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Study of Electrical Properties of Some Amphibole Asbestose

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ABSTRACT

The dielectric constant Ke, electrical susceptibility η and the voltage dependence of the electrical conductivity σ have been studied at room temperature for five specimens of amphibole asbestos, including anthophyllite, grunerite, tremolite, actinolite and rebeckite. The sudden increase in electrical conductivity at voltage 400 volt for our specified grunerite specimen indicated a surprising phenomenon and correlated with the beginning of the transition of oxidation states of iron in the specimen and creation of new electrical carriers. It is a phenomenon of voltage stabilization.

دراسة الخواص الكهربائية لبعض أنواع الامفيبول الاسبستي

الملخص

اشتمل البحث على دراسة الخواص الكهربائية: ثابت العزل الكهربائي Ke والتأثرية الكهربائية η واعتماد التوصيلية الكهربائية σ على الفولتية لخمسة نماذج منتقاة من الامفيبول الاسبستي، عند درجة حرارة الغرفة وفي مدى فولتية مستمرة (0-4000 V). حيث تضمنت الدراسة عينات من الصخور المعدنية :الانثوفيلات، كرونارايت، تريمولايت، اكتينولايت والريبيكايت. إن الزيادة المفاجئة في التوصيلية الكهربائية لعينة الكرونارايت عند الفولتية 400V، بينت ظاهرة مدهشة، تعزى إلى حصول تغيرات في حالات تأكسد أيون الحديد للعينة ويرافق ذلك خلق ناقلات جديدة للتيار الكهربائي. ويمكن استثمار هذه الظاهرة في المجال التطبيقي لتصميم عناصر تثبيت الفولتية.

INTRODUCTION

Asbestos minerals fall into two groups, serpentine asbestos and amphibole asbestos. Serpentine asbestos, a magnesium silicate mineral, possesses relatively long fibers that are capable of being woven. Amphibole asbestos forms crystalline fibers that are more brittle and is more limited in being fabricated.

Usually, amphibole asbestos minerals are divided into three groups according to the nature of the cations occupying the sites of balance in the polymeric structures: (1) the MgFe - group which comprises grunerite and anthophyllite, (2) the Ca - group, which includes tremolite and actinolite and (3) the Na - group, includes rebeckite which represents the last member of variable series (Kasir and Abada 1989).

A considerable mass of data have been carried out concerning the physical and chemical properties of amphibole asbestos, including the molecular weight, physical state, chemical formula, flexibility, melting point, specific gravity, solubility, isoelectric point and length distribution (EPA, 1985 b); (HSDB, 2001). Recent IR and NMR studies of some natural monoclinic amphibole indicated that the distribution of aluminum ions among varies sites is strongly ordered in definite site while disordered over the other sites (Welch, 1994). In a Mossbauer spectroscopic study, the oxidation states and site occupancies of iron in selected amphibole asbestos were estimated at different sites and recorded. The spectra were analyzed to obtain information on quadrupole splitting, isomer shift and iron concentration in each amphibole specimen (Kasir and Abada, 1989). On the other hand, the temperature dependence of the electrical conductivity of granite rock species containing a low percentage unspecified amphibole (0-5%) and a quartz - monzonite contained amphibole (3.8 - 7.6 %), have been studied to evaluate the hypothesis of progressing of the thermal flow from deep parts of the earth's crust and upper layers of the crust (Shanov, et al., 2000). The influence of temperature on thermal conductivity and thermal diffusivity for different types of rock including garnet - bearing amphibolite and garnet - biotite - amphibolite, using the linear function approach of thermal resistively, two general equations were determined for two species of rocks (Vosteen, et al., 2003).

The present work on selected amphiboles was performed with emphasis on the dielectric constant Ke, the electrical susceptibility η and voltage dependence of electrical conductivity σ, as well as to determine the possible correlation of σ on the relative iron concentration of the varies sites present in a given specimen of the five selected amphibole asbestos. The specimens under investigation are a collection from Ward's national scientific establishment, awarded by the department of geology - Mosul University.

EXPERIMENTAL PROCEDURE

Conducting materials differ from one to another, however, in the magnitude of the current density established by a given electric field. The ratio of the current density to the electric field intensity is called the electrical conductivity σ of the material. The electrical conductivity of a given material varies with temperature and with other physical conditions. For metals, σ is independent of the current density, but there are substances, notably the mineral rocks,for which the conductivity varies markedly with current density (Sears, 1964).

