

## NOTES

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# A simple substitute for Knudsen cells using an existing pendant-drop type electron beam evaporator

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A simple and elegant technique is outlined in which a specially designed crucible may be used for noble metal evaporation in a pendant-drop type electron beam evaporator with virtually no modifications.

Many advances in surface physics and chemistry have involved the use of artificially structured materials. A variety of techniques for growing these materials exist. The two most commonly used molecular beam epitaxy sources for fabricating the ultrathin films needed in magnetic studies are electron beam (EB) and Knudsen cell (KC) molecular beam evaporators.<sup>1</sup> The pendant-drop type EB evaporator shown in Fig. 1(a) functions by accelerating thermionically emitted electrons from a nearby filament into a rod or wire of evaporant (large disk EB sources exist but are geometrically incompatible with our improvement). This configuration limits EB evaporators for use with those materials possessing high melting points. The localized nature of the heating, however, reduces outgassing and subsequent degassing of the source to a minimal amount. Low melting point metals, such as the noble metals Cu, Ag, and Au, are usually sourced from a KC cell

which is essentially a large nonreactive oven. Therefore, the entire crucible, or oven, must be heated (typically radiatively and conductively via a  $W$  filament). This results in copious outgassing and has the added drawback of requiring large current supplies and the associated connecting hardware, a situation that is not desirable where the available space is inconsiderable, as in most experimental vacuum chambers. Thus, we have developed a technique that permits us to use a pendant-drop type EB cell with little modification to evaporate noble metals in an easily controllable way.

The trick lies in taking advantage of the high power delivered to the evaporant in an EB evaporator (50 W is typical of our small sources) and the large thermal conductivity of refractory metals. By replacing our normal evaporant with a Mo crucible and moving the filament (single turn of 0.010 in.  $W$ ) back to encircle the cavity of the crucible, we can electron beam heat the refractory metal and hence the noble metal charge. This configuration is shown in Fig. 1(b); the detailed cross section of a crucible which fits our evaporators appears in Fig. 1(c). Depending on the heat sinking capabilities of the high voltage connection and the size of the normal source rods, the clamping arm (long thin section) may be made of a different size, although we have found that keeping the mass of the crucible to a minimum works best. Additionally, we have found that premelting the charge in a bell jar system is useful when the axis of the evaporator must lie nearly horizontal. Approximately 400 Å of Au has been deposited using only  $\frac{1}{2}$  of the total charge onto a thickness monitor  $\sim 6$  in. from the source. This is comparable to the results we achieve for EB evaporation with a stationary source rod. While this source required more degassing than the simple pendant-drop type EB source does, it is a vast improvement over the KC when relative small quantities of noble metals are required.

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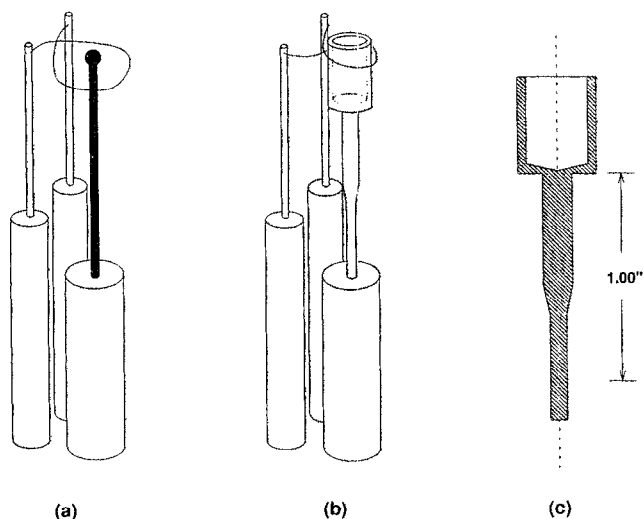


FIG. 1. (a) Typical pendant-drop type EB evaporator configuration. A tungsten filament surrounds a rod of evaporant (shaded). The rod is biased positive with respect to the filament so as to heat the source tip by electron bombardment. (b) EB source after replacing evaporant with Mo crucible. Note the placement of the filament with respect to the bore of the crucible. (c) Cross section of Mo crucible used in place of an EB evaporator source rod. Less than one hour of machining time was required to fabricate this particular crucible.

<sup>1</sup>L. I. Maissel and R. Glang, *Handbook of Thin Film Technology* (McGraw-Hill, New York, 1970), pp. 1-51.