevents the oxidation of gold: The completely occupied 5d orbital extends beyond the single valence electron which hereby is well shielded against any reaction partners.

Wet chemical etching of gold therefore requires a strong oxidizer for the separation of the unpaired valence electron, as well as a complexing agent which suppresses the reassembly of oxidized gold atoms back into the crystal.

Gold Etching With HCl/HNO_3

Mixtures of nitric acid and hydrochloric acid (in a mixing ration of 1 : 3 also called *aqua regia*) are able to etch gold at room temperature. The very strong oxidative effect of this mixture stems from the formation of nitrosyl chloride (NOCl) via

$$HNO_3 + 3\ HCl \rightarrow \quad NOCl + 2\ Cl + 2\ H_2O,$$

while free Cl radicals formed in the solution keep the noble metal dissolved as Cl-complex (tetrachloro gold-(III)-acid = $HAuCl_4$). HNO_3/HCl mixtures are not stable and decompose accompanied by the formation of nitrogen oxides and Cl_2.

The etch rate of aqua regia for gold is approx. 10 µm/min (at room temperature) and can be increased to several 10 µm/min at elevated temperatures.

Palladium, aluminium, copper and molybdenum are also etched by aqua regia. For etching platinum or rhodium, the etching solution has to be heated to attain a reasonable etch rate. Etching of iridium requires strongly heated (boiling) aqua regia.

Silver is not attacked by aqua regia due to the formation of a silver chloride passivation film. Chromium, titanium, tantalum, zirconium, hafnium and niobium also form a very stable passivation film (in many cases the metal oxide) protecting the metal against the attack of aqua regia at least at room temperature. For same reason, tungsten reveals a very slow etch rate in aqua regia.

Gold Etching With KI/I_2

Gold and iodine form gold iodide via

$$2\ Au + I_2 \rightarrow 2\ AuI.$$

The solubility of AuI is improved by adding KI to the solution. Iodine/iodide can be substituted by other halogenides excepting fluorine which does not form soluble gold compounds.

In a mixing ratio of KI : I_2 : H_2O = 4 g : 1 g : 40 ml, a room temperature etch rate of approx. 1 µm/min gold is attained. Copper reveals a comparable etch rate, while nickel is only etched in case of current linkage to gold.

Gold Etching With Cyanides

Aqueous solutions of the very toxic sodium cyanide (NaCN) or, respectively, the also very toxic potassium cyanide (KCN) dissolve gold via the formation of the soluble cyano-complex $[Au(CN)_2]$. This reaction requires oxygen from the air or supplied by decomposing hydrogen peroxide added to the etching solution.

Beside many other metals, KOH and NaOH solutions also attack silver and copper which also form aqueous soluble cyano-complexes.

Our Gold Etch

consists of HF and HNO_3 and is available in 2.5 L sales volumes, other containments on request.

Suited Photoresists and their Processing for Au Etching

All AZ® and TI resists are suited and sufficiently stable as mask for gold etching. Generally, we recommend the usage of resists with optimized adhesion such as the AZ® 1500 series (resist film thickness range approx. 0.5-3 µm via the AZ® 1505, 1512 HS, 1514 H, and 1518), or the AZ® 4533 (3-5 µm).

The deeper Au has to be etched, the ticker the resist film should be. If this requires a high aspect ratio, we recommend the high-resolution AZ® ECI 3000 series (resist film thickness range approx. 0.5-4 µm).

In order to improve the resist adhesion, a hardbake after development can be beneficial. We recommend 140-145°C for 5-10 minutes. Since the resist film hereby embrittles, the cooling down to room temperature should not take place abruptly in order to prevent the formation of cracks. Adhesion promoters such as HMDS or TI Prime will not help, since they cannot bond on gold. However, a thin, few nm thick Ti or Cr film on top of the Au gives an excellent adhesion promoter which can be etched after resist development and Au etching.

All common NaOH-, KOH-, or TMAH-based developers and all typical removers are compatible with gold.

All resists and ancillaries mentioned in this section are distributed by us and more detailed in the document Photoresists, Developers, and Removers.

Dilution Grade of the Substances Mentioned in this Document

HCl^* = 37% HCl in H_2O

HNO_3^* = 70% HNO_3 in H_2O

$H_2SO_4^*$ = 98% H_2SO_4 in H_2O

HF^* = 49% HF in H_2O

$H_2O_2^*$ = 30% H_2O_2 in H_2O

$H_3PO_4^*$ = 85% H_3PO_4 in H_2O

NH_4OH^* = 29% NH_3 in H_2O

CH_3COOH^* = 99% CH_3COOH in H_2O

Disclaimer of Warranty

All information, process guides, recipes etc. given in this brochure have been added to the best of our knowledge. However, we cannot issue any guarantee concerning the accuracy of the information.

We assume no liability for any hazard for staff and equipment which might stem from the information given in this brochure.

Generally speaking, it is in the responsibility of every staff member to inform herself/himself about the processes to be performed in the appropriate (technical) literature, in order to minimize any risk to man or machine.