CHAPTER EIGHT

Effect of ultrasonic vibrations applied to the substrate, on the growth of silver films.
8.1. INTRODUCTION:

As discussed in chapter 2, the mobility of adatoms is one chief factor in enhancing epitaxial growth. This is brought about in a number of ways, viz., heating of the substrate, smoothening of the substrate surface, oblique deposition, etc. Chopra et al. have observed that ultrasonic vibrations applied to the substrate during deposition enhances epitaxy of Ag films. They have attributed the change to an improved agglomeration of the film due to an increased adatom and cluster mobility as a result of ultrasonic vibrations. Later Ogara et al. repeated the experiment. They studied the films deposited on to the substrates, not subjected to the ultrasonic vibrations during deposition, but agitated for 30 minutes prior to deposition. They observed an improvement in orientation in such films also. They concluded that improved orientation was not due to enhanced mobility, but due to removal of adsorbed air-molecules on the substrate surface, thus increasing the substrate influence on the depositing atoms. So far there are no more reports regarding these contradictory opinions. Hence a series of experiments were conducted to study the effect of ultrasonic vibrations imparted to the substrate on the epitaxy and the details are presented below.

8.2. Experiment:

An X-cut quartz crystal was used to produce ultrasonic vibrations. Thin NaCl crystals (1mm x 5mm x 1mm) were
pasted on to the edge of the quartz crystal with araldite R, such that the crystal will vibrate perpendicular to the beam. The crystals were left overnight so that they would adhere strongly to the quartz crystal the exposed surface of the NaCl crystal was removed by cleaving with a fine razor as carefully as to see that the bonding between the quartz crystal and the NaCl slice did not weaken. The quartz crystal was later mounted inside the vacuum chamber. The crystal was held at a distance of about 12cms from the source so that heating effect due to the evaporation source radiation was not considerable. A dummy substrate of cleaved NaCl was kept side by side, for a comparative study. When a vacuum of 10⁻⁶ torr was obtained, the oscillator connected to the quartz crystal was switched on. The crystal was vibrated at 3MHZ for about 15 minutes and no fail in vacuum was observed during the vibration. Ag was evaporated on to the substrates at a rate of 3Å/sec. Immediately the oscillator was switched off (refer fig 8.5).

In another set of experiments, the NaCl crystal was vibrated for about 15 minutes before deposition and the oscillator was switched off during deposition. The films were given carbon backing and transferred on to copper grids. Both the films were studied by selected area diffraction in the electron microscope.

8.3. Observations and discussions:

Figs. 8.1, 8.1a and 8.2, 8.2a show the regions of
and selected area diffraction patterns of a 100Å thick film deposited on static and vibrating substrates respectively. Figs. 8.3 and 8.3a are the regions and selected area diffraction pattern of a 100Å thick film grown on a previbrated crystal. It is clear from Figs. 8.1 and 8.2 that the film on vibrating substrate is highly agglomerated as compared to the unvibrated crystal. The film on the vibrating substrate is peculiar, in the sense that, the aggregates have highly irregular shapes which is not usually observed in any stage of a normal thin film growth process (Pashley[86]). It means that, under the influence of ultrasonic vibrations, the growth does not follow the typical stages normally observed. The better orientation of the film on vibrating substrate is clear from the selected area diffraction pattern shown in Fig. 8.2a. The film on the vibrating substrate has developed a good 100 orientation whereas that on the static substrate show negligible preferential orientation (Fig. 8.1a).

The film on previbrated crystal (Fig. 8.3) has also shown agglomeration effects though to a lesser degree. The coalescence in the film is the one similar to the second stage coalescence as per Pashley's model, except that there are large vacant sites in between the coalesced islands. The film is once again better oriented than the film on unvibrated substrates (Fig. 8.3a). At the same time it is less oriented than the one grown on vibrating crystal.
Thus the ultrasonic vibrations applied to the substrate before or during deposition does definitely improve the orientation, in agreement with the observations of both Ogara et.al. and Chopra et.al. But the effect is more pronounced in the latter case. The agglomeration effects are more when the substrate is vibrated during deposition, leading naturally to a better oriented film. As suggested by Ogara et.al.\textsuperscript{184} the previbration may lead to degassing of the substrate surface which should naturally make the adatom and the cluster move more freely on the substrate except that they are subjected to the orienting influence of the substrate surface forces. Similar results are obtained for the vacuum cleaved crystal by Ino et.al.\textsuperscript{95}. That is why, the film on such crystal surfaces almost fits into the same growth stages as observed for other crystal surfaces, except for a higher agglomeration.

On the other hand, the more prominent role of u.s. vibrations in causing agglomeration is evident from the highly irregular aggregates in the film, as seen in Fig.8.2. The extramobility provided to the depositing atoms, makes them more selective in choosing the sites in the aggregates leading to a better oriented film. Since in both sets of experiments, substrates were previbrated for the same interval of time, the degassing of the substrate surface should be of equal degree in both the cases. Hence the results of Figs. 8.2, 8.2a are those due to substrate
cleaning and additional mobility effects of ultrasonic vibrations, where as those of Figs. 8.3 and 8.3a are due to the substrate cleaning only.

8.4. Conclusions:

Application of ultrasonic vibration to the substrate prior to or during deposition of the Ag film, improves epitaxy, though to a greater extent in the latter case.

The application of ultrasonic vibrations leads to higher agglomeration in both the cases. The agglomerates in the latter case show peculiar shapes in contrast to the former one.

Hence the improved epitaxy of deposits observed in the case of ultrasonically agitated substrates is the combined effect of the cleaning action due to degassing and enhanced mobility of the depositing atoms.