Structural studies and electrical properties of recycled glasses from glass and incinerator wastes

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The electrical behaviour of different glass compositions obtained from mixing waste glass deriving from a community glass recycling program and silicate waste from the incineration of municipal solid residues (from Reggio Emilia city) have been investigated as a function of temperature and frequency. The electrical and dielectric properties were related to structural studies performed on the same glassy materials. As the amount of incinerator wastes increases, on account of lower alkali and higher alkaline-earth content in the final glass composition, conductivity and dielectric losses decrease approaching the behaviour of type E glass fibres, so envisaging a possible use of waste-containing glasses in the production of high voltage insulators. © 2001 Kluwer Academic Publishers

1. Introduction
As the knowledge and attention to the environmental problems increase, the search of efficient disposal technologies for toxic, hazardous substances becomes more strenuous. For many industrial wastes such as fly ashes and incinerator wastes, vitrification has proved to be a successfull way to produce inert by-products [1–6]. These can not only be stored safely but also be re-used as new marketable building materials.

In the present paper the attention has been focussed on the grate ash coming from the incineration of municipal solid wastes and on waste glass coming from a community glass recycling program. The first represents the main residue fraction (approx. 25–40 wt%) of municipal waste combustion process that has several advantages. These are: the reduction in waste volume and mass in order to save scarce and valuable space on landfills, the complete destruction of all organic matter in order to guarantee a total disinfection of the waste stream, the detoxification of inorganic pollutants present in the waste, the utilisation of the energy contained in the waste stream and the possible production of high quality bottom ashes which could enable utilisation [7]. The chemical composition of the grate ash exhibits the main constituents of glasses: glass forming oxides (SiO2), melting and glass modifying oxides (Na2O, K2O) lowering melt viscosity and glass stabilizing oxides (CaO and MgO), which also lower melting temperature and viscosity. Therefore, this kind of by-product seems particularly suitable to undergo a vitrification process, through which the following useful benefits can be obtained: the immobilization of toxic elements, whenever present, the reduction of waste volume and the possibility to immobilize wastes of different origin with the same vitrification process.

Suitable amount of other raw materials have to or can be added to the waste to be vitrified in order to obtain a more homogeneous and stable vitreous melt and add further value to the final product. The introduction of conventional raw materials used for commercial glassmaking, such as sand, would however be too expensive and the waste vitrification process would become unprofitable. This can be by-passed by the exploitation of other by-products. In this way, preliminary studies have shown the feasibility to obtain glasses from mixtures of cullets and incenominator waste at different percentages [4, 8] capable also to be drawn into fibres showing promising mechanical properties [9].

Following previous work carried out on different glasses and glass-ceramic formulations which have shown excellent electrical insulating characteristics [10], the aim of this paper is to investigate the insulating characteristics of these glassy materials belonging to the alkaline and alkaline-earth aluminum silicate system as a function of their composition and to envisage possible applications.

2. Experimental procedures
Six different glass batches were obtained by dry-mixing grate ash of municipal solid wastes incenominator with soda-lime cullets in different ratios and melting in the 1400–1500°C temperature range. Glass sheets were obtained by pouring the melt on a graphite mould. The
sheets were then annealed at 550°C for 2 hours. Their composition is reported in Table I. Heavy metals (Pb, Cr, Mn, Ba) are present as trace and are not reported. As the grate ash fraction increases, the colour of glasses turns from a light green to brown and black, due to the increase of Fe₂O₃ content.

Specimens, bubbles free, were in the form of disks up to 8 mm thick and 40 mm in diameter. Specimens surfaces were polished by SiC paper of decreasing grain size till a suitable planarity was obtained.

The chemical durability was assessed by leaching tests conducted in water (ISO 719), alkali (ISO 695) and acid (DIN 12116), which simply divide glasses into categories, with the lower category number designating better durability.

Structural studies were carried out by density measurements performed by the hydrostatic method with distilled water as immersion fluid, as reported elsewhere [11]. Electrical measurements were performed in air. The volt-amperometric method was used to determine the volume electrical conductivity by means of a three-terminal electrode configuration cell according to ASTM D 257 [12]. Preliminary measurements carried out on different samples of the same batch provided reproducible results, thus assuring the reliability of the glass making process. An electric field of 2 kV/cm was applied. The current flowing through the samples was recorded as a function of time till 3600 s at different temperatures between 25 and 200°C. Dielectric measurements were carried out as a function of temperature (from 25 to 100°C) in the frequency range from 10² to 10⁵ Hz by an automated LCR bridge (Hewlett Packard 4284A).

### 3. Results and discussion

Table II summarises the results of the chemical durability test carried out as previously described.

All the investigated glasses have high water resistance (class 1) and show a very low alkali attack (class 1) but they are subjected to acid attack, however comparable to that of domestic glasses (class 3-4). These results are important to establish the final uses of the amorphous materials, particularly for fibres of reliable durability and stable mechanical properties.