RF Solid Sources for Atomic Beam Epitaxy

R. Clampitt[1] and M.B. Lee[2+]
1.Oxford Applied Research, Crawley Mill, Witney, Oxon , UK
2.Bexin Technologies Inc., Blauvelt, NY, 10913, USA
+ communicating author with e-mail: oarusa@optonline.net

1. INTRODUCTION

The efficiency of film growth depends on both the sticking probability and the reactivity of the evaporants. Reactivity of some evaporants can often be enhanced by pre-dissociation into a more reactive species prior to deposition onto the substrate. The word "cracking"- borrowed from Petrochemical Refinery terminology-has been adapted to describe this process. We report here the design of such a "cracker" which can enhance reactivities of solid charges in MBE growth.

2. EXPERIMENTAL METHODS

To achieve this, the evaporant K-cell, in which solid is loaded, is coupled to a RF plasma section to facilitate electron-induced dissociation of evaporant. The plasma is first ignited using an inert gas and the K-cell subsequently heated to evaporate the source materials into the discharge. The utility of this technique has been reported earlier.[1]
To obtain sharp multi-layer profiles we have incorporated a fast acting all-quartz valve. The general design features of such a valved cracker with 200 cc charge loading capacity are illustrated in Figure 1. For all polymeric materials except phosphorus, the transfer tube is maintained at reservoir temperature. In the case of phosphorus it is cooled in order to condense and utilize the white phosphorus resulting from the evaporation of the red phosphorus feedstock The valve characteristics (Figure 2a), measured with neon gas, demonstrate that rapid flux control can be achieved

The all-quartz valve design makes the source compatible with corrosive material such as antimony. Figure 2b shows Sb vapour deposition data on a quartz crystal microbalance, confirming the rapid flux control. Mass spectrometry using a simple residual gas analyzer (RGA) can be employed to diagnose the efficiency of RF plasma cracking of polymeric evaporants.

3. RESULTS AND DISCUSSION

A stable RF discharge in the absence of support gas has been achieved for many different solid charges, including As, Se and white P. Figure 3 show emission spectra of, respectively, Ar, Ar+As and pure As discharges.[1] A pure self-supporting white P discharge to achieve enhanced doping incorporation during growth of ZnSe has been previously reported.[2]

A Selenium-cracked spectrum shows that the Se_2 dimer is less than 10^{-4} of Se monomer (Figure 4a.) The mass spectrum of a pure self-supporting Sulphur discharge (Figure 4b.) shows that the polymeric species are almost entirely cracked into S_1 and S_2 even at the low (40W) RF power used.

Table 1. summarizes the ion current detected from the source.

The tabulated data demonstrates that all charged particles are removed from the beam when a voltage of 500/1000 V is applied across the plates, the beam now comprising only neutral particles.

	Collector voltage (V)	**Deflector voltage (V)**	**Collector Current (uA)**
1	0	0	-0.43
2	0	1000	0.03
3	-10	0	-0.13
4	-10	1000	0.06
5	+9	0	-0.43
6	+18	0	-0.88
7	-18	0	0.16
8	-18	500	0.05
9	-18	1000	0.05

Table 1: Summary of ion current detected by a 3x3 cm2 collector plate 150mm from the source. Collector bias and deflector voltage are listed in columns 1 and 2 respectively.

The instrument offers an interesting possibility of re-examining some challenging but technologically significant MBE growth processes, such as Mn doping of GaN, in which incorporation of unactivated Mn remains problematic. The source offers the unique prospect of delivering, simultaneously, both atomic nitrogen and atomic Mn, the latter potentially –activated within the RF plasma to a metastable electronic state.[3]

4. CONCLUSIONS

In conclusion, we have shown that an all-quartz valve RF cracker can be used to dissociate polymeric materials to the atomic form without adding a prohibitive thermal load to an MBE system. This advancement points to a new variation in MBE, atomic beam epitaxy, in which highly reactive atomic species are utilized.