Knowledge of electrical conductivity σ and dielectric constant Ke of a given material is necessary in the design and manufacture of products such as capacitors, audio transformers, capacitance level gauges and aerial systems. In a device that is becoming more commonly seen, the microwave oven, it is important to know the σ and Ke for the materials used in the oven to ensure that the food rather than the container is cooked. It is for this reason that the study of energy of transportation of anion and cation vacancies in solids becomes significant. It is now well known from experimental work on transport processes that electrical energy transport at high temperatures occurs predominantly due to the presence of a variety of mineral atoms and cation-anion vacancy pairs (Sharma and Kasir, 1979).

The electrical conductivity of a material is defined as the ratio of the current density J=i/A to the electric field intensity E=V/t and is represented by σ,
Where A is the cross sectional area and t is the thickness of the material specimen.

$$\sigma = \frac{J}{E} \qquad (1)$$

The dielectric constant of a material is defined as the ratio of the permittivity of that material to the permittivity of free space. But from the experimental viewpoint, however, the relation:

$$K_e = \frac{C}{C_o} \qquad (2)$$

is often made the defining equation of the dielectric constant . That is, Ke of a material is defined as the ratio of the capacitance C of a given capacitor with the material between its plates, to the capacitance Co of the same capacitor in vacuum.

For the sake of emphasizing the atomic and electronic viewpoint, the electronic susceptibility η defined as the ratio of induced charge density to electric intensity can be easily determined using the relation:

$$\eta = \varepsilon_o (K_e - 1) \qquad (3)$$

where εo the permittivity of the vacuum $=8.85\times10^{-12}$ (farad/meter) and Ke is the dielectric constant. Equation (2) however affords a direct and relatively simple and accurate method of determining the electric susceptibility η, since Ke can be measured with high precision.

EXPERIMENTAL SETUP

The amphibole rock specimens were ground and sieved through an 85μm gauge, using a mortar grainder machine-Fritsch model. The powders were compressed to a pressure 10 (metric tones/cm^2), to construct a specimen discs of (1.2cm) in diameter and (2mm) thickness. The disc specimens were sandwiched between the aluminum electrodes and then connected in the electrical circuit shown in Fig.1. The DC voltage dependence of the electrical conductivity of five mineral rocks is measured at temperature (12^oC), by recording the I-V characteristics for each amphibole specimen within the voltage range of (0 to 4000 volts).

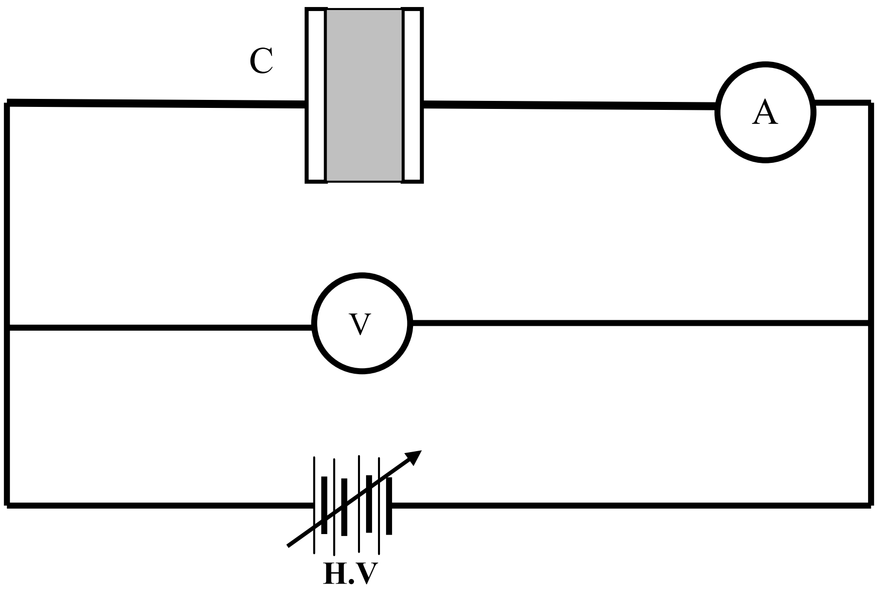


Fig.1: Diagram of electrical conductivity measuring circuit.

