RADCON: where are we heading to?

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MAIN OBJECTIVE OF THE PROJECT:
to assess the effect of radiation-induced mechanical and volumetric changes on structural integrity of concrete structures in irradiated environment

Scope:

- minerals, cements will be selected
- selected minerals will be irradiated and the effect of mechanical and chemical changes on load carrying capacity/performance will be investigated
- database comprising the irradiated minerals will be expanded with experiments on non-irradiated minerals under various temperature and humidity regimes
- numerical models of mechanical behavior will be used in structural analysis.

MAIN RESULT: a proposed assessment method which connects **mechanical and chemical changes of irradiated minerals** with long-term performance of concrete structures exposed to radiation.

Effects of prolonged exposure to radiation

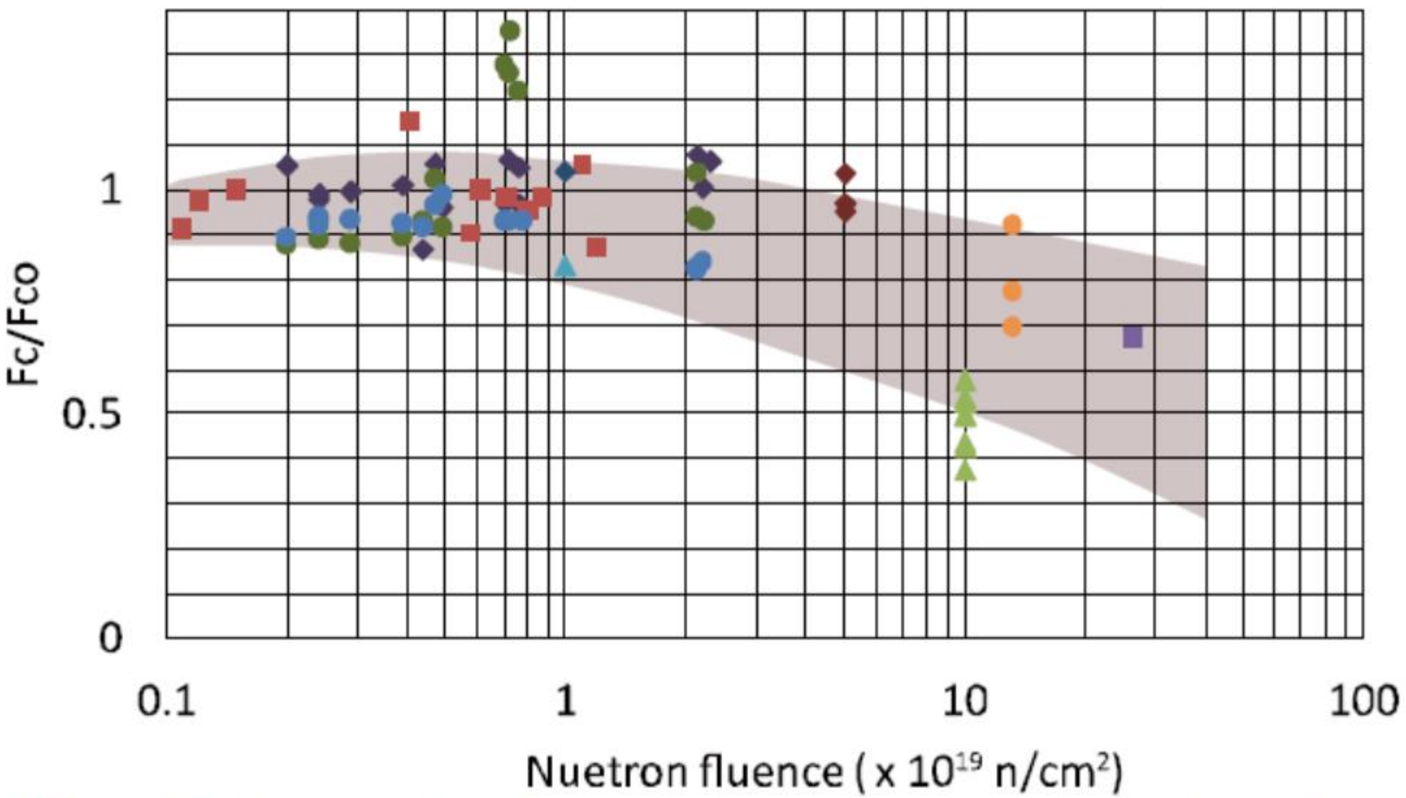


Fig. 3 Relationship between concrete strength ratio (Fc/Fco) and neutron fluence of concretes satisfying the LWR conditions (Maruyama *et al*. 2013).

