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Poling of UV-written Waveguides

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The inherent lack of second-order nonlinear optical (SONO) properties of centrosymmetric and amorphous media has prevented the development of essential photonic components, e.g. electro-optic (EO) modulators and wavelength converters, in silica-based optical fibres and planar waveguides. Electric field poling is a promising way to induce SONO effects in silica [1-6]. In the poling procedure the silica device (bulk, fibre or planar waveguide) is subjected to a strong electric field, while excited by heat [1-5] or radiation [6]. The physical processes taking place during glass poling are not fully understood, but it is widely accepted that either dipoles in the glass are oriented to the poling field or charge migration leads to the build-up of a space-charge field, which then acts on the third-order properties of the glass to give an apparent second-order response [1,2].

Waveguides were written with 248 nm radiation through an Al mask in a three layer structure, as sketched in Fig.1. The core and the top cladding were deposited by PECVD. The samples were D₂-loaded prior to UV-exposure. The UV-induced refractive index change of the glass used in the core has proven stable up to 700 °C [7], thus making poling at high temperatures possible.

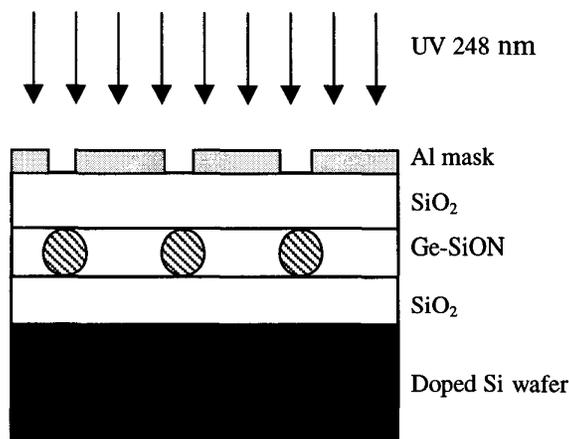


Fig.1 Cross-sectional view of waveguides during UV-writing. All glass layers are 3µm thick.

Two types of poling experiments were carried out : 1) thermally assisted poling and 2) UV-assisted poling. In all experiments the Al mask was used as the top electrode and the Si wafer as the ground electrode. The EO effect was measured in a fibre-based Mach-Zehnder Interferometer (MZI). The MZI setup is shown in Fig. 2. To our best knowledge this is the first reported poling of UV-written waveguides.

Thermally assisted poling was carried out with the samples placed on a

heater supplied with a temperature controller. The best result was obtained with thermally assisted poling at 405 °C with a voltage of -2.5 kV applied to the top electrode. The EO coefficient measured, 0.05 pm/V, is to our best knowledge one of the highest reported for a silica-based channel waveguide [3,5]. Fig. 3 shows the temperature dependence of the induced EO coefficient. The observed dependence is different from that observed for silica fibres [4], as the optimum poling temperature in our case is ~150 °C higher. The glass temperature (measured on top of the sample) was ~50 °C lower than the temperature of the heater. The temperatures given in Fig.3 is the average of the glass temperature and the heater temperature.

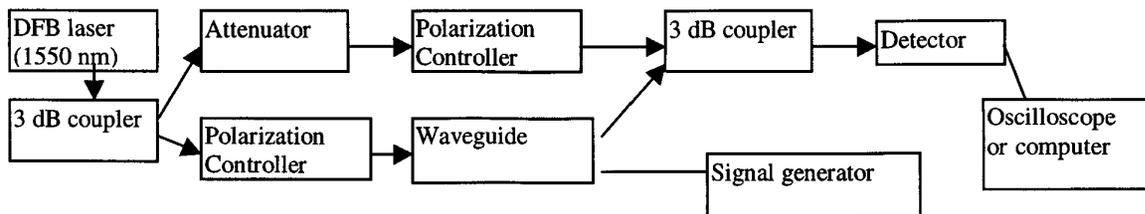


Fig.2 Fibre-based Mach-Zehnder interferometer setup.

In the UV-assisted poling experiments the samples were either poled during or after UV-writing of the waveguides. An EO coefficient of 0.01 pm/V was obtained in both cases. The combined poling and writing, which is demonstrated here for the first time, seems a very attractive fabrication method.

A sample poled at -1.5 kV and ~300 °C showed no measurable decay in the EO response when tested again 9 months after poling. The induced EO coefficient of this sample was 0.02 pm/V. The high stability might be related to the high value of the optimum poling temperature of this glass, as the activation energy for the processes taking place during poling probably is

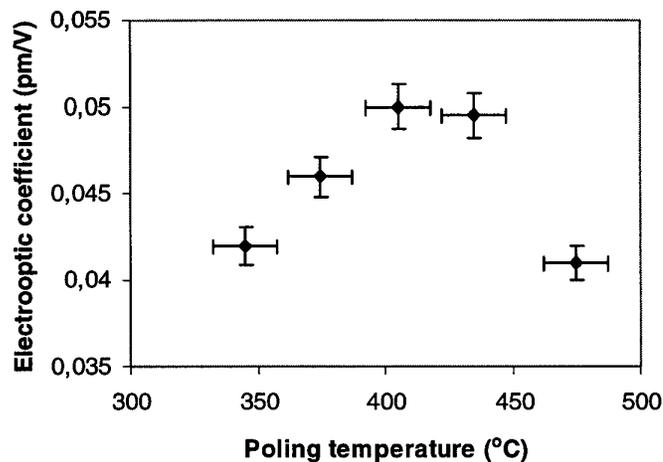


Fig. 3 Electro-optic coefficient as a function of poling temperature. The horizontal error bars only apply to the absolute temperatures, as explained in the text. The relative positions of the data points are not affected.

comparable to the activation energy for the decay.

In conclusion we have performed thermal poling and UV-poling of UV-written silica-based waveguides. An EO coefficient of 0.05 pm/V was obtained with a poling field of 2.8 MV/cm and a poling temperature of 405 °C. This is to our best knowledge one of the highest EO coefficients reported for a poled silica-based channel waveguide. The optimum poling temperature is ~150 °C higher than reported for optical fibres. We have demonstrated simultaneous UV-writing and UV-poling. However, the EO effect obtained by UV-poling is very small. Repeated measurements indicate that the induced EO effect is stable over a period of 9 months.

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