The technique used in determining the dielectric constant Ke employed a high quality resonant circuit. The basic electrical circuit is shown schematically in Fig.2. The oscillator is weakly coupled to the resonant circuit. The capacitor C is an air - spaced one, fitted with compressive springs to adjust the electrode spacing, which contains the specimen. R is a resistor of magnitude 10 ohms and L is a coil of self-inductance (0.12mH). The oscilloscope is used to monitor the resonance. To improve the loss resolution of the measurements, we designed the electrode system, taking great care to keep the assembly adequately shielded. Dielectric constant can be measured to within (1%) using the air substitution method.

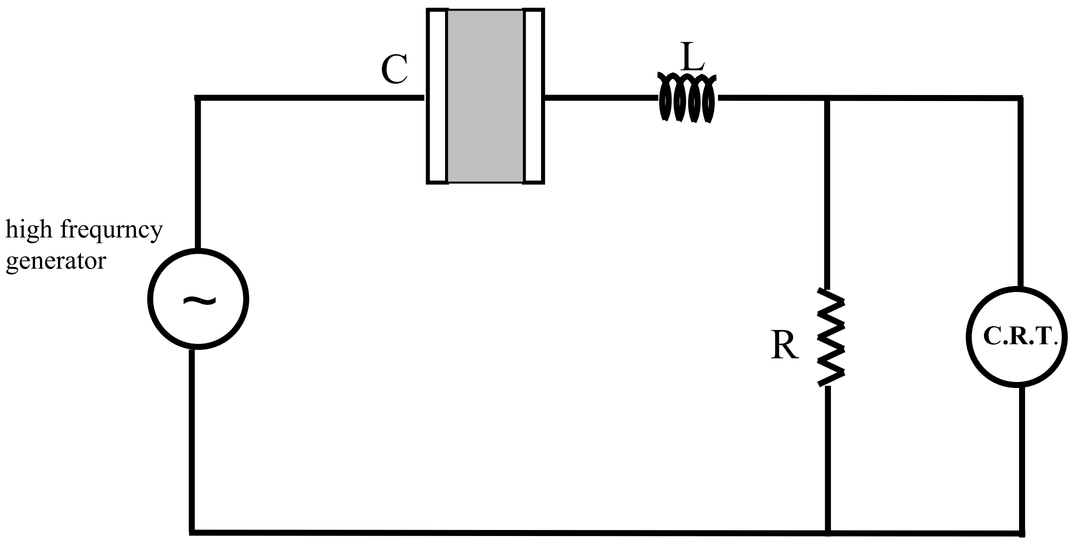


Fig.2: Diagram of dielectrical constant measuring circuit.

RESULTS AND DISCUSSION

Table1, summarizes all the values of the dielectric constants Ke, electrical conductivity σ, electrical susceptibilities and the relative concentrations of iron ions in various amphibole asbestos with respect to alpha enriched natural iron C_r, which were calculated previously from the Mossbauer spectra by the method sums of areas of all ferric and ferrous peaks which are extracted from the fully unfolded spectra (Kasir and Abada, 1989).

The electrical conductivity measurements of rocks are highly sensitive to voltage changes. As mentioned before, the charge carriers are ions, cation vacancies, anion vacancies and electrons. The total conductivity is the sum of the individual conductivity of all components. Each component is predominant in a certain voltage range.

In all cases of the present work, the change in electrical conductivity of amphibole rocks with applied voltage change, can be analyzed as a function of mineral composition, the structure and the quantity of the high electrical conductive minerals, such as ferric and ferrous iron in each sample (Kasir and Abada, 1989). The electrolyte conduction is not included in this study, because of the method of specimens preparation (powdered rock specimens additionally formatted in discs).

Table 1: Electrical Properties of Amphibole Asbestos.

