Computational Imaging Methods for CR-39 Alpha Particle Dosimetry

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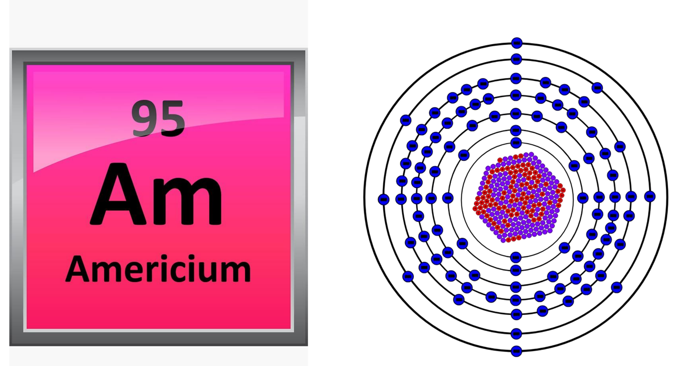
Background

CR-39 is a widely used solid-state nuclear track detector (SSNTD) for detecting charged particle radiation, particularly alpha particles. When exposed to alpha radiation, CR-39 forms microscopic damage tracks that can be revealed through chemical etching. Traditional dosimetry involves direct irradiation followed by optical or electron microscopy to analyze these tracks.



$$Q = (M_{\text{parent}} - M_{\text{daughter}} - M_\alpha)c^2$$

$$T_\alpha = Q \times \frac{M_{\text{daughter}}}{M_{\text{daughter}} + M_\alpha}$$

Figure 1. Americium Element

α-decay and Am241

Alpha decay is a type of radioactive decay where an unstable nucleus emits an alpha particle (two protons and two neutrons), reducing its atomic number by 2 and mass number by 4. This process occurs in heavy elements to increase nuclear stability.

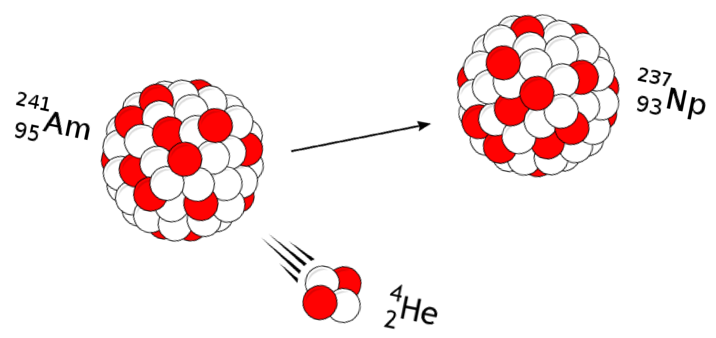


Figure 2. α-decay of Americium- α-decay 241

Americium-241 (Am-241) undergoes alpha decay, emitting 5.486 MeV alpha particles and transforming into neptunium-237 (Np-237).

CR39

Polyallyl diglycol carbonate (PADC) or CR39, a transparent polymer widely used for detecting charged particles.When an alpha particle strikes CR-39, it ionizes the polymer along its path, breaking molecular bonds and creating a latent damage track.

