Journal of Non-Crystalline Solids 391 (2014) 101–105

Contents lists available at ScienceDirect

Journal of Non-Crystalline Solids

journal homepage: www.elsevier.com/ locate/ jnoncrysol

First steps towards the thermomechanical characterization of chalcogenide glass using quantitative infrared thermography

Eric Robin [a], Jean-Benoît Le Cam [a,*], Xavier Balandraud [b,c], Evelyne Toussaint [c,d], Laurent Brilland [e]

[a] Université de Rennes 1, Institut de Physique de Rennes UMR 6251-CNRS/Université de Rennes 1, Campus de Beaulieu, Bât. 10B, 35042 Rennes Cedex, France
[b] Clermont Université, Institut Français de Mécanique Avancée, Institut Pascal, BP 10448, 63000 Clermont-Ferrand, France
[c] CNRS, UMR 6602, Institut Pascal, 63171 Aubière, France
[d] Clermont Université, Université Blaise Pascal, Institut Pascal, BP 10448, 63000 Clermont-Ferrand, France
[e] PERFOS, R&D Platform of Photonics Bretagne, F-22300 Lannion, France

ARTICLE INFO

Article history:
Received 12 November 2013
Received in revised form 17 February 2014
Available online 6 April 2014

Keywords:
Chalcogenide glass;
Thermoelastic stress analysis;
Infrared thermography

ABSTRACT

This paper focuses on the thermoelastic behavior of chalcogenide glasses. For this purpose, an original experiment was developed to measure the thermal field at the surface of an AsSe glass specimen submitted to cyclic mechanical loading. The specimen geometry was chosen in such a way that a high stress gradient was induced by the loading conditions. The temperature field was measured by means of infrared thermography. The framework of thermal stress analysis (TSA) was then used to successfully map the stress field at the surface of the specimen by processing the thermal fields. The main result is that classical thermoelastic response is observed in chalcogenide glass without disturbances such as photo-irradiation. This work is a first step towards the characterization of the thermomechanical sensitivity of chalcogenide glasses.

1. Introduction

Chalcogenide glasses have been intensively studied for a decade, due to their particular optical properties, especially their transparency in the infrared domain. This exceptional optical characteristic enables them to be a good choice for infrared component technology, even though their mechanical properties are inferior to those of more classical glasses. Thus, most of the studies reported in the literature focus on their physical and chemical characterization, and more particularly on their interaction with light [1–4], as well as on the relation between their physical properties and chemical formulation [5]. Some studies were dedicated to the mechanical properties of chalcogenide glasses [6–16]. Despite this, the physical mechanisms involved in their optical and mechanical responses are not clearly understood, and other ways of investigation have to be considered in order to provide additional information such as calorific data, energy balance… Among them, infrared (IR) thermography is an experimental technique which provides the full temperature field at the surface of an object. In the context of the thermomechanics of materials, IR cameras are used to capture the temperature changes of specimens subjected to mechanical loadings. Phenomena such as thermoelasticity, fatigue, plasticity, viscosity or phase change lead to temperature changes which can be tracked during mechanical tests. These phenomena are accompanied by heat, produced or absorbed by the material. For instance, thermoelastic coupling leads to heat production or absorption as a function of the stress variation. This coupling is the fundament of the thermoelastic stress analysis (TSA) technique which, under some test conditions, provides a stress map of the surface of the specimen [17,18]. This technique has spread in the experimental mechanics community and has found numerous applications, in particular to metallic materials. The present study applies this type of approach to the mechanics of chalcogenide glasses. For this purpose, an original specimen geometry was used to reveal their thermoelastic sensitivity during compression cyclic tests. Section 2 presents the experimental setup in terms of material, specimen geometry, mechanical loadings and thermal measurements. Section 3 gives the results of thermal measurements at the specimen surface. Lastly, Section 4 presents the stress field obtained from the temperature measurements using the framework of TSA.

2. Experimental setup

2.1. Material and specimen geometry

The glass considered in the present study is a chalcogenide glass of the AsSe system ($As_{38}Se_{62}$). Its main properties are presented in Table 1. T_g is the glassy temperature, T_x is the temperature at the beginning of crystallization, ρ is the density, α is the thermal expansion coefficient, H_v is the hardness in Vickers, G is the Coulomb (or shear) modulus, E is the Young modulus and ν is Poisson's ratio. The coefficient $A = \alpha T_0 / \rho C$ will be used for the thermoelastic analysis, where ρ is

* Corresponding author. Fax: +33 223 236 111.
E-mail address: jean-benoit.lecam@univ-rennes1.fr (J.-B. Le Cam).

http://dx.doi.org/10.1016/j.jnoncrysol.2014.03.015
0022-3093/

Table 1
Physical and chemical properties of As38Se62.

Property	Value
T_g (°C)	165
T_x (°C)	250
$\Delta T = T_g - T_x$ (°C)	85
ρ (kg/m^3)	4530
α (10^{-6} K^{-1})	25.4
C-p (J kg^{-1} K^{-1})	360
Hv (kg/mm^2)	133.6
G (GPa)	6.91
E (GPa)	17.7
v (-)	0.279

Table 2
Mechanical tests.