Radiation level treshold:
10^{20} n/cm^2
200 MGy

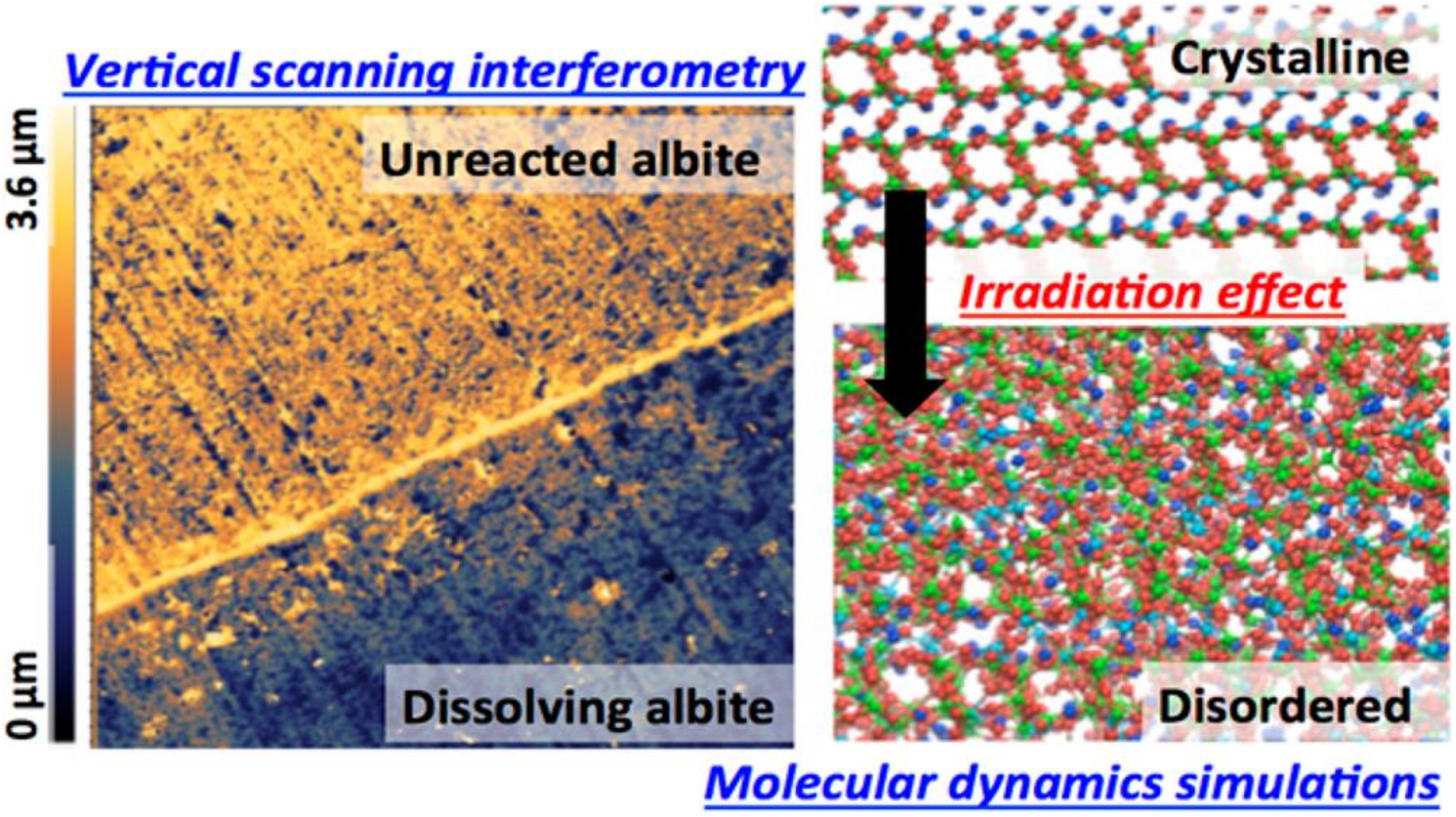
Radiation effects on materials

Radiation-induced degradation is a complex phenomenon involving multiple physical, chemical and mechanical processes, and it is controlled by nano-scaled features that are very difficult to identify even by state of-the-art techniques.

Macroscopic tests and microscopic analyses of neutron-irradiated materials require special technical efforts and facilities, and make it difficult to obtain sufficient and systematic databases.

To overcome these difficulties, theoretical modeling and simulation experiments for fundamental processes are important tools for developing prediction methods in operating reactors and for mechanistic understanding.