References:

1. Waag, A., Lugauer, H.J. and Landwehr, G. VIII Eur.Workshop on MBE, Granada, 1995 (Abstracts)
2. Calhoun, L.E. and Park, R.M.,J. App.Phys. 85,490, 1999
3. The idea of using a nitrogen supported Mn discharge for growing Mn doped GaN was first suggested to us by Prof. G. Wicks of the University of Rochester during this conference.

FIGURES

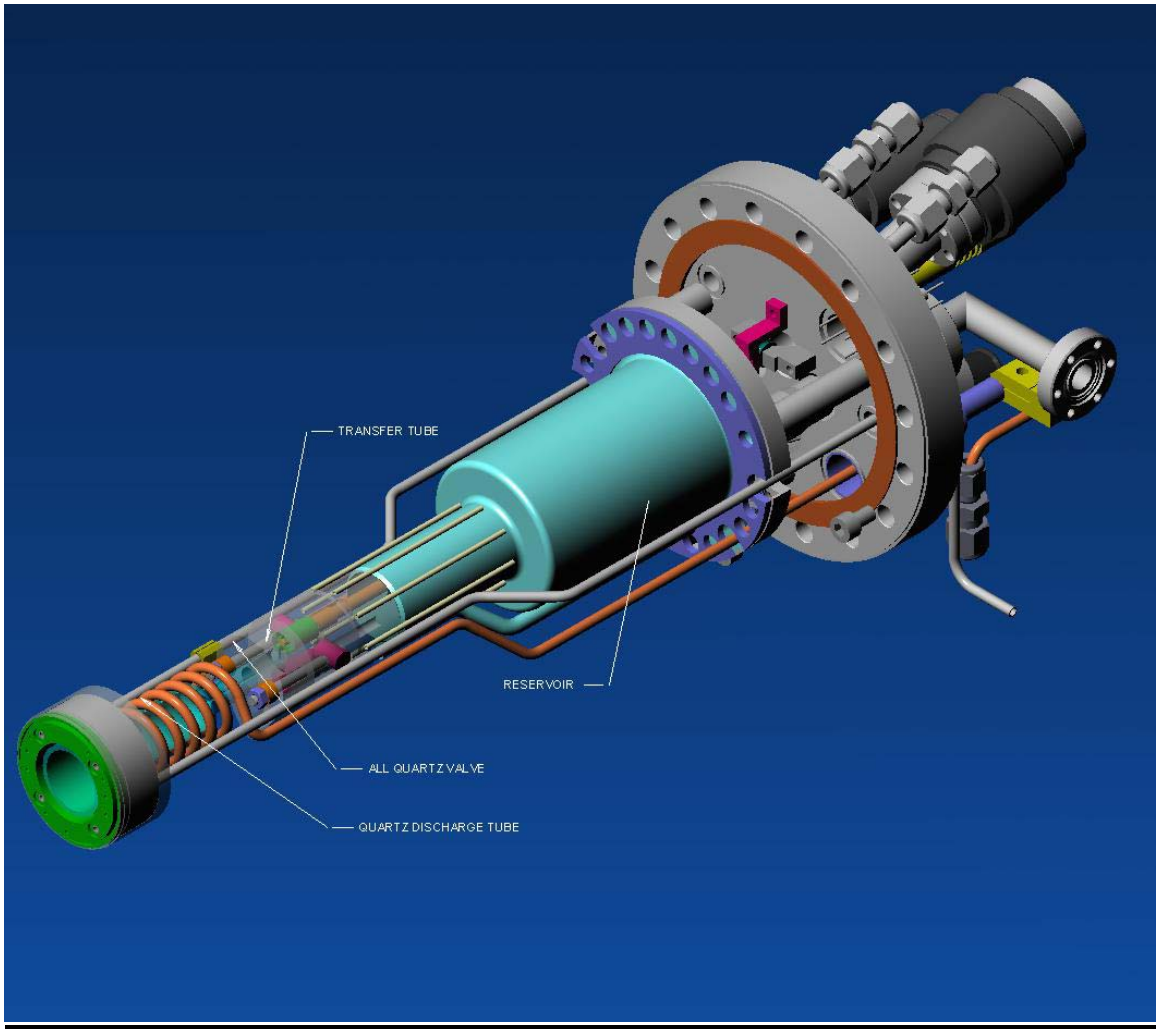

Figure 1: Illustration of all–quartz valved RF cracker

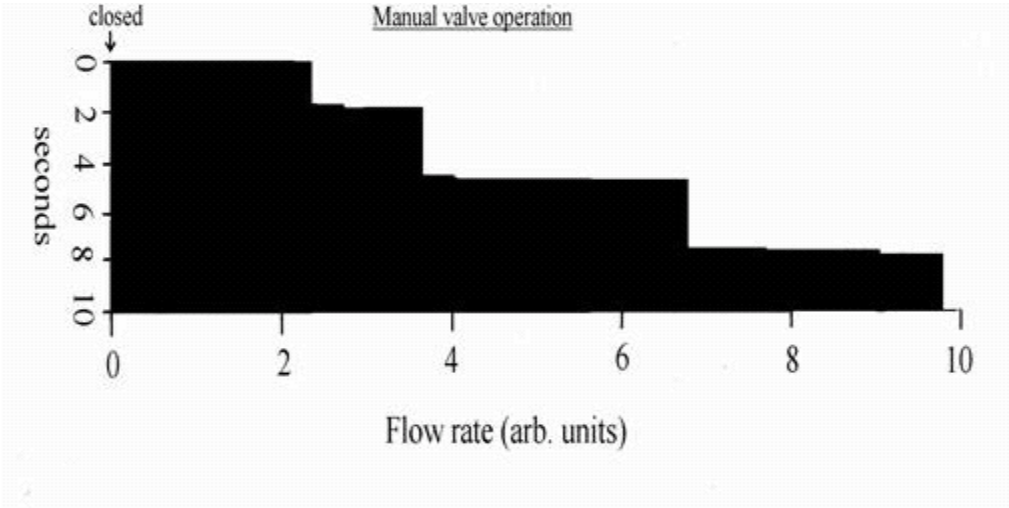

Figure 2a: Demonstration of rapid flux control by manual valve operation

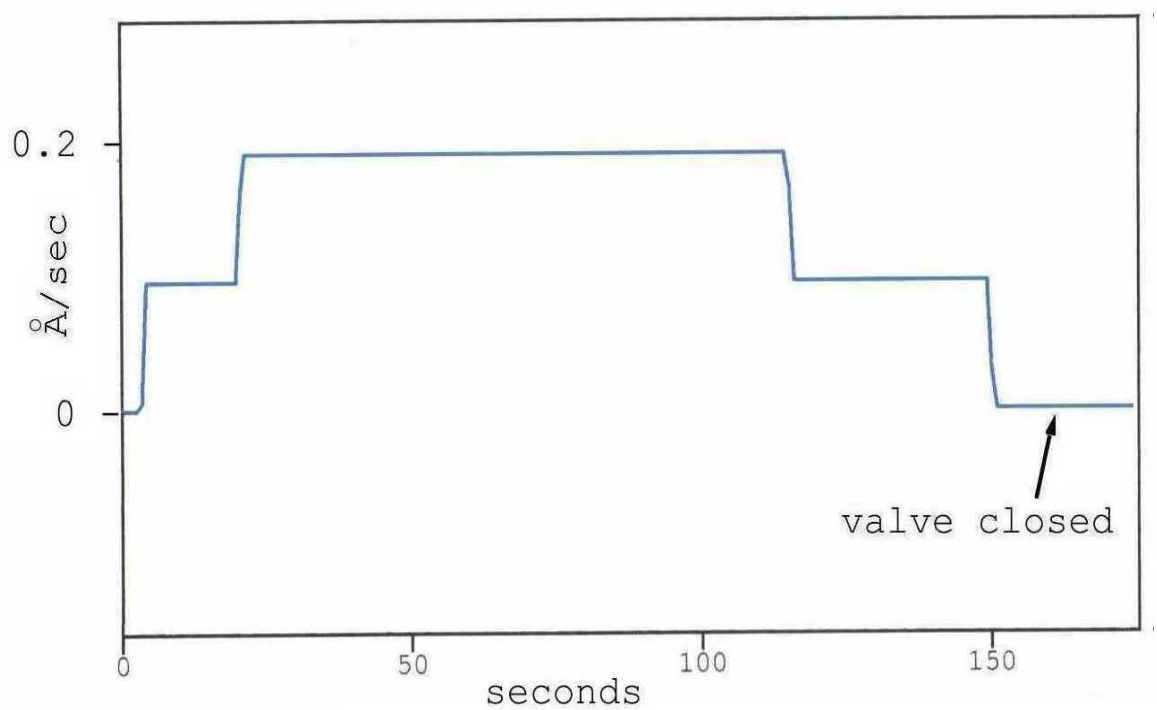

Figure 2b: Deposition of atomic antimony vapour as a function of valve position.
K-cell at 625 C; RF plasma power 250W; argon 1.2sccm