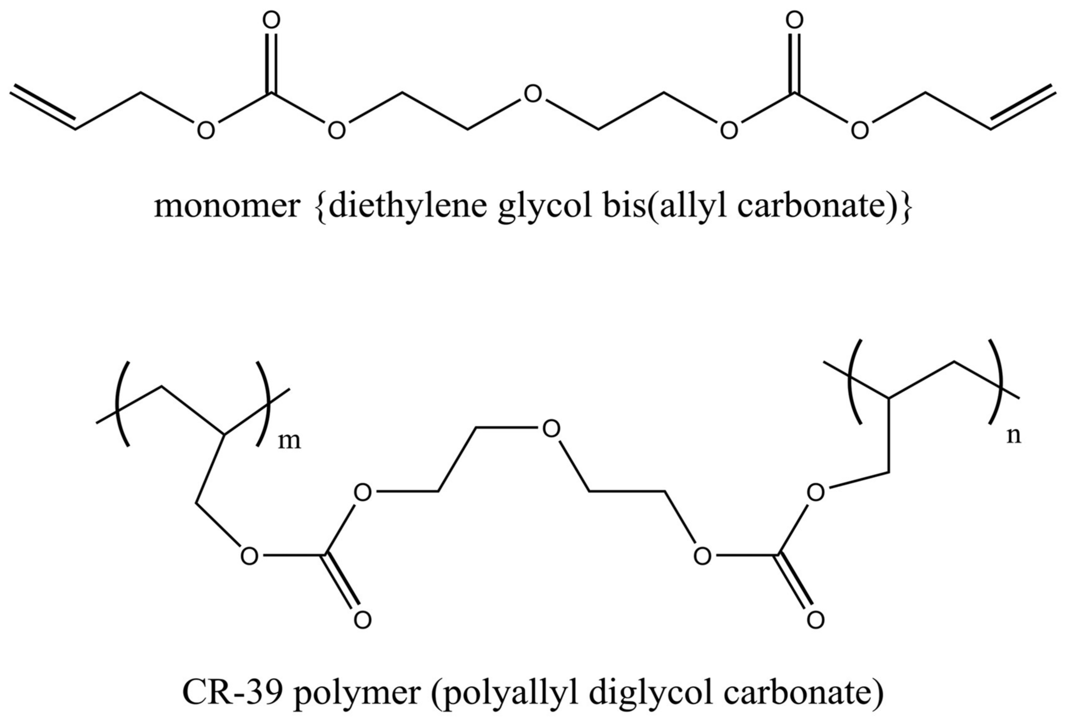


Figure 3. PADC molecular structure

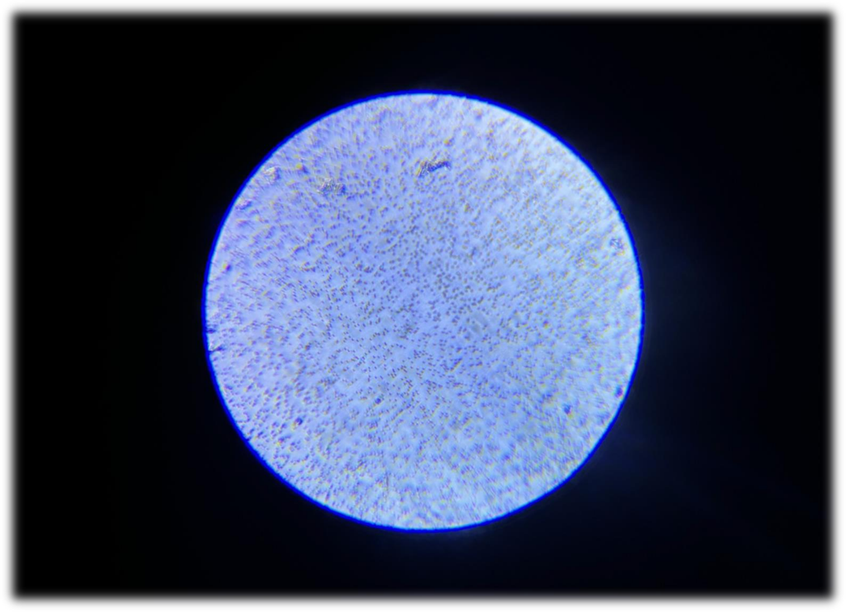


Figure 4. CR39 implementation