Hsiao i in
J. Phys. Chem. A 2017, 121, 7835−7845



When exposed to radiation the crystal structure of albite can undergo significant alterations to degrade its chemical durability.

Ar+-implanted albite → upon irradiation albite's crystal structure undergoes progressive disordering, resulting in an expansion in its molar volume (i.e., a reduction of density) and a reduction in the connectivity of its atomic network.

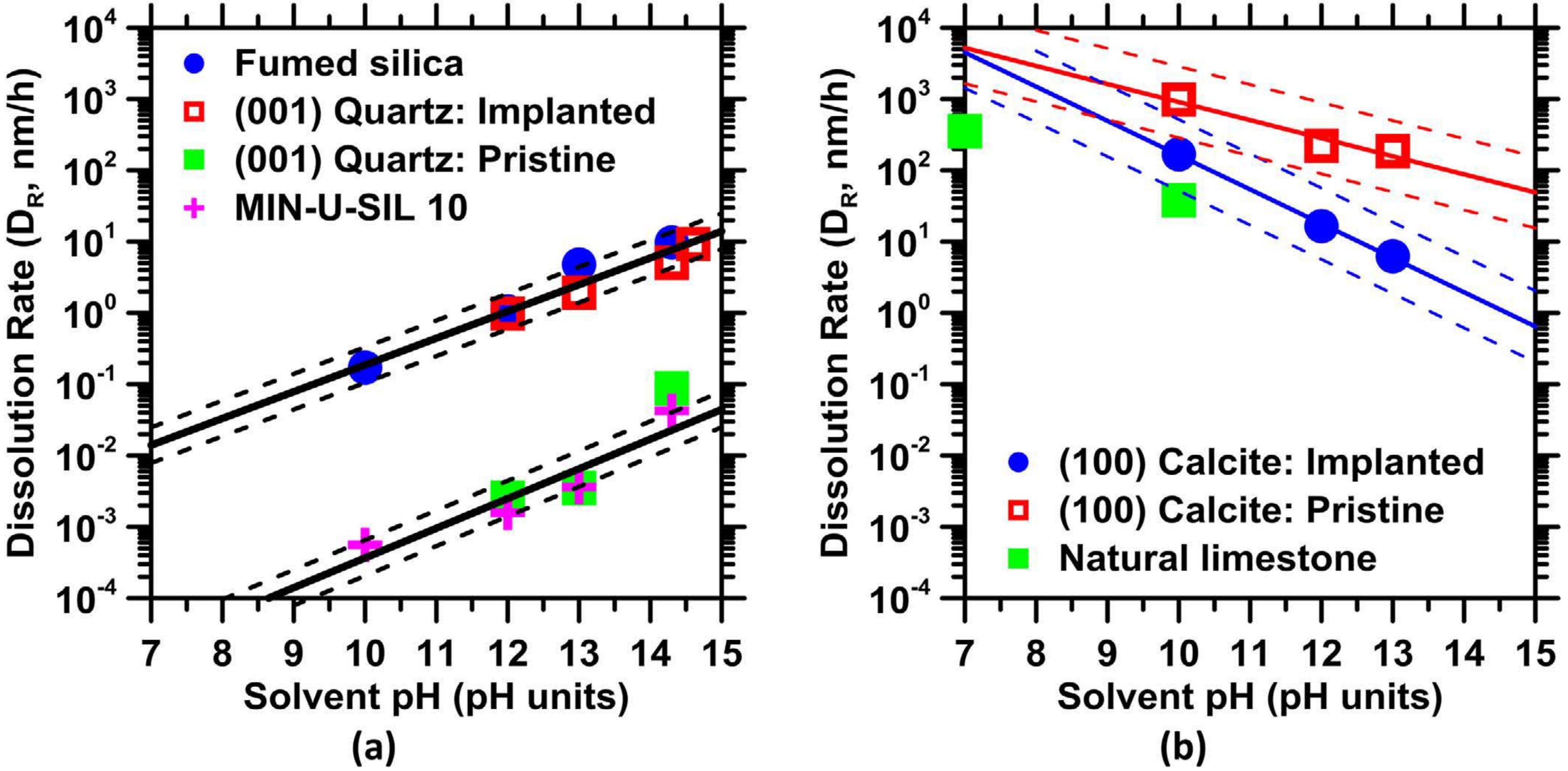
The loss of network connectivity (i.e., rigidity) results in an enhancement of the aqueous dissolution rate of albite in alkaline environments by a factor of 20.

