

Thin Films of GeC Deposited Using a Unique Hollow Cathode Sputtering Technique

R. J. Soukup and N. J. Ianno

Department of Electrical Engineering

University of Nebraska

Lincoln, NE 68588-0511

and

V. L. Dalal

Department of Electrical and Computer Engineering

Iowa State University

Ames, IA 50011

The purpose of the project is to experimentally explore thin films of the new material  $\text{Ge}_x\text{C}_{1-x}$  deposited by a unique dual plasma hollow cathode sputtering technique. The (Ge, C) system is extremely promising since the addition of C to Ge may reduce the lattice dimensions enough to allow a lattice match to silicon, while increasing the band gap close to that of c-Si. Recently, a significant advancement in the deposition of this material has been achieved by electron cyclotron resonance (ECR) plasma deposition<sup>1</sup>. This work has yielded films with up to 3% C incorporation, a band gap of 1.1eV and significantly greater optical absorption than c-Si.

The most important contribution of this work is that it shows that by using non-equilibrium growth conditions in the presence of a reactive ion beam, one can grow Group IV materials, which cannot otherwise be grown using normal CVD or MBE processes. Unfortunately, only about 3% C can be incorporated into these films. Other people<sup>2</sup> have grown films with much higher concentrations of C, up to 9%, using traditional magnetron sputtering of two targets, but at the expense of slow film growth.

For these reasons we are experimenting with the hollow cathode technique which has been successfully used in the deposition of amorphous silicon and amorphous silicon/germanium in our laboratories<sup>3</sup>. The sputtering is accomplished by igniting a plasma of the Ar and H<sub>2</sub> gases which are fed through nozzles, cylindrical tubes 30mm long with 8mm O.D. and 3mm I.D. In certain cases no hydrogen was fed through the C nozzle. The purpose of the hydrogen here is not to tie up dangling bonds as in the case of amorphous materials, but to assist in the crystalline growth of the GeC films.

Initially, the films were deposited onto both silicon and glass substrates. The initial films on the glass substrates had no or very little photo response and after a few depositions it was decided to deposit only onto silicon. The films deposited onto glass were amorphous in nature, but the films deposited onto silicon were quite crystalline. This crystallinity has been characterized with Raman spectroscopy and X-ray diffraction (XRD).

A typical Raman spectrum is shown in Fig. 1. Of course, this sample was pure Ge and is not indicative of the normal  $\text{Ge}_x\text{C}_{1-x}$  film. A more typical Raman spectrum for  $\text{Ge}_x\text{C}_{1-x}$  is shown in Fig. 2. In Fig. 2, x is about 95. The indications are that the films are polycrystalline in nature and this has been verified by XRD. Typical samples have peaks at angles which indicate that the 111, 220, and 311 faces are dominant.

Auger depth profiling studies of the GeC films have also been made. The incorporation of C into the films is

relatively uniform and is on the order of 7 to 8%, higher than any other method at this growth rate,  $\approx 1.5 \text{ \AA/s}$ .

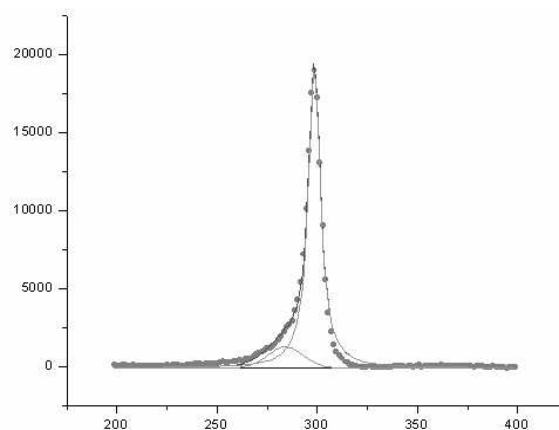


Figure 1. Raman Spectrum of a Pure Ge Sample.

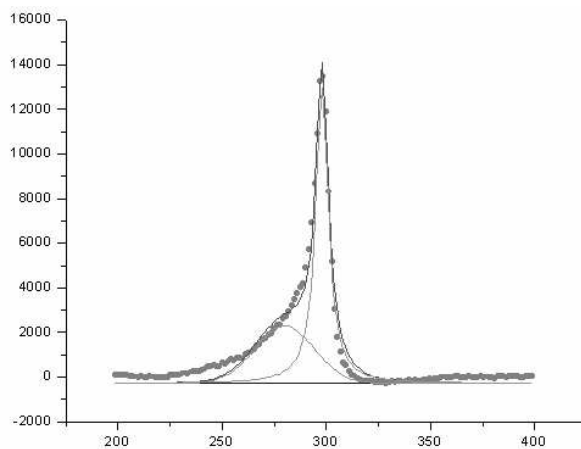


Figure 2. Raman Spectrum of a  $\text{Ge}_x\text{C}_{1-x}$  Sample

Fourier Transform Infrared Spectroscopy (FTIR) yielded interesting results. The FTIR spectrum over the wave number range of interest was featureless except for a small absorption peak ( $1110 \text{ cm}^{-1}$ ) attributable to the  $\text{SiO}_2$  at the interface between the substrate and the GeC film. This is a desirable result because it means that the hydrogen is not bonding to the film, even though a high density plasma consisting of argon and hydrogen is present in both nozzles, or in some cases, just the Ge nozzle. Prior films of a-SiGe:H had prominent peaks at  $1880 \text{ cm}^{-1}$  (see reference 3), and this indicates a GeH bond. A probable cause of this lack of H bonding is that the substrate temperature in this experiment is considerably higher during deposition..

Additional measurements on the films have been made and will be reported. These include carrier mobility, deep level defects, spectroscopic ellipsometry and optical absorption.

This material is based upon work supported by the National Science Foundation under Grant No. 0322839.

<sup>1</sup> J.T. Herrold, and V. L. Dalal, J. of Non-Cryst. Solids, **270**, 255 (1999) and J. T. Herrold and V. L. Dalal, Proc. Of MRS **664** (2001), paper 25.12.

<sup>2</sup> W. Li, Ismat Shah, D. Guerin, J. G. Chen and H. Hwu, J. Vac. Sci. Technol. **A19**, 2617 (2001).

<sup>6</sup> R. J. Soukup, N. J. Ianno, G. Pribil, and Z. Hubička, Surface and Coatings Technol. **177-178**, 676 (2004).