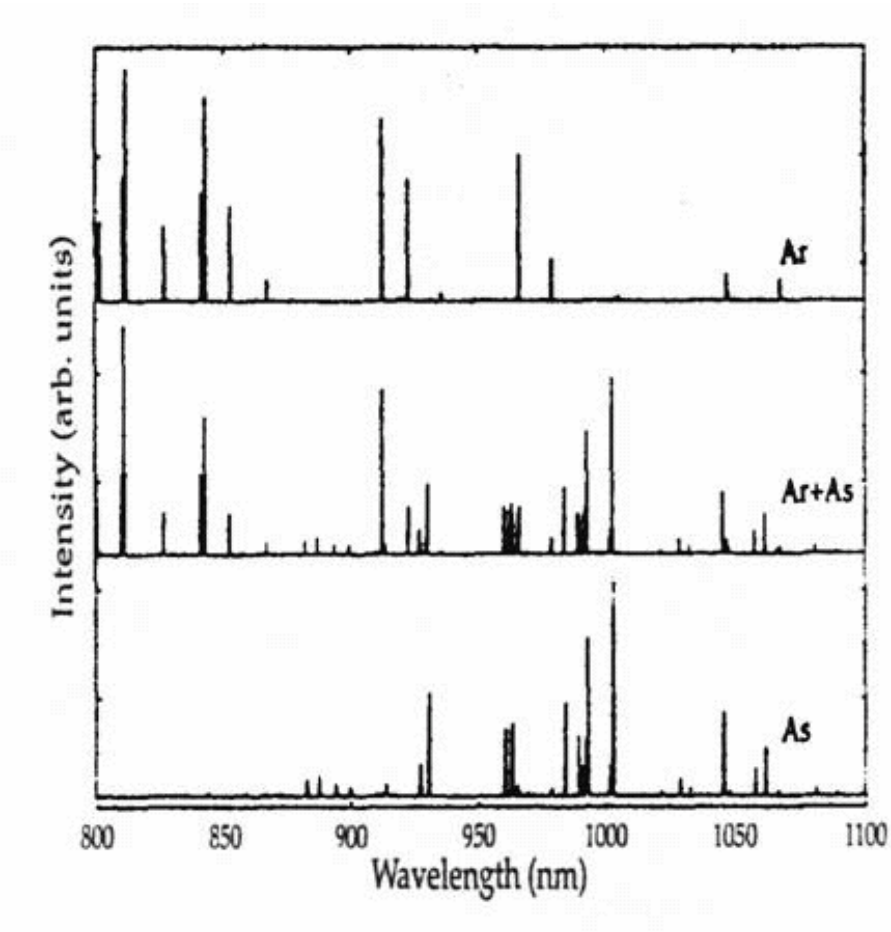

Figure3: Emission spectrum of argon-supported and pure As discharges

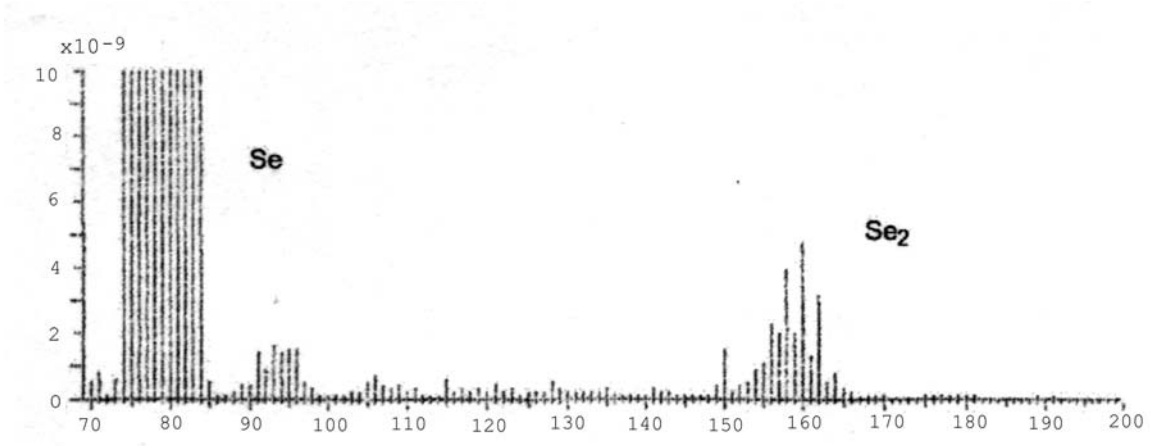

Figure 4a: A mass spectrum of species from a pure Selenium discharge.
