Subject: L070131-00: Unacceptability of 7075 Aluminum Alloy in the LIGO UHV?
From: Dennis Coyne <coyne@ligo.caltech.edu>
Date: Tue, 11 Nov 2008 11:20:24 -0800
To: Dennis Coyne <coyne@ligo.caltech.edu>

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Date: Sat, 10 Feb 2007
From: Dennis Coyne <coyne@ligo.caltech.edu>
To: VRB

On Feb 10, 2007, at 19:54, Dennis Coyne wrote:

> Mike,
> Thanks for looking up Zn vapor pressure with temperature. The best
> sources that I found for elemental Zn vapor pressure in the
> temperature range of our interest was:
> 1) McKinley & Vance, "The Vapor Pressure of Zinc between 150C and
> 350C", J of Chem Phys, v22, N6, June 1954:
> Log(Po) = -7198/T+9.664, with Po in torr and T in K for the range 150C
> < T < 350C
> So, at 120C (our nominal Aluminum bake temperature) Po = 2E-9 torr and
> at room temperature (22C) it is ~2E-15 torr (by extrapolation). At a
> high bake temperature of say 300C, Po = 1E-3 torr.
>
> 2) Aldred & Pratt, "Vapor Pressures of Zinc, Cadmium, Antimony, and
> Thallium", J of Chem & Engineering Data, v8, n3, July 1963.
> Log(Po) = -6651/T+8.843, with Po in torr and T in K for the range 300C
> < T < 400C
> So, at 120C, Po = 8E-9 torr and at room temperature (22C) it is ~2E-14
> torr (by extrapolation).
> The above Clapeyron-Clausius equations are, of course, consistent with
> your AIP handbook.
>
> On the issue of the vapor pressure of an alloy, the Zn vapor pressure
> over 7075 Aluminum (6% Zn by Wt.) should be lower than the vapor
> pressure over pure Zn. For an ideal solution (alloy) the vapor
> pressure lowering is given by Raoult's law:
> p = x(Zn) * Po, where x(Zn) is the mole fraction of Zn.
> x(Zn) ~ 0.06*Ar(Zn)/Ar(Al) = 0.025, where Ar is the relative atomic
> masses.
> So, p = 5E-17 torr at 22C and 6E-11 torr at 120C.
> Although I could not find a reference for Zn vapor pressure over a
> 7000 series aluminum, I did find a reference for Fe vapor pressure
> over a Vanadium-Fe alloy (Myles & Aldred, "Thermodynamic Properties of
> Solid Vanadium-Iron Alloys", J of Physical Chem, v68, n1, Jan 1964).
> At ~10% molar fraction, the vapor pressure is in close agreement with
> Raoult's law; The non-ideal deviation further lowered the vapor
> pressure.
>
> On the issue of physical vapor deposition of Zn onto our optics (and
> other chamber surfaces), the mass rate of evaporation is given by the
> Hertz-Knudsen equation (H. Lee, Fundamentals of Microelectronics
> Processing, 1989):
> V = 5.834E-2 * Sqrt(M/T) * p = {1.3E-18 gm/cm^/s at 22C and 1.3E-12
> gm/cm^/s at 120C}
> where the molecular mass of Zn, M = 65.38. The maximum deposition
> rate, assuming direct free-molecular streaming (no
> adsorption/desorption), disregarding solid angles and view factors,
> and no condensation rate-limited processes (if any), i.e. worst case,
> is then given as
> rd = V*As/(Pi * r^2)
> where As is the source area and r is the distance to the target
> (optic). Assuming a ~1m^2 source area at a distance of ~1m from the

> optic, then
> rd = {4.0E-19 gm/cm^2/s at 22 C and 4.2E-13 gm/cm^2/s at 120C}
> With a Zn density of 7.14 gm/cm^3, this corresponds to a maximum
> deposition rate of {5.6E-20 cm/s at 22C and 5.9E-14 cm/s at 120C}. If
> we assume a maximum tolerable thickness of ~1 nm (about 1 monolayer),
> then the minimum time to achieve this layer is {5.7E4 yr at 22 C, 470
> hr at 120C and only 25 hr at 150C}. Obviously the vapor deposition
> process is much more complicated, but this simple (and I think
> conservative) analysis gives some comfort.
>
> It seems clear to me that:
> • The use of 7075 Alu in our vacuum system at room temperature is
> acceptable. However, we should prohibit it's use in the future without
> prior approval based on a compelling reason.
> • We should not bake 7075 Alu in a vacuum bake oven; While likely
> not to cause significant contamination at 120C to subsequent loads, if
> the oven has hot spots, or a unplanned excursion to higher
> temperatures, the oven could contaminate subsequent loads.
> • Air baking 7075 Alu at 120C should be acceptable (no risk of
> contaminating the air bake oven due to operation at 1 atm)
> Dennis