Property	Tremolite TR1	Actinolite AC1	Anthophyllite AN1	Grunerite GU1	Riebeckite RB1
Dielectric Constant Ke	3.675	4.7	4.246	3.35	3.85
Electrical Conductivity σ $(\Omega.cm)^{-1}\times10^{-9}$ at V=400 v	3.71	26.2	14.8	414.5	13.2
Electrical Conductivity σ $(\Omega.cm)^{-1}\times10^{-9}$ at V=2000 v	17.83	20.2	47.4	very high	42
Electrical Susceptibility η $(F/meter)\times10^{-12}$	23.67	32.75	28.73	20.8	25.73
Relative Concentration of Iron ion Cr w.r.t. α-natural iron*	0.0015	0.0606	0.082	0.1327	0.0527

*(Sharma et al., 1986) (Kasir and Abada, 1986).

Fig.3, shows the I-V characteristics for (a) Tremolite (b) Actinolite (c) Anthophyllite (d) Grunerite and (e) Riebeckite. Fig.4, shows the electrical conductivity σ vs. the applied voltage, for the five amphibole specimens. The electrical conductivity for the four specimens TR1,AN1,GU1 and RB1 increases with increasing voltage, while the electrical conductivity for the AC1 specimen decreases with increasing the voltage applied.

The decrease of σ for Actinolite has been attributed to the decrease in the number of free anion vacancies by the law of mass-action. The study of electrical conductivity in solids included that the activation energy for migration of the anion vacancies is less than that for cation vacancy bound to an impurity atom and the conductivity is dominated by cation vacancies created for the charge compensation which indicates that the conductivity not anionic in nature (Sharma and Kasir, 1979). At voltage (400 V), the electrical conductivity of grunerite specimen GU1 is roughly of the order of (46-209) higher than that of other amphibole specimens. The jumps of σ of Gu1 during the further voltage rise can be explained by some dominant carriers of the minerals in the Grunerite rock. Usually grunerite belongs to the MgFe-group of amphiboles which comprises grunerite and kupfferite. These minerals are the two end-members of continuously variable series. The chemical formula of a unit pattern kupfferite is $Mg_7Si_8O_{22}(OH)_2$. Alternatively, if the cations are Fe^{2+}, the chemical formula would become $Fe_7Si_8O_{22}(OH)_2$ and this is represented the composition of grunerite. Since the grunerite contains of full occupation of transition element ions Fe^{2+}, we attributed the increasing in σ in grunerite is due to the increasing Fe^{2+} contents. On the other hand, the abrupt decrease in σ of Actinolite could be related somewhat to the transitions of Fe3O4 to Fe2O3 following the reaction (Shanov, et al. 2000).

