Damage Surface of Sodium-Silicate Glass by High Power Ion Beam

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Abstract – The damage of the sodium-silicate class induced by the irradiation with 50 ns pulse of high power ion beam was investigated. The damage topography of the irradiated samples was inspected by optical microscopy. Two main damage features are observed: fracture crossing the sample surface and cracking at a certain depth parallel to the surface. Influence of current density of ion beam and number pulses on feature damage was studied. The probable mechanism of damage was discussed.

1. Introduction

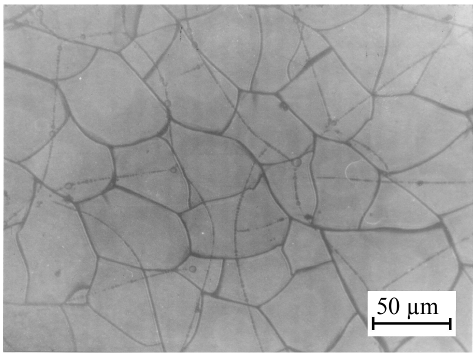
High current pulse electron beam damage of different dielectrics (mainly ionic crystals and inorganic glass) has been the subject of investigation for many years [1,2]. Such studies are of interest for better understanding of the fundamental damage processes at impulse loading. High power ion beam (HPIB) can be used for such loading also. The learning of damage mechanisms of dielectrics is also great practical importance for the development technology of modification different materials by high power ion beam irradiation. Dynamic and quasistatic mechanical stresses at materials generated by high power ion beam irradiation is significant influence on modification and damage processes. In order to learn about the damage mechanisms, it is reasonable to study one pulse damage of transparent dielectrics like inorganic glass and ionic crystals. The influence of the generated mechanical stresses on damage of surface layers of sodium-silicate glass was investigated at present work.

2. Experiment

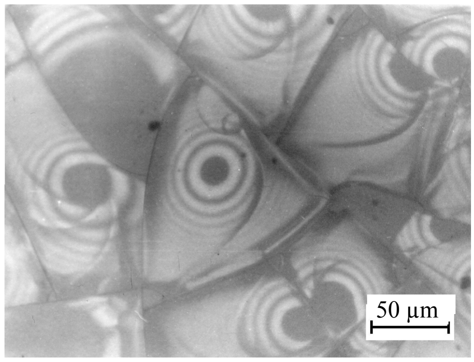
Samples of sodium-silicate glass were 20x20x1,5 mm^3. The thickness of samples were much more penetration depth of ion at glass. Preparated samples were annealed at temperature 200° C within 2 hours. High power ion beam was generated by the "Temp" accelerators. The compositions of beam were 70% of C^+ and 30% H^+. The ion accelerating voltage was 300 kV, averaged ion current densities were 50 – 150 A/cm^2 and pulse duration was 50 ns. After high power ion beam irradiation surface morphology of samples was observed with optical microscope "Neophot-2". In experiments the averaged ion current density and the number of irradiation pulses was varied.

3. Results and discussion

The typical damage of glass surface for averaged ion current density 100 A/cm^2 can be seen in Fig. 1a and Fig. 1b.



a



b

Fig. 1. Surface (a) and near-surface (b) damage of the sodium-silicate glass by HPIB irradiation with j=150 A/cm^2, n=1

Two main damage features are observed: fracture crossing the sample surface and cracking at a certain depth parallel to the surface. For first damage feature tiles in the shape triangles, trapeziums and polygons are formed. A small part of tiles removed from surface at higher ion current density or repeated HPIB irradiation. The area of tile is in the range 100 ÷ 4000 μm^2. Reflection microscopy was used to obtain Newton's ring pattern from curved fragments. The Fig. 2 explains the origin of the ring pattern. Radii of dark rings obey the relation:

$$r = (n\lambda R)^{1/2},$$

where n – the order, R – the radius of curvature, λ – wavelength of the light used for observation.

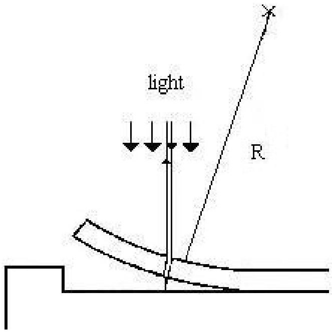


Fig. 2. The origin of ring pattern for sample of glass irradiated by HPIB

Since we employed white light, an averaged wavelength of λ=580 nm was used for the calculation of *R*. Thirty fragments on each sample were analyzed. All this fragments at different sites in irradiated area of sample have curvature of $R \approx 800 \div 1500$ µm. In our experiments an appreciable variation of *R* with the ion current density was not found. The average thickness of fragment was 6±2 µm. It was found that the cracking at a certain depth parallel to the surface can appear over a long period of time after pulse of irradiation by high power ion beam. These time intervals achieved up to 5 day.

These damage features can be described by a model based on the simple thermoelastic considerations,which was developed for the case laser-damage CaF_2 [3, 4]. HPIB irradiation result in a formation of the nonstationary temperature fields at the sample. The temperature variation in lateral direction gives rise to stress which causes across cracking. The fracture takes place when this stress exceeds the tensile strength. The temperature gradient into the depth can actuate fracture parallel to the sample surface resulting in the formation of the tiles seen in Fig. 1.

4. Conclusion

Single-pulse damage of the glass surface irradiated by HPIB has been studied. It is shown that damage features can be described by the model based on the simple thermoelastic considerations.

References

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