CURRENT TOPICS ON NON-CRYSTALLINE SOLIDS

Proceedings of the First International Workshop on Non-Crystalline Solids

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M. D. Baró
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M. D. Baró

Departament de Física
Universitat Autònoma de Barcelona
Bellaterra, Spain

N. Clavaguera

Facultat de Fisica
Universitat de Barcelona
Barcelona, Spain

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FOREWORD

One of Oscar Wilde's dramatic characters remarked that "the truth is rarely pure, and never simple." If Wilde had been a scientist, he might have said the same thing about glasses. That is why it takes courage to assemble a group of scientists to lecture and argue about glasses . . . their structure, physics, chemistry and mechanics. The world of glass science is really an assembly of separate, slightly overlapping worlds, and when one brings together the physicists, chemists, metallurgists, mineralogists and engineers who study these tantalising materials, one may be forgiven for expecting either fireworks or mutual incomprehension. Fireworks, however, are all to the good; after all, Oscar Wilde cried, on another occasion: "Ah, don't say you agree with me. When people agree with me I always feel that I must be wrong."

To Professor Maria Teresa Mora belongs the great credit of having initiated this Workshop, a "first" for Spain and, in a world perspective, an occasion of exceptional breadth. Many kinds of scientist came, and the pursuit of impure and un-simple truth led, indeed, to argumentative fireworks, but that was of course the hoped-for outcome of the occasion. Professor Mora was actively helped by a number of colleagues, the great majority Spanish scientists, to bring this initiative to fruition, and the organizers were rewarded by an attendance of around 70 participants who came together from around the globe. There were many fruitful interactions, and even physicists and chemists were able to emulsify, if not perhaps to achieve mutual solubility. Those of us who came from other lands are deeply indebted to our Spanish hosts for a most rewarding week of science, lubricated by much good company, much good food and wine and some good weather.

¡ Viva el vidrio !

Robert Cahn
University of Cambridge

PREFACE

The First International Workshop on Non-Crystalline Solids was held in Sant Feliu de Guixols (Costa Brava), Spain, from 26 to 30 May 1986. Reflecting the ever increasing interests in the research and development of this particular branch of Condensed Matter, the Workshop was attended by 85 scientists from 12 countries.

The scientific program, which covered different aspects of non-crystalline solids, from basic problems to possible technical applications, consisted of 15 plenary lectures of one hour, 45 contributed papers subjected to poster presentation and 3 scientific debates related to the poster sessions. The posters were displayed for the duration of the whole Workshop to give maximum possibility for discussion, and the author(s) were present to man their posters at specific poster sessions.

The persons and institutions who have contributed to the success of the Workshop by their personal engagement in committees or by financial support are listed on the following pages and are gratefully acknowledged.

In this book are compiled most of the plenary lectures and the contributed papers presented at the Workshop. The later were subjected to a fast-refereeing procedure during the Workshop and revisions have been made if necessary. We express our thanks to all the authors for accepting to keep their papers limited in length and for their cooperation in preparing camera-ready typescripts. Also, thanks are due to the various referees for their critical reading of the papers.

As editors we are thankful to the publishers for their advice and help given during the planning and production of this book and we hope that it will be informative and encouraging for further growth and expansion of this interesting interdisciplinary scientific field.

Finally it is our pleasure to announce that the next Workshop will be held in San Sebastián in 1986, being chaired by Professor J. Colmenero.

Bellaterra/Barcelona, July 1986.

M. D. Baró
N. Clavaguera
Editors

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PLENARY LECTURES

DIFFUSION IN METALLIC GLASSES - AN INTRODUCTION

Robert W. Cahn

University of Cambridge, Department of Metallurgy and Materials Science, Pembroke Street, Cambridge CB2 3QZ, England

ABSTRACT

The measurement of the diffusivities of metallic and metalloid species in metallic glasses has necessitated the development of techniques capable of a resolution of a few nm over a total penetration depth of less than a micron. Various profiling techniques employing ion beams, and the ultrasensitive multilayer technique, are outlined. Generalities concerning the diffusion of different solutes in the same glass or family of glasses, and the diffusion of the same solute in different glasses, are presented, and the effect of solute concentration and relaxation discussed. The article concludes with an outline of the recent use of sputtered metallic glasses as diffusion barriers in microelectronic integrated circuits.

1. INTRODUCTION

Metallic glasses - or, to use a more general designation, amorphous alloys - were first studied in depth by the late Pol Duwez, who discovered in 1959 that an Au-Si melt, when frozen very fast, became a solid with a liquid-like configuration - that is, a metallic glass. Similar materials are now being studied in scores of laboratories all over the world, but the studies are no longer restricted to fast-quenched melts. Amorphous alloys are made by co-evaporation or co-sputtering[1,2] (this is the oldest approach); ion implantation[3]; ion-mixing of bilayers and multilayers[4,5]; electron or ion irradiation of crystalline solid solutions[6]; transient melting of an alloy surface layer by a moving or pulsed laser beam[7]; chemical or electro-plating[8]; or by means of a solid-state (diffusive) amorphisation reaction (SSAR)[9,10]. The cited publications give specific instances or overviews of these various techniques. I shall restrict myself to phases made by two techniques only - deposition by co-evaporation or co-sputtering, and rapid quenching from the melt; for simplicity, all such materials will be denoted by the term "metallic glasses".

The variety of metallic glasses which has been made is by now very large, certainly more than 100 distinct combinations, most of them in various proportions, and described in a literature which, since 1959, probably now exceeds 10^4 papers. For brevity, and omitting semiconductor phases such as amorphous silicon, they can be divided into two large families alloys of metals (most commonly early transition metals) with one or more metalloids, usually boron, phosphorus or silicon; and alloys of pairs of metals, one or both of which are commonly transition metals. Metals in the first group have usually been made by melt-quenching, those in the second, by all the methods listed.

Readers who desire a general overview of the preparation composition, structure and properties of amorphous alloys have available an embarras de richesses: there have been dozens of books, monographs and review articles in the past ten years. Some of the most recent publication include Luborsky[11] (the most comprehensive single source), Chen[12] Cahn[13] and Herman[14].

In what follows, I shall make no distinctions in terms of mode o preparation: to date, on the few occasions when a physical property of a amorphous alloy has been measured in samples made by two or mor different techniques, no significant differences have as a rule bee observed.

2. DIFFUSION: EXPERIMENTAL TECHNIQUES

Atomic transport, or diffusion, in a metallic glass is linked, in or way or another, with many of its most important properties. Self-diffusic - i.e., the transport of a species initially present in the solid - is linked t viscosity, creep under applied stress, changes with time of ferromagnet properties and electrical resistivity, internal friction, the rate (crystallization. Chemical diffusion - i.e., the transport of an external supplied species - determines the kinetics of oxidation, compound formatic and breakdown of an amorphous barrier layer by reaction with substrate (overlay; it can also modify crystallization kinetics.