4 Fe3O4 + O2 ⟶ 6 Fe2O3

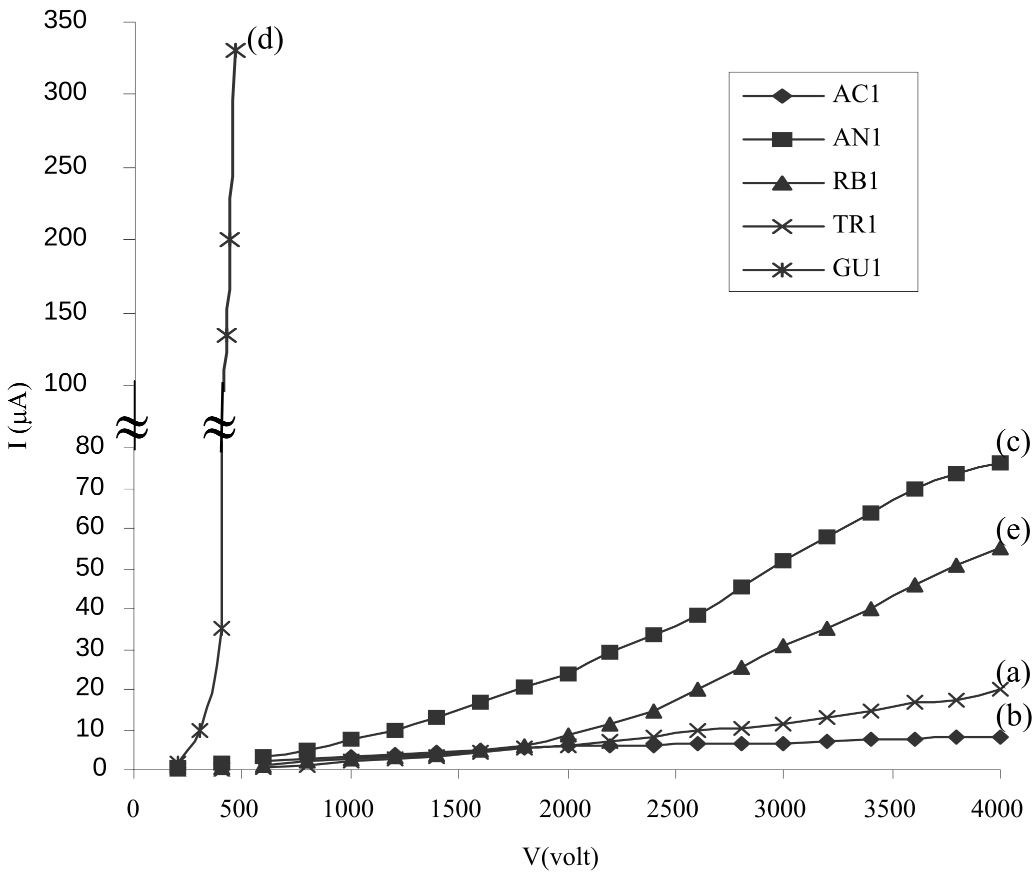


Fig.3: I-V characteristics of five amphibole rocks.

