

# Characterization of arsenic-rich waste slurries generated during GaAs wafer lapping and polishing.

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## Abstract

The toxicology of gallium arsenide is well established; it is classified by the state of California as a known carcinogen. Consequently, environmental aspects of GaAs wafer manufacture are coming under greater scrutiny, with the cost of waste disposal becoming an economic issue for fabs operating under this jurisdiction. It is estimated that up to 93% of a GaAs boule is lost during manufacturing and device packaging, which ends up land filled or incinerated as hazardous waste. This percentage is likely to increase as final wafer thickness is reduced to improve thermal dissipation. GaAs wafer backthinning and polishing generates waste slurries that are contaminated by arsenic and must be disposed of as hazardous waste. Although GaAs is largely insoluble in H<sub>2</sub>O, it is readily oxidized to soluble oxides and hydroxides, especially during chemo-mechanical polishing. Further, the valency state of the arsenic species determines the toxicity of effluent. Waste slurries from three sources were studied by ICP-MS and voltammetric analysis to determine the amount of arsenic in the supernate. This data was related to mechanical lapping processes, such as the size distribution of particles in the slurry, and to the oxidation chemistry of the polishing processes. The analytical results provide guidance as to the most effective strategy to minimize the environmental impact of slurries produced during wafer thinning and polishing.

## Experimental

Waste slurries were collected from three companies working with single crystal gallium arsenide substrates. These represented the main types of waste flow; slurries of GaAs particles from cutting and grinding operations, wafer lapping slurries and chemical polishing slurries. These were compared to slurries prepared under laboratory conditions to have similar physical characteristics, as shown in Table 1.

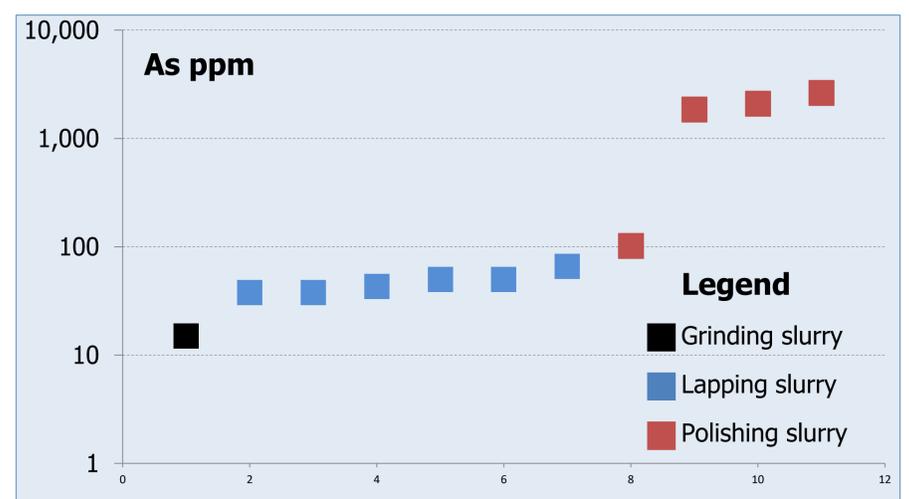
**Table 1: Classification of slurry types**

Type	Source	Characteristics	pH	Total GaAs g l <sup>-1</sup>
Grinding slurry	Grinding of boules, wafering and dicing.	Clear solution with visible GaAs particles and surfactant.	7.0	0.25 -1.25
Lapping slurry	Wafer back thinning.	Grey slurry of alumina and fine GaAs particles.	8.0	0.45 – 1.75
Polishing slurry	Prime wafer polishing & backside polishing.	Clear solution with alumina & SiO <sub>2</sub> fines. May be alkaline or acidic.	10 – 11 (6.0)	1.25 – 2.65

Potential hazards associated with GaAs wafer fabrication were first brought to the attention of the industry by NIOSH in 1987, following studies on *in vitro* solubility and toxicity by Webb et al (1984). This recognized the potential hazard from airborne GaAs particles and recommended that proper handling policies for GaAs be developed and that cutting, grinding and polishing be done in a wet medium to minimize the generation of particulates. Jones, Sheehy et al (1988) expanded this work to inspect three GaAs fabs and identified areas of concern in crystal growth. At the time of these papers it was common for crystal growth, wafering and device fabrication to be carried out at a single site; the industry has since evolved to a well-defined supply chain with a small number of companies supplying all the substrate material. Other studies (Peterson, 2000; Jadvar et al 1991, Fayter, 1996) looked at methods to minimize and treat arsenic waste. It has been the practice in most semiconductor fabs to collect all the lapping and polishing waste to have it disposed of by an approved contractor, although some reclamation of gallium is possible.

## Methods and Materials

Waste slurries were first separated into solids and the supernate by centrifuge. Three analytical techniques were used to determine the concentration of arsenic within the liquid phase. The simplest method employs a Hach [9] field test kit designed for measurement of arsenic in groundwater and uses indicator strips to estimate arsenic content within the range 0 – 500 ppb. This was found to be effective method to screen the samples for later ICP-MS and VA analysis. The solid phase of the lapping slurry was inspected using SEM and the particle size distribution estimated using laser scattering.



**Figure 1: Arsenic concentration of slurries**

## Results and Discussion

Results are shown in Figure 1. It can be seen that the slurries fall into three main bands. Grinding slurries have the lowest concentration of dissolved arsenic; typically less than 20 mg l<sup>-1</sup>. This is in the same range as determined from static solubility experiments, suggesting minimal interaction with the carrier. Lapping slurries are within the range 50 – 100 mg l<sup>-1</sup>; this is primarily controlled by the degree of slurry dilution during wafer processing, although lapping time does appear to be a factor. Lapping produces finer particles, typically around 0.4 microns in diameter, with a greater surface area for oxidation. Not surprisingly, chemical polishing slurries have the highest dissolved arsenic content. The values of 1,000 – 2,500mg l<sup>-1</sup> are consistent with 100% GaAs going into solution from stoichiometric calculations.

## Conclusion

Wafer thinning creates significant volumes of arsenic rich liquid waste. The Hach test is an effective and inexpensive screening tool. There are marked differences in the percentage of GaAs that goes into solution depending on the thinning method with polishing > lapping > grinding. Both Ga and As solubility is related to solution pH and the particle size of the slurry, in controlling the surface area available for oxidation to soluble species.

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