Note that even the dimer intensity is negligible compared to atomic Se ($3x10^{-5}$A)

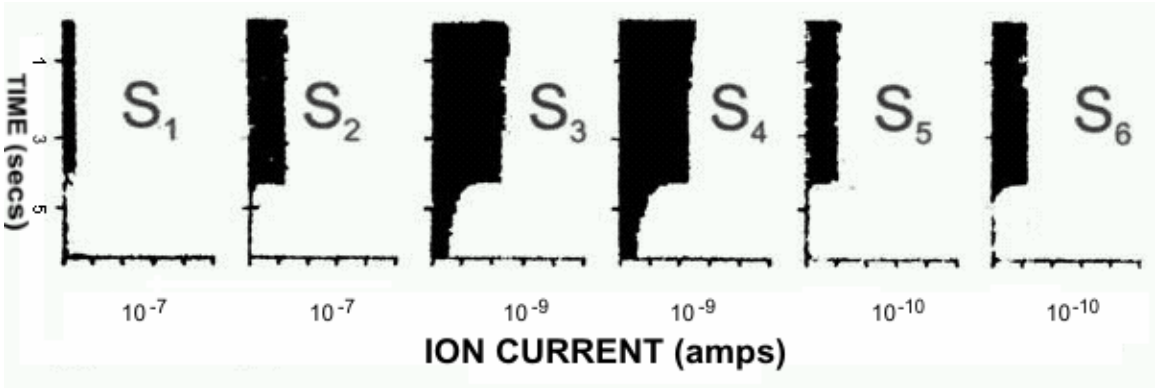

Figure 4b: A mass spectrum of a 40W discharge in pure sulphur,
showing the dominance of the monomer and dimer