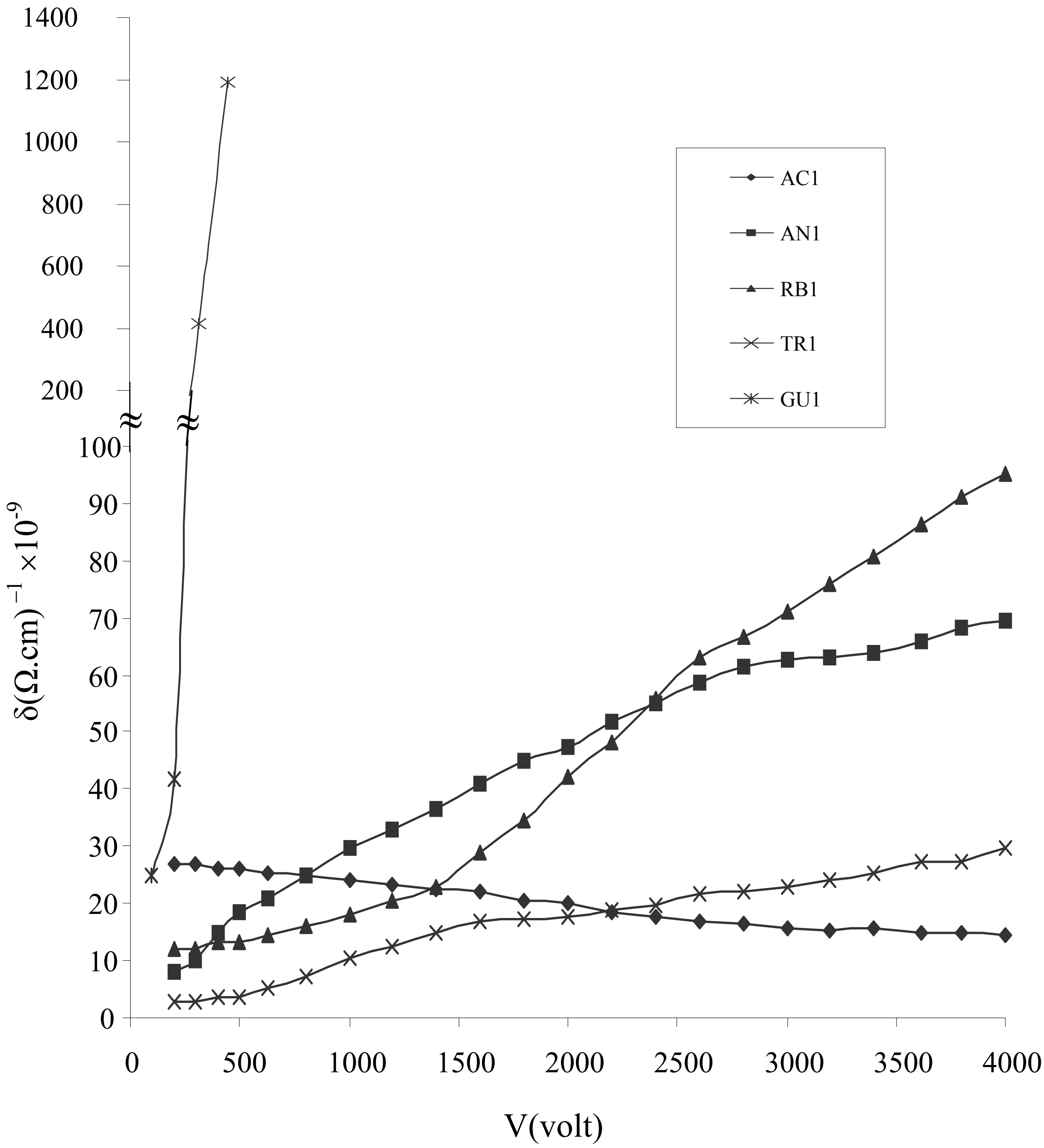
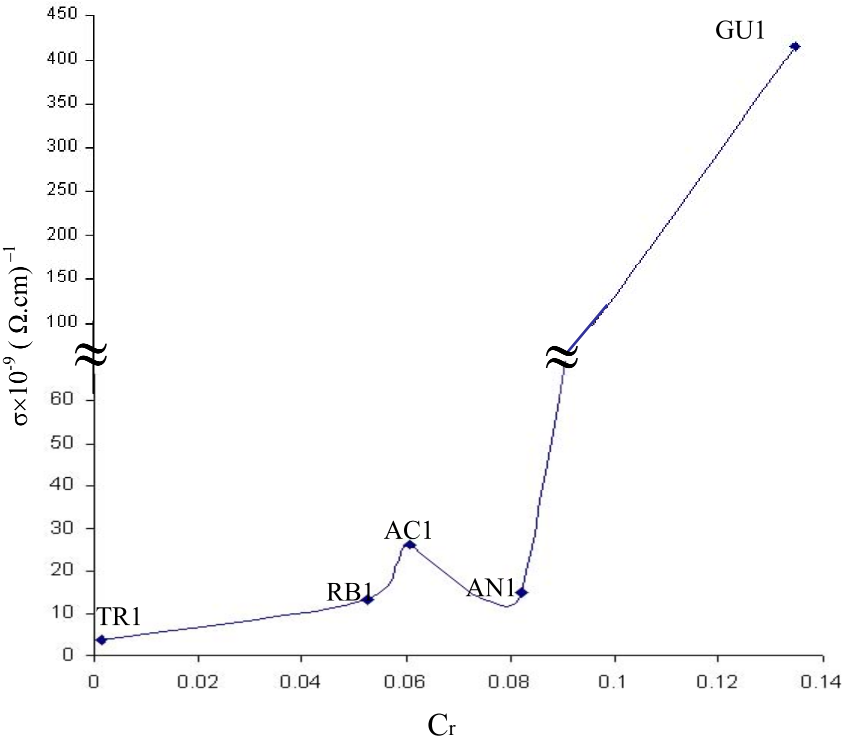
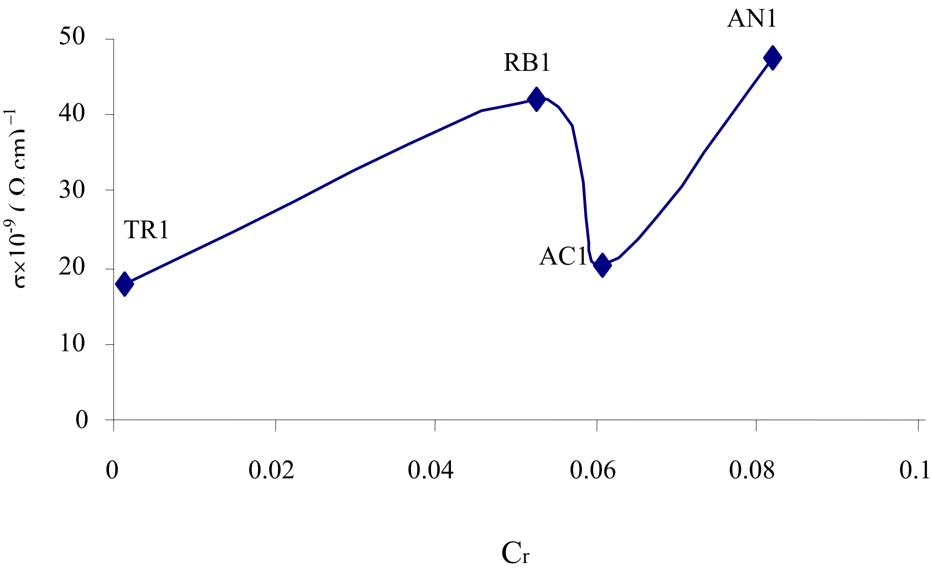