of Iphone pocket dosimeter

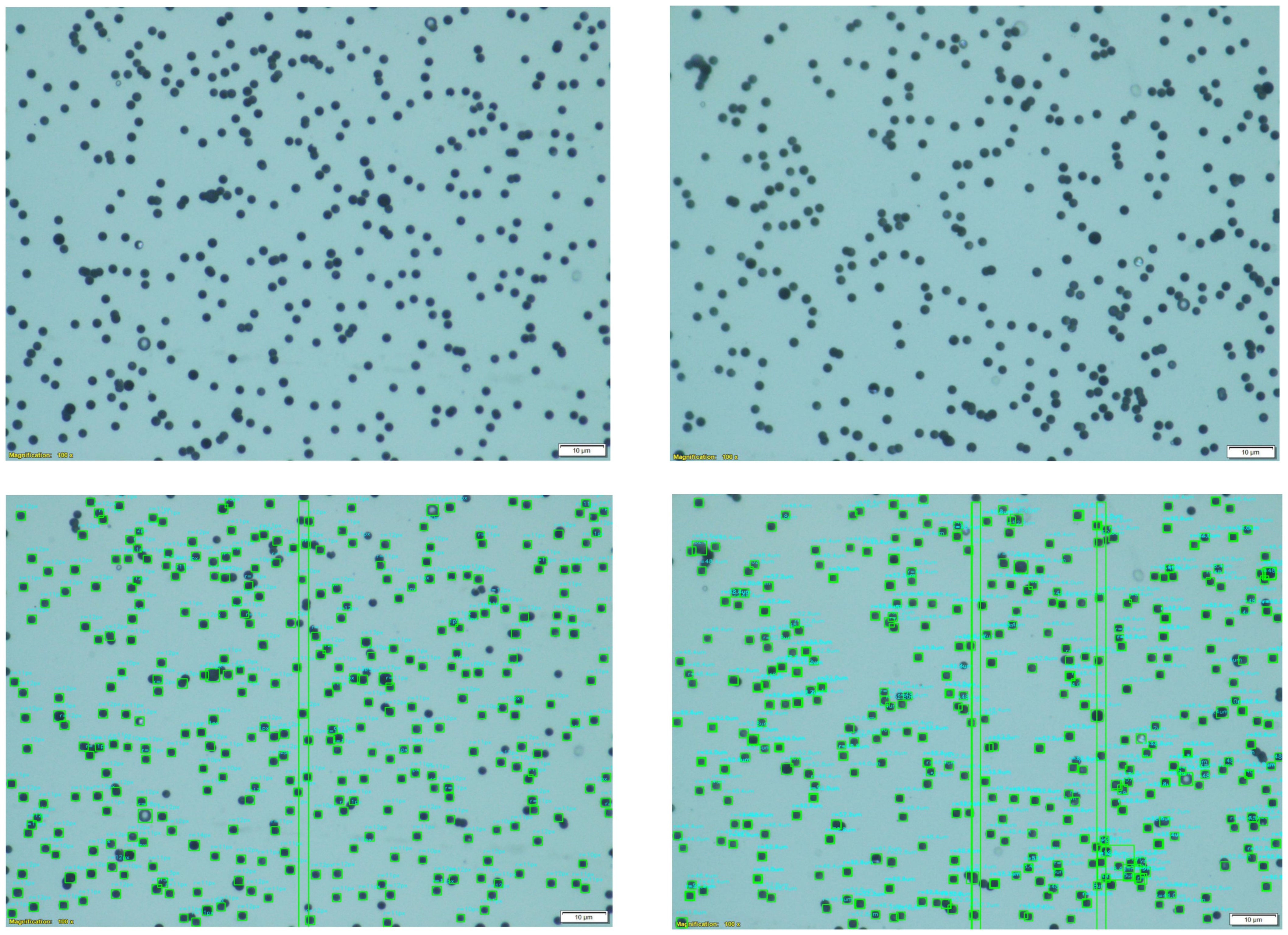
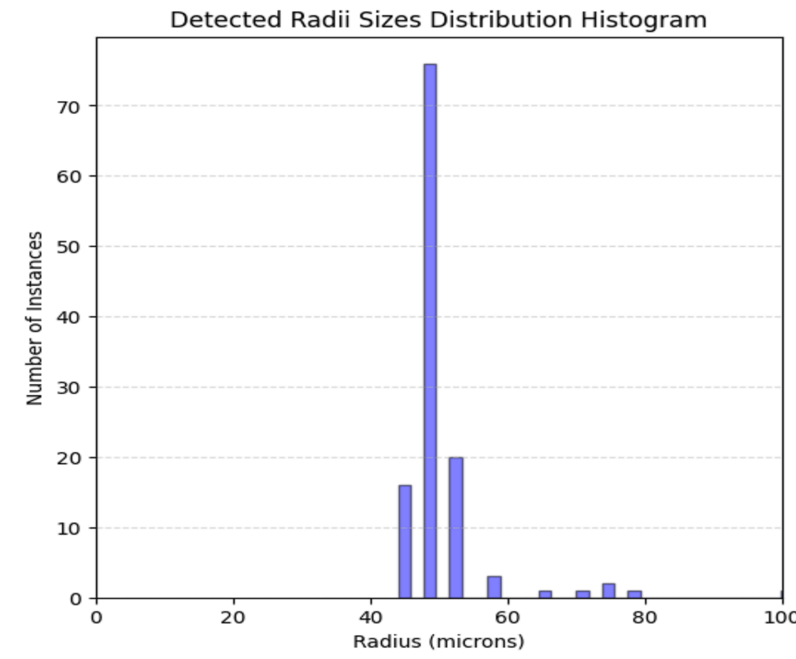
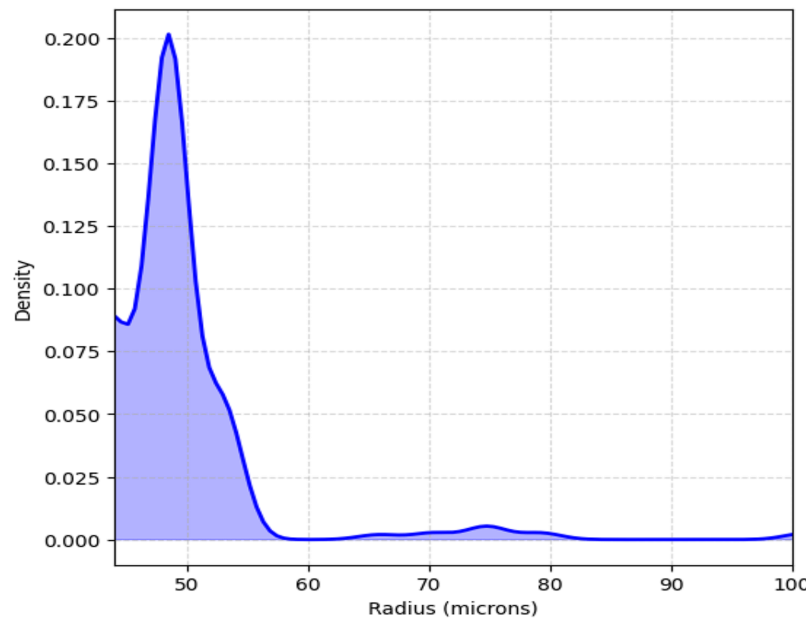