Pignatelli i in
Scientific Reports | 6:20155 (2015)

Direct evidence acquired on **Ar+-ion** irradiated calcite and quartz indicates that such minerals may be significantly altered by irradiation.
Quartz undergoes disordering of its atomic structure resulting in a near complete lack of periodicity.
Calcite only experiences random rotations, and distortions of its carbonate groups.

As a result, irradiated quartz shows a reduction in density of around 15%, and an increase in chemical reactivity, described by its dissolution rate, similar to a glassy silica.
Calcite shows little change in dissolution rate - although its density is reduced by ≈9%.

These differences are correlated with the nature of bonds in these minerals, i.e., being dominantly ionic or covalent, and the rigidity of the mineral's atomic network that is characterized by the number of topological constraints that are imposed on the atoms in the network.



Synthetic single crystals of α -quartz and calcite with dimensions 10 mm × 10 mm × 1 mm (l × w × h).
The calcite crystals are (100)-oriented, whereas the quartz crystals are sectioned perpendicular to their optical axis (i.e., corresponding to the crystallographic c-axis), and are thus (001)-oriented.
The quartz and calcite single-crystals were ion-beam irradiated at room temperature using an implantation energy of 400 keV with Ar+-ions to a total fluence of 1.0 × 1014 ions/cm2.

Current and planned topics by IPPT PAN +collaborion

G: Effects of gamma radiation	M: Modeling of radiation effects	N: Effects of neutron radiation	R: Materials characterization using radiation
Gamma influence on cement setting and early hardening	Modeling of early cement hydration with boron compounds	Neutron activation at BNC (rock powder, cement, mortar 18x18x80)	Elementary composition of cements, aggregates (PGAA, NAA-part 1)
Gamma influence on elasticity and early strength of concrete		?	Air void characterization by mCT, NI and optical microscopy 2D
Gamma influence of expansive phenomena (ASR, …)	Identification of paste, rock properties for expansion model		Water uptake by neutron imaging (CZ+H)
Gamma influence on rock-paste interfacial bond strength/toughness	Mechanical model of interface		
Gamma influence on steel corrosion in cement mortar (?)			
Gamma influence on cement mortar carbonation (reaction $CO_2+Ca(OH)_2$)		Ion implantation as substitute for neutron damage on surface of minerals (nanoindentation)	
Gamma influence on bound water content in cement paste (radiolysis)	Separation of gamma and temperature effects		Bleeding phenomena by neutron imaging

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Thank you for your attention!

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