Fig.4: Electrical conductivity for AN1, TR1, AC1, RB1 and GU1 *vs*. voltage.

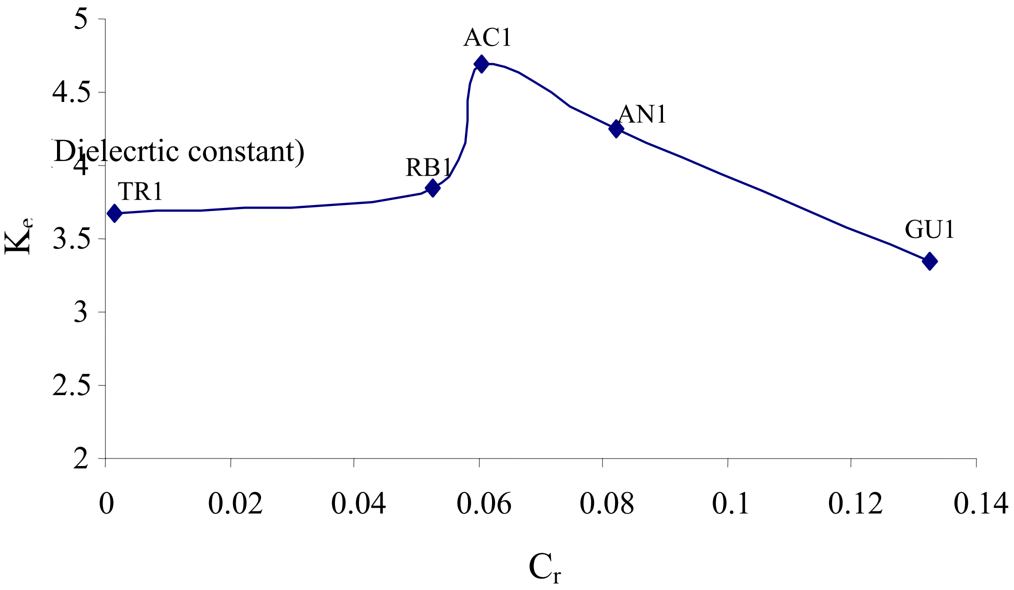
Fig.5a and Fig.5b, show the electrical conductivity vs. the relative concentration of iron in each of the five individual amphiboles recorded at (400V and 2000V) respectively. Fig.6 again shows the relation of dielectric constant Ke with the relative concentration of iron in each of the five individual amphiboles.



: Electrical Conductivity σ vs. relative concentration of Iron C_r, in amphibole specimens, at voltage 400 V.



: Electrical Conductivity σ vs. relative concentration of Iron C_r, in amphibole specimens, at voltage 2000 V.



: Dielectric constant Ke *vs*. relative concentration of Iron C_r, in amphibole specimens.

CONCLUSION

The main properties of asbestos that can be exploited in industrial applications are their thermal, electrical, and sound insulations. The extent of electrical properties of amphibole asbestos is an important evaluation criterion that is commonly measured by several techniques, namely electric conductivity, permitivity, dielectric constant and electric susceptibility. These properties are also used as a measure of amphibole fiber openness and amphibole conduction capacity. The unidentified phenomenon in electrical conductivity for Grunenite rock mineral constitutes another key criterion for the evaluation of this mineral in designing electrical elements of various accepted geometrical dimensions to cover a widely range of voltage stabilization used in electronic devices. In addition, considerable effort has to be devoted to understand the unexpected decrease in electrical conductivity when the voltage increases for the actinolite rock mineral.

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