Figure 5. 100x surface image: pixel diameter estimation (right), um diameter estimation (left)





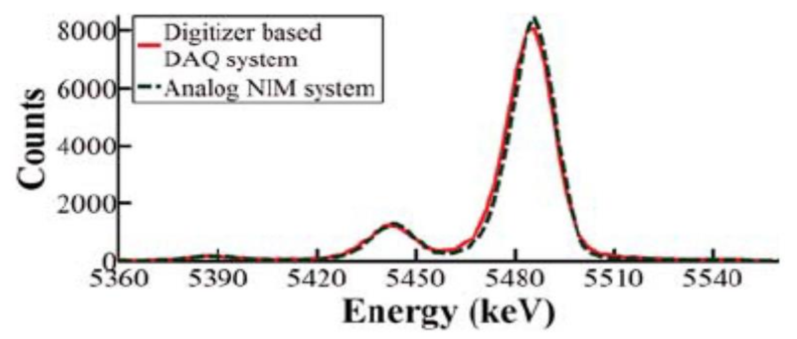


Figure 7. Observed distribution vs. experimentally confirmed [3]

Methods

1. Microscopic Imaging of CR-39 Tracks

To analyze **α-induced** damage, high-magnification microscope images of etched CR-39 tiles are captured. These images are processed to enhance contrast and minimize noise.

2. Image Processing & Feature Extraction

- Edge detection and adaptive thresholding techniques are applied to segment track craters
- Morphological features such as diameter, shape, and depth indicators
- Automated measurements of track radii

3. Machine Learning-Based Track Identification

- A supervised classification model is trained on detected craters to differentiate projectile-induced features from background noise
- A regression model is implemented to predict crater size distributions, which correlate with the energy of the impacting alpha particles

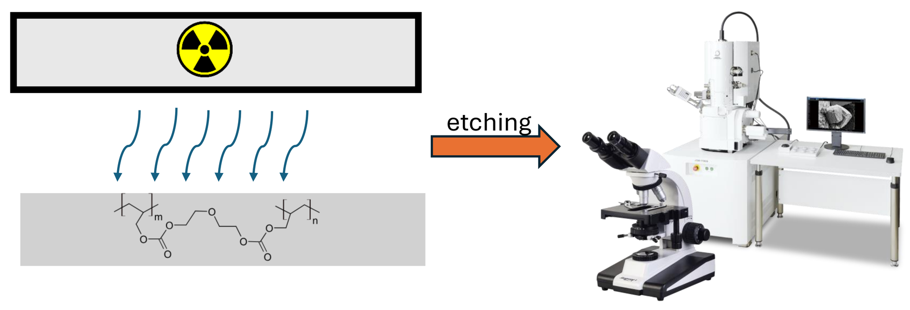


Figure 8. Experimental Setup

1.Grayscale Conversion: $I_{\text{gray}} = 0.2989R + 0.5870G + 0.1140B$

2.Gaussian blur: $G(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}$

3a.Circle Equation: $(x-a)^2 + (y-b)^2 = r^2$

3b.Edge Detection Gradient: $G_x = \frac{\partial I}{\partial x}, \quad G_y = \frac{\partial I}{\partial y}$

Magnitude and Direction: $G = \sqrt{G_x^2 + G_y^2}, \quad \theta = \tan^{-1}\left(\frac{G_y}{G_x}\right)$

4.For each edge pixel(x,y),the possible circle centers(a,b)satisfy:

$$a = x + r\cos\theta, \quad b = y + r\sin\theta$$

Results & Discussion

- Preliminary analysis confirms the feasibility of automated track identification through **image processing**
- ML models have the potential to accurately classify and measure damage features, though they may result in slower image processing
- Image processing techniques have the potential to be implemented on **portable devices**
- Energy estimation, though indirect, aligns qualitatively with expected trends in CR-39 alpha track formation

Acknowledgements

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References

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