Hot-wall chemical vapour deposition (CVD) process for germanium sulphide glass waveguides fabrication

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Introduction:
The conventional method of fabricating a chalcogenide glass involves melting in a sealed ampoule. The glass then further processed to form, for example, thin films, optical fibre and optoelectronic devices. Thin films of chalcogenide glass can also be deposited by a number of methods including evaporation, sputtering, and ablation. These techniques in general suffer from difficulties associated with the incorporation of impurities or non-stoichiometry, which degrade the optical properties of the glass. Chemical vapor deposition (CVD) process for the fabrication of chalcogenide materials have been reported with unsatisfactory process and unstable film quality [1-2].

Experimental methods:
The CVD apparatus for germanium sulphide deposition is shown in figure 1. Thin films of germanium sulphide glass form on a substrate through reaction between $GeCl_4$ vaporized by means of a bubbler into argon carrier gas and H_2S gas at temperature in the range of 450°C-600°C. This is a hot-wall CVD process, in which a horizontal quartz tube reactor is heated in a tube furnace. The reactive gas, H_2S, and the carrier gas for $GeCl_4$, argon, are delivered through the mass flow controllers (MFC). Furthermore, the GeO_2 buffer layer on silicon wafer was prepared by the reaction between $GeCl_4$ and O_2 at 1000°C.

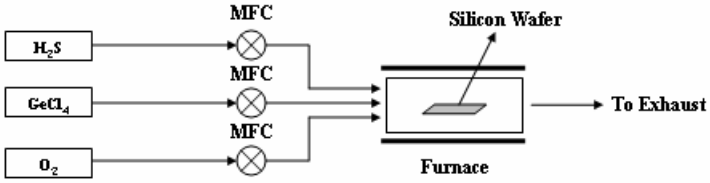

Fig. 1. Hot-wall Chemical vapour deposition (CVD) system for the germanium sulphide glass waveguide fabrication

Results:
Germanium sulphide glass (~2.4μm) has been successfully deposited on silicon wafer with a germanium oxide (~4.5μm) buffer layer on the top. Scanning electron microscope (SEM) technique has been applied to study the germanium sulphide glass films deposited. From the top and the cleaved edge of the germanium sulphide glass film on the Silicon wafer with germanium oxide buffer layer are shown in figure 2. They show bubble and crack free thin films, free of any obvious inhomogeneity. The composition of the film has been characterized by Raman spectroscopy. From the spectrum, we can verify the germanium sulphide glass with a sulphur to germanium ratio of ~2.

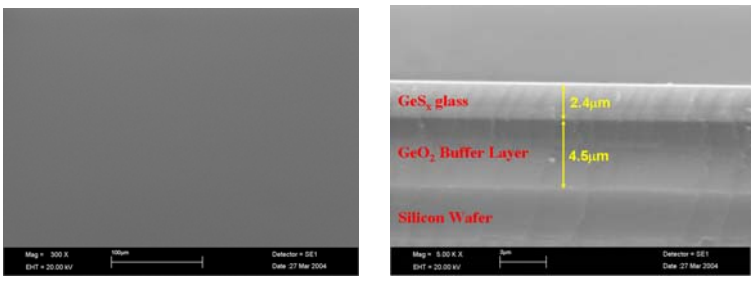

Fig. 2 SEM picture from top view (left) and side view (right) of the germanium sulphide glass film on silicon wafer with GeO_2 buffer layer

Summary:
The germanium sulphide glass planar waveguide has been successfully fabricated on a silicon wafer with the GeO_2 buffer layer through the direct hot-wall chemical vapour deposition (CVD) process. The glass film has been characterized by SEM and Ramon spectroscopy. These results show this fabrication technique has a great potential in optoelectronics, particularly as waveguides for optical integrated circuits applications.

References:
1. P. J. Melling, "Alternative Methods of Preparing Chalcogenide Glasses", Ceramic Bulletin, 63, 1427-1429, 1984.
2. E. Sleeckx, P. Nagels, R. Callaerts and M. Vanroy, "Plasma-enhanced CVD of amorphous Ge_xS_{1-x} and Ge_xSe_{1-x} films", J. de Physique IV, 3, 419-426, 1993.