Specimen number	F_{max} (N)	F_{min} (N)	f (Hz)	ΔF (N)
1	−80	−8	1	±36
2	−80	−8	3	±36
3	−160	−16	1	±72
4	−160	−16	3	±72
5	−240	−24	1	±108
6	−240	−24	3	±108

the density, α the thermal expansion coefficient and T_0 the mean temperature of the test in Kelvin. For the present material, it is equal to 4.64 mK/MPa at ambient temperature. The specimen geometry was a 16 mm diameter disc with a hole whose diameter was equal to 3 mm. The disc thickness was 17.6 mm.

2.2. Mechanical tests

The specimen was tested under compressive cyclic loading at ambient temperature using a 15 kN MTS testing machine. An overview of the experimental setup is given in Fig. 1. Table 2 summarizes the cyclic loading conditions applied. F_{max} and F_{min} are the maximum and minimum values of the force applied, respectively. The load ratio R_F, defined as the ratio between the maximum and the minimum values of the force, was equal to 0.1 for all the tests in order to maintain the contact between the disk and the plates. The force range, *i.e.* twice the force amplitude, is denoted ΔF in the following. Two loading frequencies f were applied: 1 and 3 Hz. The shape of the effort signal was sinusoidal. Thanks to the low thermal diffusivity of the material compared to metallic and polymer materials, a low frequency (typically of the order of a few Hertz) was assumed to be sufficient to achieve adiabatic conditions within the specimen. This is more precisely addressed in the following.

2.3. Temperature measurement

Temperature measurement was performed at ambient temperature using a Cedip Jade III-MWIR infrared camera, which features a matrix of 320×240 pixels with detectors in a wavelength range of 3.5–5 μm. The integration time was set to 1500 μs and the acquisition frequency was equal to 147 Hz. Thermal resolution was equal to 20 mK. The size of a pixel, *i.e.* the individual IR detector size projected on the specimen, was equal to 0.16 mm. During the thermal measurements, a home-made casing surrounded the IR camera in order to avoid any disturbance such as photo-irradiation. To ensure that the internal temperature of the camera was stabilized during the measurements, the camera was set up and switched on 4 h before the experiment. The stabilization of the temperature inside the camera was necessary to avoid any drift of the measurements during the test. Temperature changes were measured by subtracting the initial temperature, captured in practice just before the beginning of the test, from the current one. In the present study, the initial temperature is the reference temperature. It can be noted that measurement noise was reduced using a spatial filter. In practice, we have applied a mean filter whose kernel dimensions were 5×5 pixels. The temperature change range $\Delta\theta$, *i.e.* twice the temperature change amplitude, was extracted at each pixel using a Fourier transform, from several cycles (here during 10 s) once the temperature evolution was stabilized.

2.4. Remarks about test preparation

It should be pointed out that the brittle nature of glass material makes harder the mechanical tests. Indeed, the first difficulty encountered was the application of a load without breaking the specimen. For this reason, a thin piece of polymer was placed between the grips and

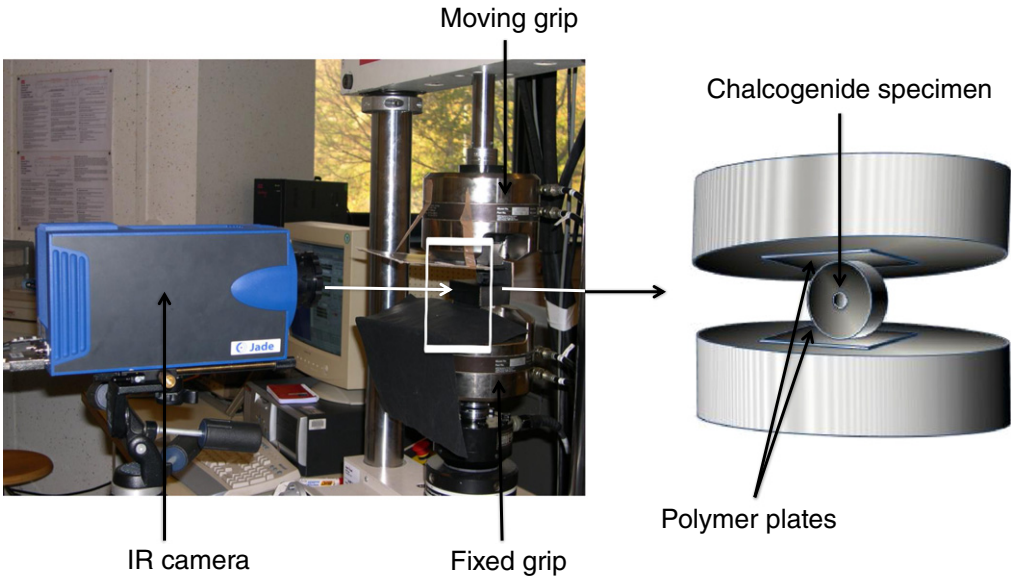

Fig. 1. Overview of the experimental setup.